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# Effect of moisture regimes and pesticides of different biodegradability on transformation of different forms of inorganic and organic N in a dominant soil series of West Bengal

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**Abstract**

A laboratory experiment was conducted to study the effect of pesticides of different biodegradability on changes in inorganic and organic forms of N in soil maintained under two different moisture regimes. Results revealed that irrespective of pesticides and N treatment, comparatively higher amount of available N is recorded in waterlogged then the soil kept at 60% MHC. Addition of pesticides at lower dose affects the transformation process of organic N in soil. Irrespective of pesticide treatment, in general, hydrolysable $NH_4^+$ -N decreased but on the other hand amino acid N increased in soil. Again, the intensity of decrease or increase is more in waterlogged than the soil maintained under 60% of the MHC.

**Highlights**

- The changes in different N forms in comparison to different moisture regimes in soil.
- Affectivity of pesticides on different N forms is evaluated in both waterlogged and 60% MHC conditions.

**Keywords**: Moisture regimes, pesticides, hydrolysable $NH_4^+$ -N and amino acid N.

Nitrogen is one of the major nutrients required by plant for growth and metabolic activities, mostly taken from the soil. N present in soil generally comes from natural sources and applied fertilizers. Both types of N are important for growing plants. Introduction of high yielding varieties of crops has drawn further attention for efficient use of N-fertilizers in particular. The amount of N supplied naturally during a cropping season is influenced by many factors (Jenny and Raychoudhuri 1960; Brady and weil 2007; Liu *et al.* 2007). Environmental conditions as well as management practices change the liberation process and quality of soil N released. The efficient utilization of N from native or applied sources depends on the clear understanding of different transformation processes in soil (Nyiraneza and Snapp 2007; Srivastava and Singh 1996). Management practices do influence the N transformation process. Different N transformation processes in soil may proceed simultaneously and they interact in several ways (Aulakh *et al.* 2000, 2001a, 2001b). It is therefore necessary to understand all the processes involved in totality to get a clear picture of N transformation in soil.

Mineralization of N in soil varies due to various factors like soil characteristics, different management practices, climate, cropping etc. As it is now well established that native soil N transformation is different from that of fertilizer N, it is necessary to understand the N transformation process, which ultimately influence the N uptake by plants.

Our knowledge on the interchange of inorganic and organic N in soil was mostly obtained from studies that measure only the net result of two opposite forces, namely immobilization and mineralization. But very few attempts have so far been made to relate mineralization of N with simultaneous decrease of different forms of organic N present in the soil under different micro environmental conditions.

Pesticides play a vital role on different processes of N-transformation in soils. The degraded products of pesticides as well as persistence of pesticides in soil may influence different N-transformation processes occurring in soils in different ways. Sometimes the effect of pesticides is injurious to certain group of organisms which in turn is beneficial to others. Microorganisms responsible for nitrification is sometimes adversely affected, quite interestingly enough, however, ammonification is often benefited by pesticides' use. Pesticides' use to protect standing crop is now a regular practice to farmers. Soil application of pesticides causes an accumulation of the degraded products in top soil (Elimache *et al.* 2012), the sphere of maximum microbial activities. However, conflicting reports (Gaur 1990; Moorman 1989; Paul *et al.* 2010; Singh and Prasad 1991) are available regarding the effect of pesticide on microbial activities in soils. Different N transformation processes are influenced due to soil application of pesticides (Syversen and Haarstad 2005). Both negative (Prabhu and Raut 2011; Kar 1990; Martinez-Toledo *et al.* 1992; Meghraj *et al.* 1988) and positive (Balanger *et al.* 1985; Jana *et al.* 1987; Kucuk *et al.* 2012) response on biological N fixation are reported by number of workers due to application of pesticides in soil. Microorganisms responsible for nitrification are sometimes adversely affected quite interestingly enough; however, ammonification is often benefited by pesticides' use (Edward 1966; Okamoto *et al.* 1999). Limited information is available regarding the effect of pesticides on distribution of different fractions of inorganic and organic N in soils.

Moisture is an important factor for the growth of microorganisms and in controlling the rate of organic matter decomposition. Although presence of moisture above a certain level is not congenial for microbial activity (Chen *et al.* 2012) indirectly it is important, because higher the moisture present in soil lesser the oxygen available for microbial growth. Standford and Epstein (1974) reported a near linear relationship between N mineralization and soil water content in the range of 1/3 to 15 bar. The present investigation was, therefore, conducted to study the changes of different forms or inorganic and organic N in soil treated with pesticides of different biodegradability and maintained under different moisture regimes.

**Materials and Methods**

A composite soil sample was collected from a cultivated field (0 -15 cm depth) of a dominant soil series of Chakdaha in the district of Nadia, West Bengal. The soils were air dried ground and passed through 0.5 mm. sieve. The relevant physical and chemical characteristics of the soil are presented in Table 1.

Each of 10g air dried soil was taken in 100 ml beaker for the experimentation purpose. Two doses of Chlorinated hydrocarbon pesticide (Endosulfan) and Organophosphorus pesticide (Chlorpyriphos) at 0.5 kg a.i. $ha^{-1}$ and 1 kg a.i. $ha^{-1}$, respectively and two levels of moisture viz. 60% of the Moisture holding capacity (MHC) of the soil and waterlogged condition were maintained for incubation study. N-treatment was included in the study at 100 mg N $kg^{-1}$ through $(NH_4)_2SO_4$ . All the treatments were replicated thrice.

**Table 1. General characteristics of the soil used for the investigation**

| Parameters | | Characteristics |
|---|---|---|
| Mechanical Separates | Sand (%) | 22.07 |
| | Silt (%) | 33.88 |
| | Clay(%) | 44.05 |
| Moisture holding capacity (%) | | 49.45 |
| Bulk density (g c.c$^{-1}$) | | 1.22 |
| pH | | 7.17 |
| Electrical conductivity (dS m$^{-1}$) | | 0.35 |
| Cation exchange capacity [cmol ($p^+$) kg$^{-1}$ soil] | | 11.39 |
| Oxidisable organic carbon (%) | | 0.79 |
| Exchangeable $NH_4^+$ (mg kg$^{-1}$) | | 111.194 |
| Soluble $NO_3^-$ (mg kg$^{-1}$) | | 52.595 |
| Available N (mg kg$^{-1}$) | | 163.789 |
| Available Phosphorus (kg ha$^{-1}$) | | 68.08 |
| Exchangeable potash (kg ha$^{-1}$) | | 334.58 |
| Nomenclature according to USDA classification | | Aeric Endo Aquepts |

**Treatment adopted for the experiment may be written as follows:**

$T_0$ = Soil kept at 60% of M.H.C.

