



Research Article

Effect of Different Mulches and Nitrogen Doses on Nutrient Transport under in situ Field Soil Condition II. Impact on Nitrogen Transport and Crop Parameters

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ABSTRACT

A field study was carried out to evaluate the nitrogen transport under different hydrothermal regimes, induced by black polythene and rice husk mulches in a sandy loam (*Typic Haplustept*) soil of Indian Agricultural Research Institute farm, New Delhi. Nitrate and ammonium nitrogen distribution under different mulching and nitrogen treatments at different soil depths were monitored. In a separate experiment, crop nitrogen uptake by maize as influenced by same mulch and nitrogen treatments was also determined. Black polythene mulch increased soil temperature by about 2°C while the soil was relatively cooler under rice husk by about 1°C compared no mulch treatment. Soil water flux was reduced and nitrate nitrogen was conserved in soil to the maximum extent and for longer period under black polythene followed by rice husk mulch. Differences in nitrogen uptake by maize crop were observed between control (no application of nitrogen) and fertilized (120 kg N ha⁻¹) plots. Mulch treatments showed a significant varying effect on nitrogen uptake. Overall, both rice husk and black polythene mulches could perform well in arresting nitrogen loss in soil profile and ensuring its availability same to crop for a longer period of time.

Key words: Rice husk, Polythene, Nitrogen uptake, Maize, Ammonium N, Nitrate N

Introduction

Nitrogen is one of the primary nutrients, which plays a vital role in the life cycle of a crop. An adequate concentration of nitrogenous fertilizer in the root zone is of utmost importance for optimum plant growth, whereas its excessive presence leads to succulency in plants, making it

vulnerable to lodging and susceptible to attack by pests and diseases. Whereas the availability of nitrogen influences crop productivity more than any other single management factor, its use efficiency is generally very low, seldom exceeding 50 per cent (Chaudhary and Bhatnagar, 1976) because of leaching losses in solution form (Shibu and Ghuman, 2003; and Antil *et al.*, 2002), in gaseous form by volatilization and denitrification (Majumdar *et al.*, 2000) and through organic immobilization.

Great deal of attention is being given currently to the conservation of surface and ground water resources, especially protection with

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respect to nitrate pollution. Prediction of nitrate behavior in the long term thus becomes a subject of displacement and transformation (Lafoile, 1991). Thus, required nitrate availability to plants and nitrogen displacement in soil are in conflict. Nitrogen transport indeed depends strongly on water content, soil temperature and nitrate concentration (Rodigo *et al.*, 1997). On the other hand, nitrate leaching is also controlled by water and solute transport processes. Therefore, a sound understanding of soil processes is necessary to enable better management of human activities that will result in minimizing groundwater and surface water contamination (Hack-ten Broeke and De Groot, 1998; Hendriks *et al.*, 1999; Sung *et al.*, 2002).

Several mulching practices are being advocated for their potential effectiveness in modifying the soil hydrothermal regime, which has a direct impact on soil water as well as nitrogen transport within soil profile. Polythene mulch conserves soil moisture by reducing evaporation losses, particularly during the dry season (Li, 2004; Zhang, 2000). In addition, polythene mulch increases soil temperature during early spring and winter, when soil temperatures are usually low (Wang, 2003; Barton, 2000). Thus use of polythene mulch not only favours early crop establishment by conserving soil water and fertility but also by increased crop yield (Huang, 2001; Wang, 2003; Barton, 2000). On the other hand, bio-degradable biological mulch like rice husk is also known to reduce evaporation, increase soil water, decrease diurnal soil temperature variations and increase saturated hydraulic conductivity (Bristow and Campbell, 1986; Dahiya *et al.*, 2003).

The physical processes of nitrogen transport under different hydrothermal regimes as modified by application of mulches are still not well documented due to the lack of knowledge of transport parameters under the modified soil environment, which are difficult to experimentally determine under in situ field conditions. There exists therefore an information gap on the effects of varying moisture and temperature conditions on these transport parameters under field

conditions. The present investigation was conducted to quantify the effect of black polythene and rice husk mulches on nitrogen movement by modifying the soil hydrothermal regimes as well as their impact on crop growth parameters.

Materials and Methods

Study area

The present investigation was carried out at the research farm of Indian Agricultural research Institute, New Delhi, situated at 28°37' N latitude, 77°11' E longitude and at an altitude of 228.7 m above mean sea level.

