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Nitrogen Dynamics under Aerobic and Anaerobic Soil Conditions

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ABSTRACT

An experiment was conducted under aerobic and anaerobic soil conditions to study N transformations using nitrification inhibitors. Maximum drop in NH_4 concentration was observed in control (aerobic) treatment followed by flooded and aerobic +N serve treatments. High increase in Nitrate N was registered under aerobic condition followed by +N serve and flooded treatments. Nitrification of NH_4–N to NO_3 was the lowest under flooded condition. Mineral nitrogen with aerobic as well as N served treatments increased with the increase in time of incubation. Under flooded condition, mineral nitrogen concentration showed a declining trend from day zero to day 9. The treatments, aerobic soil condition and nitrification inhibitors showed comparatively minimum nitrogen losses.

Key Words: N-Transformations; N Losses; Soil Conditions; N-Serves; Aerobic; Anaerobic

INTRODUCTION

Nitrogen is universally deficient in majority of the agricultural soils and successful arable farming is impossible without the use of nitrogenous fertilizers. Moreover, nitrogen fertilization aims at a high economic return of the investment through optimized crop yield and quality. Although nitrogen is, from a quantitative point of view, the most important nutrient in crop production in comparison with phosphorus and potassium, its efficiency is low for crop production. Fertilizers upon application to soil are subjected to numerous reactions, transformations and N loss mechanisms such as NH_3 volatilization (Sloan & Auderson, 1995), nitrification and subsequent denitrification (Rolston & Broadbent, 1977) leaching (Wild & Cameron, 1980; Nielson, 1982), chemical and microbial immobilization (Shimpi & Savant, 1975) and surface runoff (Takamura *et al.,* 1977). Thus quite a high proportion of the applied N is lost one way or the other (Smith & Whitfield, 1990; Shah *et al*., 1993). As a result, N use efficiency for crop production is discouraging low. For upland grain crops, it hardly exceeds 50% (Roy & Chandra, 1979) and for irrigated flooded and lowland rice, it varies between 30-45% (Hardy *et al.,* 1975; Mikkelson & DeDatta 1979; Craswell & Vlek, 1979; Vlek & Craswell, 1981; Zia & Waving, 1987). In view of the high cost of nitrogen fertilizer, it is important to improve the N utilization efficiency for crop production with the objective to reduce cost of crop production.

Urea is the major N fertilizer used for optimum crop yields all over the world. Addition of urea in soil, by virtue of its hydrolysis, increases soil pH thereby causes tremendous ammonia volatilization losses (Mengel *et al*., 1982; Fan & Mackenzie *et al*., 1993; Hamid *et al*., 1998). Also the fields under alternate flooding and drying, a significant amount of nitrogen is lost due to nitrification followed by denitrification as a result of oxidation and reduction (Burford & Bremner, 1975). Losses of the applied nitrogenous fertilizers can be reduced through fertilizer management practices (Rao, 1987; Fiez *et al.,* 1995; Saad *et al.,* 1996). Reduction in such losses still becomes easily manageable if their reactions and transformations are clear and easily understood. This study was, therefore, envisaged to understand N transformations under aerobic and anaerobic soil conditions influenced by nitrification inhibitor.

MATERIALS AND METHODS

A laboratory experiment was conducted to study the nitrogen transformations under aerobic and anaerobic soil conditions using nitrification inhibitor. Following treatments were used in this study:

T1 = Control (aerobic)
T2 = Aerobic + N serve
T3 = Flooded

Aliquots (40 g) of fresh soil were weighed into plastic shaking bottles (63 in all). The Physico-chemical characteristics of the soil used in the study are given in Table I. The moisture content was adjusted with de-ionized water to 75% water holding capacity. The bottles were sealed with parafilm having four holes for gas exchange. One set of the

Table I. Physico-chemical analysis of the soil used in study

Parameter	Unit	Soil value
pH	-	7.8
Total Carbon	%	4.9
Total N	%	0.5
Biomass N (mg N g^{-1} of Soil)	%	9.86
P	mg Kg^{-1}	8.0
Sand	%	26.2
Silt	%	28.4
Clay	%	40.9
Textural class	-	Sandy loam

bottle (21) was flooded to just above the soil. Another set treated with 0.5 cm^3 N serves; a nitrification inhibitor. All placed in constant room temperature at 10°C and allowed to equilibrate for three days.