$T_1 = T_0$ + N at 100 mg kg$^{-1}$

$T_2$ = Soil kept under waterlogged condition

$T_3 = T_2$ + N at 100 mg kg$^{-1}$

$T_4 = T_0$ + Endosulfan at 0.5mg a.i. kg$^{-1}$

$T_5 = T_4$ + N at 100 mg kg$^{-1}$

$T_6 = T_2$ + Chlorpyriphos at 0.5 mg a.i. kg$^{-1}$

$T_7 = T_6$ + N at 100 mg kg$^{-1}$

$T_8 = T_0$ + Endosulfan at 1mg a.i. kg$^{-1}$

$T_9 = T_8$ + N at 100 mg kg$^{-1}$

$T_{10} = T_2$ + Chlorpyriphos at 1mg a.i. kg$^{-1}$

$T_{11} = T_{10}$ + N at 100 mg kg$^{-1}$

Soils were allowed to incubate at room temperature ($30 \pm 2)^o$ C for a period of 60 days. Four separate sets were maintained for laboratory analysis on 0$^{th}$, 15$^{th}$, 30$^{th}$ and 60$^{th}$ day of incubation. Samples of all sets were identically collected for analysis of exchangeable $NH_4^+$, soluble $NO_3^-$, total hydrolysable organic N, hexosamine – N, hydrolysable organic $NH_4^+$ -N and amino acid - N. Loss of moisture due to evaporation was replenished by the addition of distilled water on every alternate day by difference in weight.

2(M) KCl solution was employed for extraction of exchangeable $NH_4^+$ and soluble $NO_3^-$ - N and were determined by the method of Bremner and Keeney (1966). Exchangeable $NH_4^+$ soluble $NO_3^-$ is considered as available N in the text. Different forms of organic N were estimated by the method of Stevenson (1996).

## Results and Discussion

Irrespective of moisture regimes, the amount of exchangeable $NH_4^+$ in soil tended to decrease with increase in the period of investigation (Table 2). This trend of results is observed both in presence and absence of inorganic N. The decrease in exchangeable $NH_4^+$ is due to loss of N through volatilization (Broadbent and Tusneem 1971) or due to immobilization of N into organic forms. However, in presence of both endosulfan and chloropyriphos, the amount of exchangeable $NH_4^+$ tended to decrease upto 15$^{th}$ day, thereafter showed an increase on 30$^{th}$ day followed by decrease upto 60$^{th}$ day of incubation. This trend of result is observed irrespective of moisture regimes and inorganic N additions. The sudden increase in exchangeable $NH_4^+$ on 30$^{th}$ day of incubation is perhaps due to spurt in activities of ammonifying bacteria (Das 1997). Data further reveal that irrespective of moisture regimes and pesticide addition, comparatively higher amount of exchangeable $NH_4^+$ is accumulated in the N-treated over the untreated system throughout the period of investigation (Table 2). This is the effect of N-addition. In general, comparatively higher amount of

**Table 2. Effect of pesticides and moisture regimes on changes in the amount (mg $kg^{-1}$) of exchangeable $NH_4^+$ in soil treated with or without inorganic N**

| Treatments | Moisture regimes | N-fertilization | Incubation period (Days) | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 15 | 30 | 60 |
| Soil | 60% of MHC | - | 56.73 | 49.04 | 41.13 | 34.8 |
| | | + | 143.96 | 82.26 | 75.94 | 49.04 |
| | Waterlogged | - | 56.93 | 44.29 | 41.13 | 41.13 |
| | | + | 137.12 | 82.36 | 69.62 | 52.2 |
| Soil + Endosulfan at 0.5 mg a.i kg-1 | 60% of MHC | - | 52.2 | 50.62 | 112.32 | 39.55 |
| | | + | 147.12 | 105.97 | 148.71 | 41.3 |
| | Waterlogged | - | 64.53 | 53.78 | 175.92 | 96.56 |
| | | + | 148.73 | 83.51 | 186.67 | 117.06 |
| Soil + Chloropyriphos at 0.5 mg a.i kg-1 | 60% of MHC | - | 58.54 | 77.52 | 99.67 | 50.62 |
| | | + | 137.63 | 80.35 | 147.13 | 58.53 |
| | Waterlogged | - | 72.26 | 60.12 | 129.72 | 83.83 |
| | | + | 145.09 | 66.44 | 161.36 | 96.5 |
| Soil + Endosulfan at 1.0 mg a.i kg-1 | 60% of MHC | - | 50.62 | 93.34 | 120.19 | 41.13 |
| | | + | 149.68 | 146.61 | 169.27 | 64.47 |
| | Waterlogged | - | 55.42 | 44.29 | 100.03 | 50.62 |
| | | + | 117.03 | 80.68 | 169.27 | 79.28 |
| Soil + Chloropyriphos at 1.0 mg a.i kg-1 | 60% of MHC | - | 69.93 | 66.44 | 109.16 | 34.83 |
| | | + | 142.38 | 121.81 | 159.79 | 72.77 |
| | Waterlogged | - | 72.84 | 56.95 | 124.98 | 87.01 |
| | | + | 148.41 | 129.72 | 142.38 | 88.53 |
| CD (P=0.05) | Endosulfan | Soils(S) | 0.0176 | 0.0375 | 0.0176 | 0.0176 |
| | | Nitrogen(N) | 0.0144 | 0.0308 | 0.0144 | 0.0144 |
| | | Moisture(M) | 0.0144 | 0.0308 | 0.0144 | 0.0144 |
| | | SXN | 0.0246 | 0.0534 | 0.0246 | 0.0246 |
| | | SXM | 0.0246 | 0.0534 | 0.0246 | 0.0246 |
| | | NXM | 0.0202 | 0.0434 | 0.0202 | 0.0202 |
| | | SXNXM | 0.0349 | 0.0754 | 0.0349 | 0.0349 |
| | Chloropyrophos | Soils(S) | 0.0185 | 0.0402 | 0.9889 | 0.7657 |
| | | Nitrogen(N) | 0.0152 | 0.0328 | 0.8073 | 0.6252 |
| | | Moisture(M) | 0.0152 | 0.0328 | 0.8073 | 0.6252 |
| | | SXN | 0.0264 | 0.0569 | 1.3983 | 1.0827 |
| | | SXM | 0.0264 | 0.0569 | 1.3983 | 1.0827 |
| | | NXM | 0.0214 | 0.0463 | 1.1417 | 0.8842 |
| | | SXNXM | 0.0372 | 0.0804 | 1.9777 | 1.5314 |