The soil of the experimental site belongs to the major soil group of Indo-Gangetic alluvium. It is coarse, loamy, non-acid, mixed, hyperthermic family of *Typic Haplustepts*. The colour varies from dark brown (10YR 4/4) to yellowish brown (10YR 5/4). Surface and subsoil texture varies from sandy loam to sandy clay loam, with angular blocky structure and besides the soil is non-calcareous.

Experimental set-up

In this study two experiments were carried out simultaneously to investigate the transport of nitrogen under modified hydrothermal regimes induced by polythene and rice husk mulches and their impact on crop plant growth and yield.

Set-up-1

In first part of the experiment, a field study was conducted to investigate the effect of mulch induced hydrothermal regimes on nitrogen movement in soil profile and the consequent effects on plant growth parameters. The experiment was laid out in a randomized block design with two replications under different mulching practices and nitrogen treatments with maize (cultivar EHM-2) as a test crop. The mulching treatments were No mulch (M_0) as control, Rice husk mulch (M_H) and Black polyethylene mulch (M_B), whereas, nitrogen treatments were No nitrogen (N_0) as control and 120 kg N ha⁻¹ (N_{120}) as 100% of the recommended

dose. The crop was sown with a row to row spacing of 75 cm and plant to plant 20 cm. The entire recommended dose of P_2O_5 and K_2O , as single super phosphate (SSP) and muriate of potash (MOP) respectively, were applied at the time of sowing. Nitrogen as urea was applied in two equal splits, 50% at sowing and 50% at tasseling stage. Two irrigations were applied to the crop at 21 and 53 days after sowing (DAS). First and second irrigation cycle were between 30th Dec'05 to 19th Jan'06 and 20th Jan to 20th Feb'06, respectively.

Set-up-2

A second experiment in a bare field (without crop) was carried out with the same treatments as in first experiment to eliminate the crop nutrient uptake part. Nitrogen was applied as urea according to the treatments. Initially 50% of nitrogen dose was applied followed by an adequate irrigation to saturate the field. The soil samples were collected at 3 days interval to study nitrogen movement in the profile for 21 day. Then the remaining 50% nitrogen was applied followed by a second irrigation to saturate the soil profile. The soil samples were collected at 4 days interval upto 32 days after second irrigation. First and second irrigation cycle were between 30th Dec'05 to 19th Jan'06 and 20th Jan to 20th Feb'06, respectively.

Data collection

Soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm depth by screw auger (disturbed) at a regular interval of 3 days and 4 days in the first and second irrigation cycles, respectively. Undisturbed core samples were used to determine NO_3-N and NH_4-N concentration in the soil. Soil nitrate and ammonium contents have been determined by distillation process using Kjeldhal method.

Upper ground plant samples were collected at 30, 60, 75 DAS. After measuring the leaf area index (LAI) of these samples, they were kept in oven at 65° to $70^\circ C$ for 48 hours for drying. The dry weight biomass was then recorded and the plant samples were kept for nitrogen estimation.

Estimation of the total nitrogen in plant was done by Kjeldhal method. The total plant N-uptake is a product of percentage nitrogen content per plant and dry matter.

Results and Discussion

The results obtained from the field investigations carried out to study the soil nitrogen transport under different hydrothermal regimes, have been presented and discussed in the following sections. The 'F'-test (CD 5%) have been carried out for each of the following section to evaluate the significance of each treatment in modifying soil nitrogen status as well as plant growth parameters.

Ammonium transport under different hydrothermal regimes induced by mulching

In the study on nitrogen movement among different mulch treatments, M_0N_{120} was used as control, as it is expected that in no fertilizer (N_0) treatment the variation of nitrogen concentration among different mulching practices will be negligible in different soil layers.

It was observed that mulching had very little impact on the NH_4-N concentration. The data of NH_4-N concentration in different layers indicated that, in 0-15 cm and 15-30 cm layers the effect of mulch in conserving NH_4-N concentration was significant upto 15 days after saturation, after which the effect of mulches on NH_4-N concentration practically diminished. Beyond 60 cm the variation in NH_4-N concentration was not influenced at all by the mulch treatments.