Labeled ammonium ($^{15}NH_4$) was added to the soil @ 20 µg N g^{-1} as ($^{15}NH_4$-O_4). One cm^3 of solution was added to each 40g cylinder of soil. The 3-fold replications were employed. Samples were taken 0, 1, 2, 3, 4, 5, 7, 9 days after label addition. At each sampling, three cylinders from each treatment were sacrificed. At sampling, the soil from each cylinder was extracted for one hr in 200 cm^3 1M KCl, the extracts filtered through glass fiber filter paper and stored in refrigerator to await analysis.

After extraction, the extracts were analyzed for NH_4 and NO_3 using flow injection. NH_4 flasks were set for NH_4. The NH_4 discs were then removed and placed over $CaSO_4$, then were shook overnight and opened to remove last traces of NH_4.

RESULTS AND DISCUSSION

Studies to account for nitrogen transformations under different soil conditions have given divergent results and several explanations have been advanced for each effect.

Ammonical nitrogen (NH_4–N) in soil. The NH_4 concentration under different treatments dropped significantly within a short period of days. Maximum drop was observed in control (aerobic) treatment followed by flooded and aerobic +N serve treatments (Fig. 1). Ammonical N persisted more in +N serve treatment as compared with flooded treatment. Less amount of NH_4-N in control (aerobic) treatment might be due to its oxidation to NO_3. Whereas, under flooded condition the conversion of NH_4–N to NO_3–N was inhibited because of reduced condition created by high carbon in soil (Table I) and elimination of air by water. Vlek and Craswell (1981) and Saffigna *et al.* (1982) have documented similar conclusions. The NH_4–N concentration although was comparatively higher under +N serve treatment as compared to flooded treatment but it could not totally eliminate the nitrification of the NH_4, therefore, NH_4–N concentration dropped with passage of time due to its conversion to nitrate. After day 7, NH_4–N concentration again increased probably due to mineralization from organic pool. Further, the stimulatory effect of NH_4 ion on nitrification prior to hydrolysis might also played a role in reducing the accumulation of excessive NH_3 and this suppressed the NH_3 volatilization (Hamid *et al.,* 1998).

Nitrate nitrogen (NO_3–N) in soil. Nitrate nitrogen concentration in soil increased gradually from day 0 to 9 (Fig. 2). Maximum increase was registered in control (aerobic) treatment followed by +N serve and flooded (anaerobic) treatments. Rate of increase of NO_3–N concentration was much higher in control as compared to +N serve and flooded treatments. This is very well reflected from sharp rising trend of the curve in control treatment as compared to +N serve and flooded treatments where the curves were flatter. Higher NO_3–N concentration in control treatment is attributed to nitrification of NH_4–N under aerobic condition. +N serve although reduced the nitrification process but could not completely eliminate it. Hence, the ammonical N was nitrified at rather low rate as compared to that under aerobic condition. Nitrification of NH_4–N to NO_3–N was the lowest under flooded (anaerobic) condition since the soil was highly in recurred state because of high carbon content in soil. These results are in line with Wild and Cameron (1980) Magalhaes and Chalk (1987), and Saad *et al.* (1996).