**Table 3. Effect of pesticides and moisture regimes on changes in the amount (mg $kg^{-1}$) of soluble $NO_3^-$ in soil treated with or without inorganic N**

| Treatments | Moisture regimes | N-fertilization | Incubation period (Days) | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 15 | 30 | 60 |
| Soil | 60% of MHC | - | 41.13 | 60.12 | 69.54 | 50.62 |
| | | + | 34.8 | 73.07 | 83.9 | 52.2 |
| | Waterlogged | - | 39.55 | 34.8 | 31.64 | 72.77 |
| | | + | 53.79 | 87.01 | 55.37 | 109.16 |
| Soil + Endosulfan at 0.5 mg a.i kg-1 | 60% of MHC | - | 30.06 | 58.54 | 99.67 | 37.37 |
| | | + | 30.06 | 71.19 | 102.82 | 41.14 |
| | Waterlogged | - | 31.64 | 47.46 | 75.94 | 93.34 |
| | | + | 42.71 | 61.7 | 96.5 | 104.41 |
| Soil + Chloropyriphos at 0.5 mg a.i kg-1 | 60% of MHC | - | 49.05 | 26.9 | 80.69 | 31.64 |
| | | + | 41.14 | 56.95 | 60.12 | 28.48 |
| | Waterlogged | - | 34.8 | 64.86 | 63.29 | 72.76 |
| | | + | 47.46 | 82.43 | 72.77 | 87.01 |
| Soil + Endosulfan at 1.0 mg a.i kg-1 | 60% of MHC | - | 42.71 | 50.63 | 66.45 | 53.79 |
| | | + | 37.97 | 39.55 | 90.18 | 72.78 |
| | Waterlogged | - | 72.77 | 87.01 | 68.03 | 87.01 |
| | | + | 80.68 | 91.76 | 104.41 | 107.58 |
| Soil + Chloropyriphos at 1.0 mg a.i kg-1 | 60% of MHC | - | 29.74 | 25.31 | 56.95 | 37.97 |
| | | + | 28.48 | 53.79 | 66.45 | 39.55 |
| | Waterlogged | - | 52.21 | 36.39 | 50.62 | 69.62 |
| | | + | 58.53 | 68.03 | 69.61 | 75.94 |
| CD (P=0.05) | Endosulfan | Soils (S) | 0.8854 | 0.0176 | 0.0176 | 0.0176 |
| | | Nitrogen(N) | 0.7229 | 0.1437 | 0.1437 | 0.1437 |
| | | Moisture(M) | 0.7229 | 0.1437 | 0.1437 | 0.1437 |
| | | SXN | 1.2522 | 0.0246 | 0.0246 | 0.0246 |
| | | SXM | 1.2522 | 0.0246 | 0.0246 | 0.0246 |
| | | NXM | 1.022 | 0.0202 | 0.0202 | 0.0202 |
| | | SXNXM | 1.771 | 0.0349 | 0.0349 | 0.0349 |
| | Chloropyrophos | Soils (S) | 0.0185 | 0.0185 | 0.0463 | 0.0182 |
| | | Nitrogen (N) | 0.0152 | 0.0152 | 0.0378 | 0.0150 |
| | | Moisture (M) | 0.0152 | 0.0152 | 0.0378 | 0.0150 |
| | | SXN | 0.0264 | 0.0264 | 0.0654 | 0.0258 |
| | | SXM | 0.0264 | 0.0264 | 0.0654 | 0.0258 |
| | | NXM | 0.0214 | 0.0214 | 0.0534 | 0.0211 |
| | | SXNXM | 0.0372 | 0.0372 | 0.0924 | 0.0628 |

**Table 4. Effect of pesticides and moisture regimes on changes in the amount (mg $kg^{-1}$) of available N in soil treated with or without inorganic N**