Fig. 1. Ammonium dynamics in soil under aerobic and anaerobic conditions influenced by nitrification inhibitors

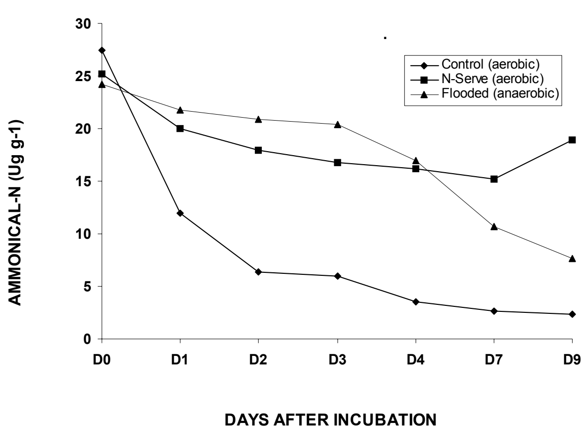
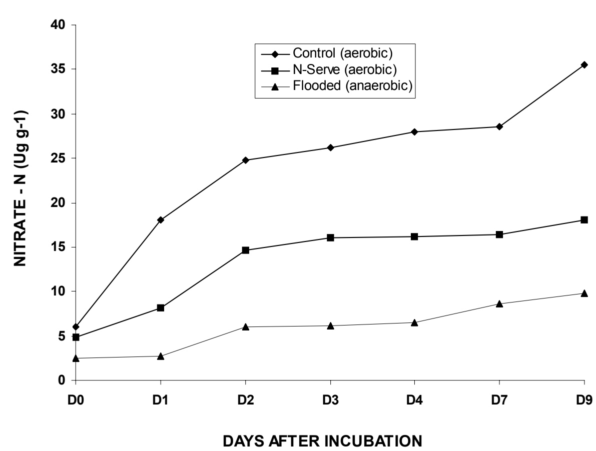


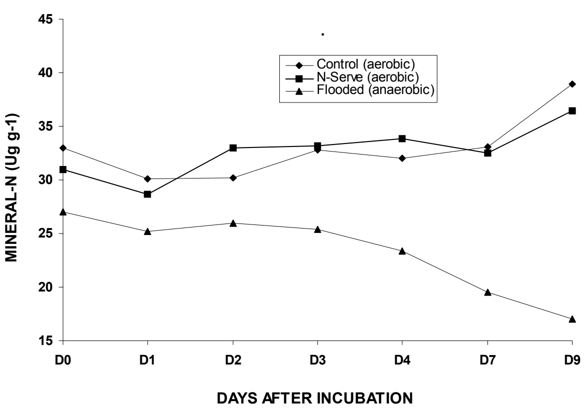
Fig. 2. Nitrate dynamics under aerobic and anaerobic soil conditions influenced by nitrification inhibitors



Mineral nitrogen (N) and losses. Mineral N (NH_4 and NO_3–N) under control (aerobic) and +N serve (aerobic) treatments increased as time of incubation increased (Fig. 3). Under both the treatments, it adopted almost similar pattern. There was slight declining trend in its concentration upto day 1 after that there was a sharp rise upto day 9. Since the soil was rich in organic matter, therefore, increase in mineral nitrogen concentration can be attributed to mineralization of N from organic pool under aerobic conditions. On the other hand, under flooded (aerobic) condition, mineral N concentration continuously showed a declining trend from day zero (D0) to 9 (D9). Mineral N concentration dropped from 27 μg N g^{-1} to 17 μg N g^{-1}. This declining trend in mineral N concentration is attributed to denitrification of NO_3–N under reduced soil system. Oxygen continued to diffuse into the system causing nitrification of NH_4. Therefore, mineral N diminishes at a rapid pace in this treatment. These results are supported by the conclusions of Saffigna *et al.* (1982), and Magalhaes and Chalk (1987).

From the study, it is concluded that even under reduced system, nitrification continued and nitrate thus formed were lost due to denitrification. Such losses can be reduced by the use of nitrification inhibitors and keeping fields in aerobic condition through improved drainage especially in Pakistan wheat fields sown after rice.

Fig. 3. Mineral N dynamics under aerobic and anaerobic soil conditions influenced by nitrification inhibitors



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