| Treatments | Moisture regimes | N-fertilization | Incubation period (Days) | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 15 | 30 | 60 |
| Soil | 60% of MHC | - | 97.86 | 109.16 | 110.67 | 85.42 |
| | | + | 178.76 | 155.33 | 159.84 | 101.24 |
| | Waterlogged | - | 96.48 | 79.09 | 72.77 | 113.9 |
| | | + | 190.91 | 169.37 | 124.99 | 161.36 |
| Soil + Endosulfan at 0.5 mg a.i $kg^{-1}$ | 60% of MHC | - | 82.26 | 109.16 | 211.99 | 76.92 |
| | | + | 177.18 | 177.16 | 251.53 | 82.44 |
| | Waterlogged | - | 96.17 | 101.24 | 251.86 | 189.9 |
| | | + | 191.44 | 145.21 | 283.17 | 221.47 |
| Soil + Chloropyriphos at 0.5 mg a.i $kg^{-1}$ | 60% of MHC | - | 107.59 | 104.42 | 180.36 | 82.26 |
| | | + | 178.77 | 137.3 | 207.25 | 87.01 |
| | Waterlogged | - | 107.06 | 124.98 | 193.01 | 156.59 |
| | | + | 192.55 | 148.87 | 234.13 | 183.51 |
| Soil + Endosulfan at 1.0 mg a.i $kg^{-1}$ | 60% of MHC | - | 93.33 | 143.97 | 186.64 | 94.92 |
| | | + | 187.65 | 186.16 | 259.45 | 137.25 |
| | Waterlogged | - | 128.19 | 131.3 | 168.06 | 137.63 |
| | | + | 197.71 | 172.44 | 273.68 | 186.86 |
| Soil + Chloropyriphos at 1.0 mg a.i $kg^{-1}$ | 60% of MHC | - | 99.67 | 91.75 | 166.11 | 72.8 |
| | | + | 170.86 | 175.6 | 226.24 | 112.32 |
| | Waterlogged | - | 125.05 | 93.34 | 175.6 | 156.63 |
| | | + | 206.94 | 197.75 | 211.99 | 164.47 |
| CD (P=0.05) | Endosulfan | Soils(S) | 0.4515 | 0.02755 | 0.0176 | 0.0176 |
| | | Nitrogen(N) | 0.36865 | 0.08725 | 0.07905 | 0.07905 |
| | | Moisture(M) | 0.36865 | 0.08725 | 0.07905 | 0.07905 |
| | | SXN | 0.6384 | 0.039 | 0.0246 | 0.0246 |
| | | SXM | 0.6384 | 0.039 | 0.0246 | 0.0246 |
| | | NXM | 0.5211 | 0.0318 | 0.0202 | 0.0202 |
| | | SXNXM | 0.90295 | 0.05515 | 0.0349 | 0.0349 |
| | Chloropyrophos | Soils(S) | 0.0185 | 0.02935 | 0.5176 | 0.39195 |
| | | Nitrogen(N) | 0.0152 | 0.024 | 0.42255 | 0.3201 |
| | | Moisture(M) | 0.0152 | 0.024 | 0.42255 | 0.3201 |
| | | SXN | 0.0264 | 0.04165 | 0.73185 | 0.55425 |
| | | SXM | 0.0264 | 0.04165 | 0.73185 | 0.55425 |
| | | NXM | 0.0214 | 0.03385 | 0.59755 | 0.45265 |
| | | SXNXM | 0.0372 | 0.0588 | 1.03505 | 0.7971 |

**Table 5. Effect of pesticides and moisture regimes on changes in the amount (mg kg$^{-1}$) of hydrolysable organic $NH4^{+}$ -N in soil treated with or without inorganic N**

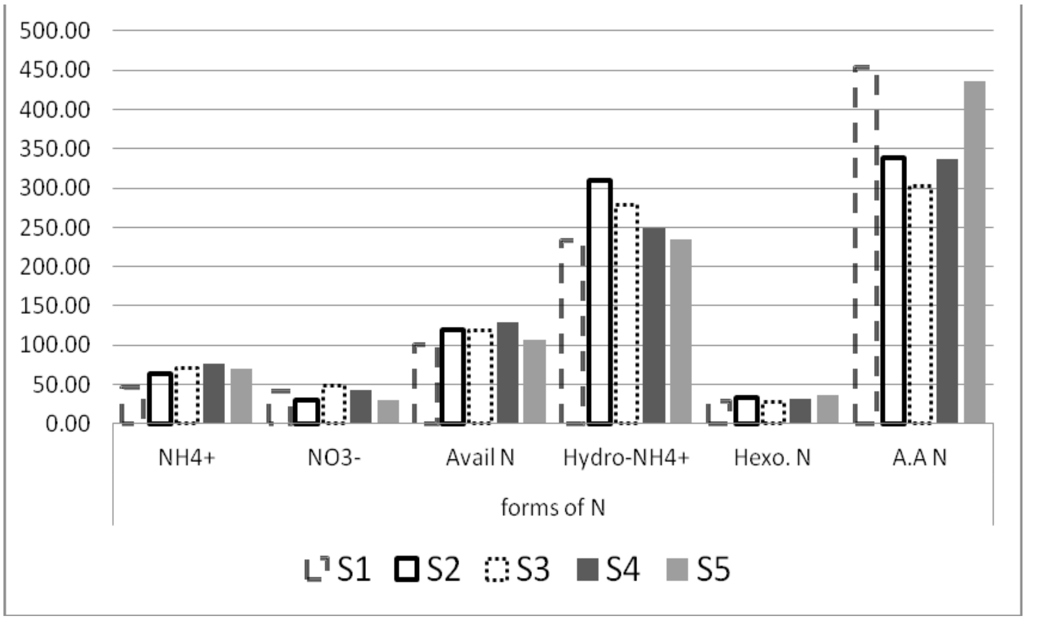
| Treatments | Moisture regimes | N-fertilization | Incubation period (Days) | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 15 | 30 | 60 |
| Soil | 60% of MHC | - | 232.95 | 174.72 | 244.02 | 279.30 |
| | | + | 232.90 | 276.60 | 220.78 | 225.10 |
| | Waterlogged | - | 218.34 | 284.76 | 222.90 | 162.62 |
| | | + | 241.57 | 295.70 | 215.86 | 255.64 |
| Soil + Endosulfan at 0.5 mg a.i kg$^{-1}$ | 60% of MHC | - | 320.30 | 291.00 | 267.26 | 359.10 |
| | | + | 305.79 | 295.04 | 255.64 | 359.10 |
| | Waterlogged | - | 264.81 | 274.30 | 185.92 | 116.20 |
| | | + | 241.54 | 269.54 | 271.84 | 174.30 |
| Soil + Chloropyriphos at 0.5 mg a.i kg$^{-1}$ | 60% of MHC | - | 249.44 | 276.67 | 290.16 | 299.10 |
| | | + | 174.70 | 253.28 | 266.32 | 319.20 |
| | Waterlogged | - | 204.27 | 316.25 | 222.90 | 185.92 |
| | | + | 205.75 | 295.45 | 211.28 | 197.54 |
| Soil + Endosulfan at 1.0 mg a.i kg$^{-1}$ | 60% of MHC | - | 218.40 | 280.49 | 220.78 | 279.30 |
| | | + | 293.16 | 292.86 | 220.78 | 298.50 |
| | Waterlogged | - | 215.88 | 216.45 | 285.04 | 255.64 |
| | | + | 234.52 | 363.80 | 250.72 | 272.88 |
| Soil + Chloropyriphos at 1.0 mg a.i kg$^{-1}$ | 60% of MHC | - | 218.10 | 174.68 | 290.50 | 252.20 |
| | | + | 276.64 | 305.75 | 174.30 | 259.10 |
| | Waterlogged | - | 255.62 | 216.40 | 288.04 | 185.92 |
| | | + | 272.89 | 263.86 | 258.00 | 174.30 |
| CD (P=0.05) | Endosulfan | Soils(S) | 2.5097 | 2.7654 | 0.0176 | 0.0176 |
| | | Nitrogen(N) | 2.0493 | 2.2581 | 0.0144 | 0.0144 |
| | | Moisture(M) | 2.0493 | 2.2581 | 0.0144 | 0.0144 |
| | | SXN | 3.5493 | 3.9109 | 0.0246 | 0.0246 |
| | | SXM | 3.5493 | 3.9109 | 0.0246 | 0.0246 |
| | | NXM | 2.898 | 3.1933 | 0.0202 | 0.0202 |
| | | SXNXM | 5.0197 | 5.5309 | 0.0349 | 0.0349 |
| | Chloropyrophos | Soils(S) | 2.2129 | 2.4450 | 0.0185 | 0.0185 |
| | | Nitrogen(N) | 1.8071 | 1.9962 | 0.0152 | 0.0152 |
| | | Moisture(M) | 1.8071 | 1.9962 | 0.0152 | 0.0152 |
| | | SXN | 3.1297 | 3.4575 | 0.0264 | 0.0264 |
| | | SXM | 3.1297 | 3.4575 | 0.0264 | 0.0264 |
| | | NXM | 2.5555 | 2.8229 | 0.0214 | 0.0214 |
| | | SXNXM | 4.4262 | 4.8895 | 0.0372 | 0.0372 |

**Table 6. Effect of pesticides and moisture regimes on changes in the amount (mg kg-1) of hexosamine-N in soil treated with or without inorganic N**

| Treatments | Moisture regimes | N-fertilization | Incubation period (Days) | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 15 | 30 | 60 |
| Soil | 60% of MHC | - | 27.36 | 25.00 | 27.56 | 33.20 |
| | | + | 38.40 | 28.60 | 40.62 | 36.48 |
| | Waterlogged | - | 27.36 | 24.92 | 26.86 | 29.68 |
| | | + | 38.40 | 26.74 | 27.40 | 32.12 |
| Soil + Endosulfan at 0.5 mg a.i $kg^{-1}$ | 60% of MHC | - | 27.36 | 34.36 | 41.56 | 32.48 |
| | | + | 31.04 | 36.48 | 29.86 | 26.60 |
| | Waterlogged | - | 27.46 | 27.04 | 26.30 | 30.46 |
| | | + | 28.32 | 30.48 | 31.26 | 36.28 |
| Soil + Chloropyriphos at 0.5 mg a.i $kg^{-1}$ | 60% of MHC | - | 29.20 | 28.96 | 25.80 | 29.46 |
| | | + | 38.41 | 39.34 | 26.20 | 38.70 |
| | Waterlogged | - | 30.32 | 37.30 | 30.86 | 29.36 |
| | | + | 29.40 | 33.70 | 26.64 | 26.82 |
| Soil + Endosulfan at 1.0 mg a.i $kg^{-1}$ | 60% of MHC | - | 31.04 | 32.68 | 36.06 | 29.70 |
| | | + | 26.32 | 27.36 | 31.28 | 25.62 |
| | Waterlogged | - | 26.86 | 34.28 | 29.86 | 29.48 |
| | | + | 23.24 | 36.40 | 26.82 | 30.82 |
| Soil + Chloropyriphos at 1.0 mg a.i $kg^{-1}$ | 60% of MHC | - | 34.04 | 34.68 | 39.66 | 36.30 |
| | | + | 39.12 | 26.86 | 36.22 | 34.70 |
| | Waterlogged | - | 27.04 | 26.27 | 27.58 | 34.28 |
| | | + | 19.28 | 24.48 | 28.46 | 36.26 |
| CD (P=0.05) | Endosulfan | Soils(S) | 0.0185 | 0.4179 | 0.0185 | 1.2572 |
| | | Nitrogen(N) | 0.0152 | 0.3411 | 0.0152 | 1.0267 |
| | | Moisture(M) | 0.0152 | 0.3411 | 0.0152 | 1.0267 |
| | | SXN | 0.5991 | 3.796 | 1.9956 | 1.7813 |
| | | SXM | 0.5991 | 3.796 | 1.9956 | 1.7813 |
| | | NXM | 0.4892 | 3.0995 | 1.6294 | 1.4546 |
| | | SXNXM | 0.8472 | 5.3681 | 2.822 | 2.5194 |
| | Chloropyrophos | Soils(S) | 0.4238 | 2.6842 | 1.4112 | 1.2596 |
| | | Nitrogen(N) | 0.3460 | 2.1915 | 1.1522 | 1.0285 |
| | | Moisture(M) | 0.3460 | 2.1915 | 1.1522 | 1.0285 |
| | | SXN | 0.0264 | 0.5909 | 0.0264 | 1.778 |
| | | SXM | 0.0264 | 0.5909 | 0.0264 | 1.778 |
| | | NXM | 0.0214 | 0.4824 | 0.0214 | 1.4519 |
| | | SXNXM | 0.0372 | 0.8358 | 0.0372 | 2.5147 |

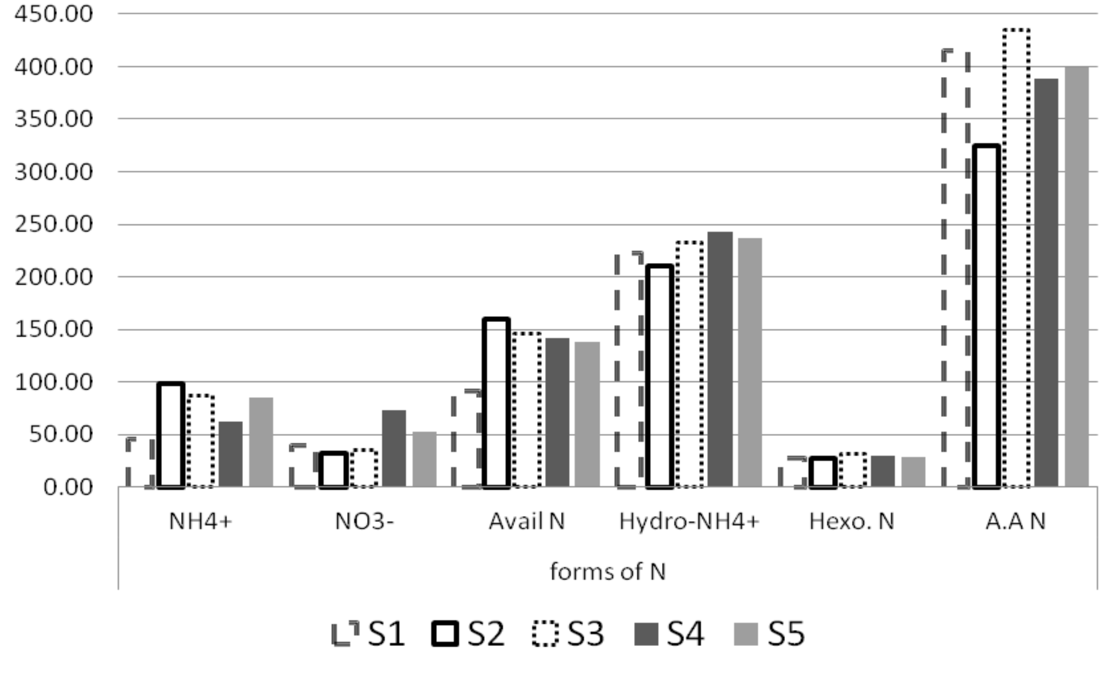
**Table 7. Effect of pesticides and moisture regimes on changes in the amount (mg kg$^{-1}$) of Amino acid-N in soil treated with or without inorganic N**

| Treatments | Moisture regimes | N-fertilization | Incubation period (Days) | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 15 | 30 | 60 |
| Soil | 60% of MHC | - | 582.40 | 360.22 | 606.09 | 266.00 |
| | | + | 291.20 | 336.98 | 697.20 | 372.40 |
| | Waterlogged | - | 313.74 | 648.62 | 255.64 | 441.56 |
| | | + | 429.94 | 449.78 | 406.70 | 464.80 |
| Soil + Endosulfan at 0.5 mg a.i kg-1 | 60% of MHC | - | 393.12 | 139.44 | 518.70 | 305.90 |
| | | + | 305.76 | 336.98 | 499.66 | 305.90 |
| | Waterlogged | - | 313.74 | 357.11 | 302.12 | 325.36 |
| | | + | 306.22 | 523.22 | 325.36 | 406.70 |
| Soil + Chloropyriphos at 0.5 mg a.i kg-1 | 60% of MHC | - | 276.64 | 252.49 | 430.08 | 252.70 |
| | | + | 218.40 | 267.26 | 571.90 | 212.80 |
| | Waterlogged | - | 429.94 | 427.72 | 418.32 | 464.80 |
| | | + | 502.81 | 561.46 | 450.72 | 429.92 |
| Soil + Endosulfan at 1.0 mg a.i kg-1 | 60% of MHC | - | 232.96 | 209.16 | 649.74 | 252.70 |
| | | + | 305.76 | 300.58 | 383.46 | 292.60 |
| | Waterlogged | - | 327.82 | 411.32 | 232.40 | 581.00 |
| | | + | 383.46 | 480.26 | 441.56 | 697.20 |
| Soil + Chloropyriphos at 1.0 mg a.i kg-1 | 60% of MHC | - | 495.04 | 345.61 | 558.32 | 345.80 |
| | | + | 324.96 | 363.72 | 383.46 | 372.40 |
| | Waterlogged | - | 499.66 | 411.32 | 325.36 | 360.22 |
| | | + | 604.24 | 645.47 | 476.42 | 453.18 |
| CD (P=0.05) | Endosulfan | Soils(S) | 0.0176 | 0.0176 | 0.0176 | 0.0176 |
| | | Nitrogen(N) | 0.0144 | 0.0144 | 0.0144 | 0.0144 |
| | | Moisture(M) | 0.0144 | 0.0144 | 0.0144 | 0.0144 |
| | | SXN | 0.0246 | 0.0246 | 0.0246 | 0.0246 |
| | | SXM | 0.0246 | 0.0246 | 0.0246 | 0.0246 |
| | | NXM | 0.0202 | 0.0202 | 0.0202 | 0.0202 |
| | | SXNXM | 0.0349 | 0.0349 | 0.0349 | 0.0349 |
| | Chloropyrophos | Soils(S) | 0.0088 | 0.7657 | 0.0185 | 42.3286 |
| | | Nitrogen(N) | 0.0152 | 0.6252 | 0.0152 | 34.5610 |
| | | Moisture(M) | 0.0152 | 0.6252 | 0.0152 | 34.5610 |
| | | SXN | 0.0264 | 1.0827 | 0.0264 | 59.8614 |
| | | SXM | 0.0264 | 1.0827 | 0.0264 | 59.8614 |
| | | NXM | 0.0214 | 0.8842 | 0.0214 | 48.8768 |
| | | SXNXM | 0.0372 | 1.5314 | 0.0372 | 84.6568 |



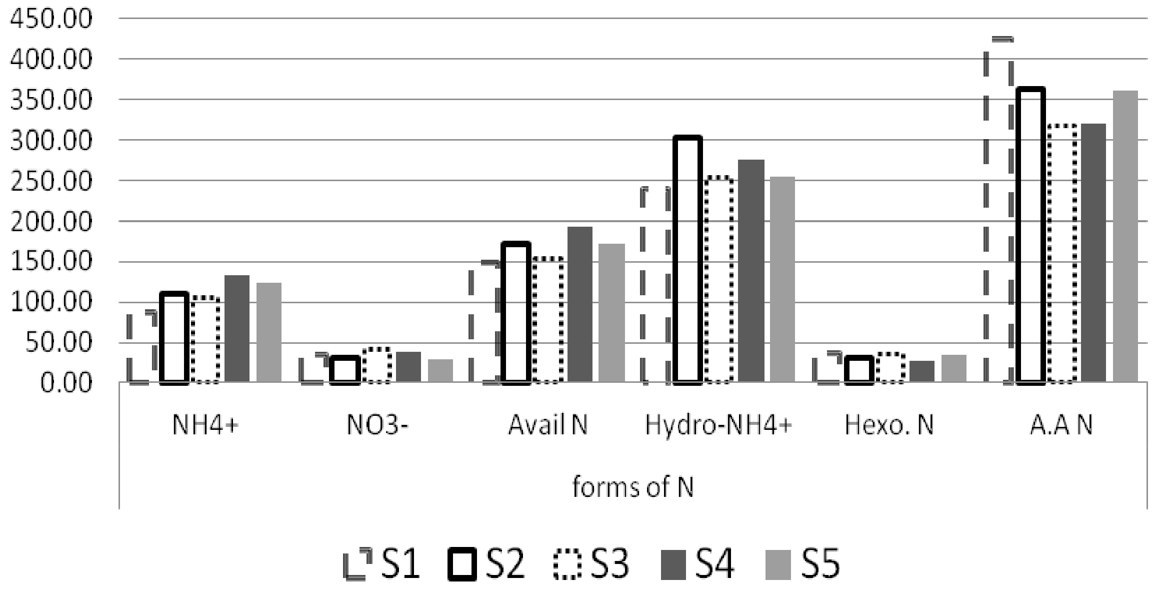

S1 = Control soil, S2 = S1 + Endosulfan at 0.5 mg a.i $kg^{-1}$, S3 = Soil + Chloropyriphos at 0.5 mg a.i $kg^{-1}$, S4 = Soil + Endosulfan at 1.0 mg a.i $kg^{-1}$and S5 = Soil + Chloropyriphos at 1.0 mg a.i $kg^{-1}$

**Figure 1.** Effect of pesticides on change in different forms of N at 60% MHC of soil treated with inorganic N



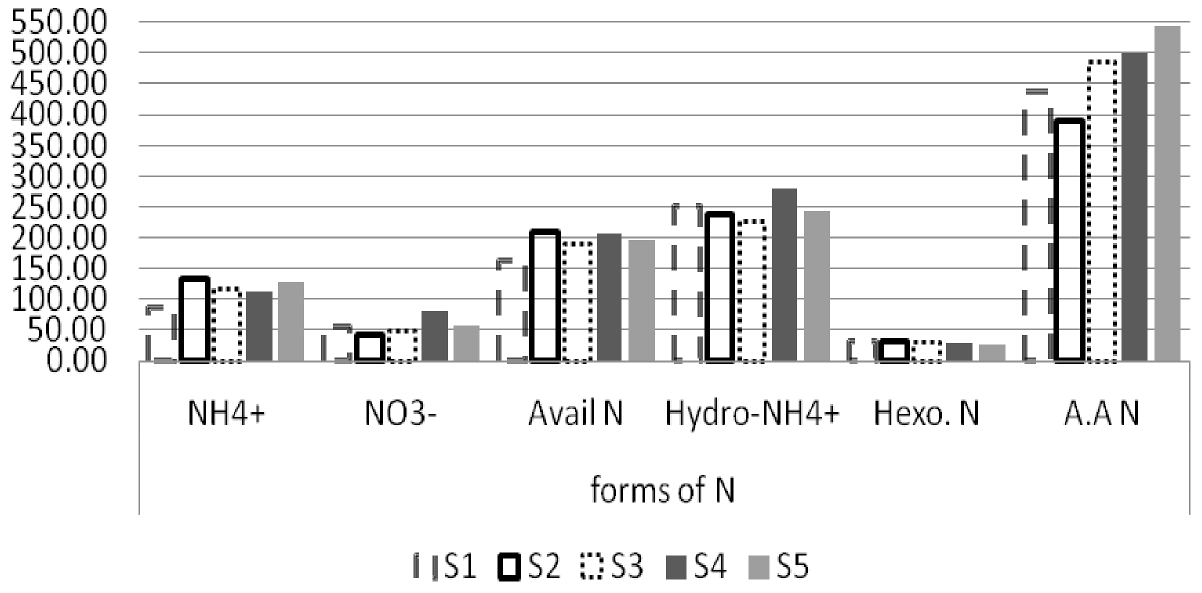

S1 = Control soil, S2 = S1 + Endosulfan at 0.5 mg a.i $kg^{-1}$, S3 = Soil + Chloropyriphos at 0.5 mg a.i $kg^{-1}$, S4 = Soil + Endosulfan at 1.0 mg a.i $kg^{-1}$ and S5 = Soil + Chloropyriphos at 1.0 mg a.i $kg^{-1}$

**Figure 2.** Effect of pesticides on change in different forms of N under waterlogged soil treated without inorganic N




S1 = Control soil, S2 = S1 + Endosulfan at 0.5 mg a.i kg$^{-1}$, S3 = Soil + Chloropyriphos at 0.5 mg a.i kg$^{-1}$, S4 = Soil + Endosulfan at 1.0 mg a.i kg$^{-1}$ and S5 = Soil + Chloropyriphos at 1.0 mg a.i kg$^{-1}$

**Figure 3.** Effect of pesticides on change in different forms of N at 60% MHC of soil treated with inorganic N




S1 = Control soil, S2 = S1 + Endosulfan at 0.5 mg a.i kg$^{-1}$, S3 = Soil + Chloropyriphos at 0.5 mg a.i kg$^{-1}$, S4 = Soil + Endosulfan at 1.0 mg a.i kg$^{-1}$ and S5 = Soil + Chloropyriphos at 1.0 mg a.i kg$^{-1}$

**Figure 4.** Effect of pesticides on change in different forms of N under waterlogged soil treated with inorganic N

exchangeable $NH_4^+$ is recorded in waterlogged system over the soil maintained under 60% of the moisture holding capacity (MHC) at all stages of incubation. This trend of result is observed both in presence and absence of inorganic N and pesticides (endosulfan and chloropyriphos) addition. Higher amount of exchangeable $NH_4^+$ produced in waterlogged soil due to faster rate of mineralization of organic N over unflooded situations but very little is transformed to $NO_3^-$ form perhaps due to lower N requirement of the microbial population under anaerobic environment and to their lower synthetic efficiency (Saha and Mukhopadhyay 1983b). Again, irrespective of N-additions, comparatively lower amount of exchangeable $NH_4^+$ is recorded in waterlogged soil treated with higher dose of endosulfan, whereas, almost similar amount of exchangeable $NH_4^+$ is recorded in waterlogged soil treated with both the higher and lower doses of chloropyriphos throughout the period of investigation. However, soil kept at 60% MHC showed an exactly opposite trend of results both in higher doses of endosulfan and chloropyriphos. Thus it is clear from the results that addition of pesticides of different biodegradability hinders the ammonification process particularly under waterlogged situation in presence of inorganic N (Okamoto *et al.* 1999).

Irrespective of pesticides (endosulfan and chloropyriphos) addition, moisture regimes and period of investigation, comparatively, higher amount of soluble $NO_3^-$ is accumulated in N-treated over the untreated system (Table 3). In general, irrespective of pesticides and inorganic N, higher amount of soluble $NO_3^-$ is recorded in soil kept at lower moisture regime. However, at the last stage of incubation, comparatively higher amount of soluble $NO_3^-$ -N is accumulated in waterlogged system than the soil maintained at 60% MHC (Table 3). The higher dose of endosulfan favours nitrification even under waterlogged condition. This finding is due to less scope of loss of N through leaching as well as denitrification. The nitrification process is found to be accelerated at last stage of incubation (Saison *et al.* 2009).

Comparatively higher amount of available N is accumulated in N treated over the untreated system (Table 4). Again, irrespective of chloropyriphos treatment and N fertilization, in general, comparatively higher amount of available N was recorded in waterlogged over that of the soil maintained at 60% of MHC. The explanation furnished earlier is equally appreciable here as well. Soils maintained at 60% of MHC and fertilised with inorganic N showed a decrease in available N over the experimentation period is due to conversion of exchangeable $NH_4^+$ to other forms of N and loss through volatilization (Broadbent and Tusneem 1971) and or immobilization (Saharawat 1982). Furthermore irrespective of moisture regimes, available N increased up to 30$^{th}$ day in both the doses of Chlorpyriphos treated systems. The result is at par with earlier works of Das (1997). However, after 30 days, a decreasing trend was observed up to the last stage of incubation. This is because of immobilization of exchangeable $NH_4^+$ in soil (Pal *et al.* 1987).

Irrespective of moisture regimes and pesticides addition, in general, comparatively higher amount of total hydrolysable $NH_4^+$ is accumulated in N-treated over the untreated system throughout the period of investigation (Table 5). Data also reveal that in absence of endosulfan but presence of chloropyriphos and inorganic N, in general, comparatively lower amount of hydrolysable $NH_4^+$ -N is recorded in waterlogged over the soil maintained at 60% of MHC in particularly at the later stages of incubation. At lower dose of both the pesticides, comparatively lower amount of hydrolysable organic $NH_4^+$ -N was accumulated in waterlogged system over the soil kept of 60% MHC, whereas, at higher dose no definite trend of results was obtained. Conversion of hydrolysable $NH_4^+$ -N to other organic forms and vice-versa was suggested (Devi 2009; Saha 1987). Thus it is clear that introduction of pesticides in the system slowed down the N-mineralization process (Ollivier *et al.* 2011; Ukru 2005) and maintenance of lower level of moisture is congenial for accumulation of higher order of hydrolysable $NH_4^+$ in soil through inter-conversion of other forms of organic N.

Data in Table 6 revealed that both the doses of endosulfan has no drastic effect in accumulation of hexosamine N in soil treated with or without inorganic N. However, at the lower dose of Chloropyriphos treated, comparatively lower amount of hexosamine – N was recorded at the end of incubation period in the soils treated with inorganic N. The decrease was more pronounced in waterlogged situation than the soils maintained under 60% MHC. Soils treated with higher dose of chloropyriphos showed an increasing trend of accumulation of hexosamine – N throughout the period of incubation. The recorded higher amount of hexosamine – N in untreated soils at the end of incubation period is due to immobilization of inorganic forms of N in soils. This trend of results is observed for the soils maintained under both the moisture levels.

Perusal of the results in Table 7 revealed that irrespective of moisture regimes and pesticides addition, comparatively higher amount of amino acid-N is accumulated in N-treated over the untreated system particularly at the later stage of investigation. Again, irrespective of N-fertilization, at higher dose of pesticides, a favourable environment was created to register a comparatively higher amount of amino acid-N in waterlogged over the soil maintained at 60% of the MHC. Similar findings were also reported earlier by Mukhopadhyay *et al.* (1985). The increase in amino acid-N with concomitant decrease in hydrolysable organic $NH_4^+$ -N under waterlogged situation leads to conclude that different fractions of organic N are inter-convertible within themselves depending upon the microenvironment of the rhizosphere soil (Saha 1999).

To get a clear picture of the effect of pesticides on changes in different forms of N in soil maintained under two different moisture regimes in presence and absence of added inorganic N, the mean value of the data at different stages are graphically presented in Figure 1 to 4. Irrespective of pesticidal treatments, in general, high amount of available N is accumulated in waterlogged than the soil maintained at 60% of NHC (Figure 1 and 2). N addition leads to accumulation of higher amount of available N in soil (Figure 3 and 4). Addition of pesticides has little effect on hexosamine N in soil (Figure 1 to 4). However, pesticide treatment influenced the accumulation of hydrolysable $NH_4^+$ and amino acid N in soils. Addition of pesticides either endosulfan or chloropyriphos at lower dose, in general, decreased the hydrolysable $NH_4^+$ but on the other hand, increased amino acid N in soil. Therefore, it is clear that pesticides have an impact on mineralization and immobilization of organic and inorganic N in soil.

## Conclusion

Addition of pesticides of different biodegradability hinders the ammonifying process but on the other hand, encourages nitrification. Higher dose of endosulfan favours nitrification even under waterlogged situation. Addition of Endosulfan and Chloropyriphos increased the accumulation of available N in soil particularly under waterlogged situation. Different forms of organic N are inter-convertible within themselves.

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