In M_0N_{120} , the initial peak of NH_4-N was in upper 0-15 cm soil layer. At 9 days after irrigation, the distribution of NH_4-N was almost uniform throughout the profile, after which the NH_4-N concentration in upper soil decreased rapidly. In M_B , the depletion of NH_4-N was mainly in the upper soil layer (upto 45 cm depth) and the rate of depletion of concentration was slower than in M_0 . Beyond 60 cm layer, the depletion was very less. M_H followed the similar trend of NH_4-N distribution in soil profile like that of M_B , but the rate of decrease in NH_4-N

concentration was intermediate between M_B and M_0 , throughout the profile during experimental period. The same kind of trends in NH_4 -N transport was observed in the second irrigation cycle also (Figure 1 *a-c*).

The NH_4 -N form of nitrogen is mainly moved by the diffusion process within the soil due to its adsorption to the clay particles because of its positive charge. With the application of irrigation, differential downward displacement of ammonium and nitrate-N occurred. As expected, the extent of displacement was smaller for ammonium-N, which being prone to soil adsorption, is transported to a lesser degree through massflow. Therefore, in mulched soil, the restricted water flow in the upper soil layers checked the NH_4 -N flow than that in no mulched soil under N_{120} . Again, as the soil moisture was conserved in the mulched soil, the degree of aeration was lower than that in the no mulch, so the process of hydrolysis was enhanced but the nitrification process was delayed in mulch treated soil. As a consequence, the rate of decrease of NH_4 -N in the upper soil layer was slower under mulched soil than that of no mulched soil.

Nitrate transport under different hydrothermal regimes induced by mulching

The NO_3 -N profile in N_{120} under different mulch treatments has been shown in Figure 1 *d-f*. In N_{120} , nitrification plays an important role for conversion of NH_4 to NO_3 as well as for their transport mechanisms. In M_0 , it was observed that the NO_3 -N was moving very fast throughout the soil profile. At 3 days after irrigation, the initial concentration peak was at 30 cm, but after 6 days, there was a marked decrease in NO_3 -N concentration at 30 cm layer. An increase in NO_3 -N concentration at 60 cm soil layer was observed at 6 days after saturation. The peak again moved to lower layer with decrease in NO_3 -N at 30-60 cm soil layer. After 12 days, the concentration was very low in upper 0-30 cm soil layer.

In M_B , the initial peak of NO_3 -N was observed at around 15-30 cm layer. With increase in time, a decrease in concentration in 0-30 cm soil layer was observed. The concentration of NO_3 -N

increased in 30-60 cm soil layer. But the rate of decrease in concentration was much slower in M_B than M_0 . Unlike M_0 , no sharp decrease in NO_3 -N was observed even 12 days after irrigation. In upper 0-15 cm soil layer, the concentration of NO_3 -N decreased at a very slow rate and the range of decrease in this depth was very small under this treatment.

In M_H , the trend was similar to that of M_B , but a sharp depletion of NO_3 -N concentration was observed at 30-60 cm 15 days after irrigation. The rate of NO_3 -N flow in M_H was intermediate between M_B and M_0 . The movement of nitrate within the soil layers followed the same trend under second irrigation like that of the first irrigation (Figure 1 *d-f*).

There was a significant variation in NO_3 -N concentration in 0-15 cm soil layer under different mulch treatments throughout the experimental period. The magnitude of variation in NO_3 -N concentration between M_B and M_0 increased with time in this layer. At 9 days after saturation, a significant effect of M_H over M_0 was observed in conserving NO_3 -N concentration in 0-15 cm soil layer. A similar trend was observed in 15-30 cm and 60-90 cm soil layer at 3 days after saturation.

Nitrate-N, being non reactive, was displaced deeper in soil. Whereas the trend of nitrate-N distribution was similar under different mulch treatments, the magnitude of peak nitrate-N concentration and rate of depletion actually varied. The peak of nitrate-N concentration in M_0 was beyond root zone (30 cm). Since under the mulch treated soil, the water flux was restricted the nitrate-N concentration was comparatively higher in the upper soil layer than that of no mulch soil. Different simulation models were tried for soil water and nitrate nitrogen concentration distribution in soil by various researchers. Nitrate concentration and transport was found to be highly dependent on soil water content (Santos *et al.*, 1997).

As the soil at surface was aerated to a greater degree in M_0 , the nitrification was faster, as a consequence the NO_3 -N concentration at initial days was maximum in M_0 than M_B and M_H in N_{120} soils. As more NO_3 -N was transformed from

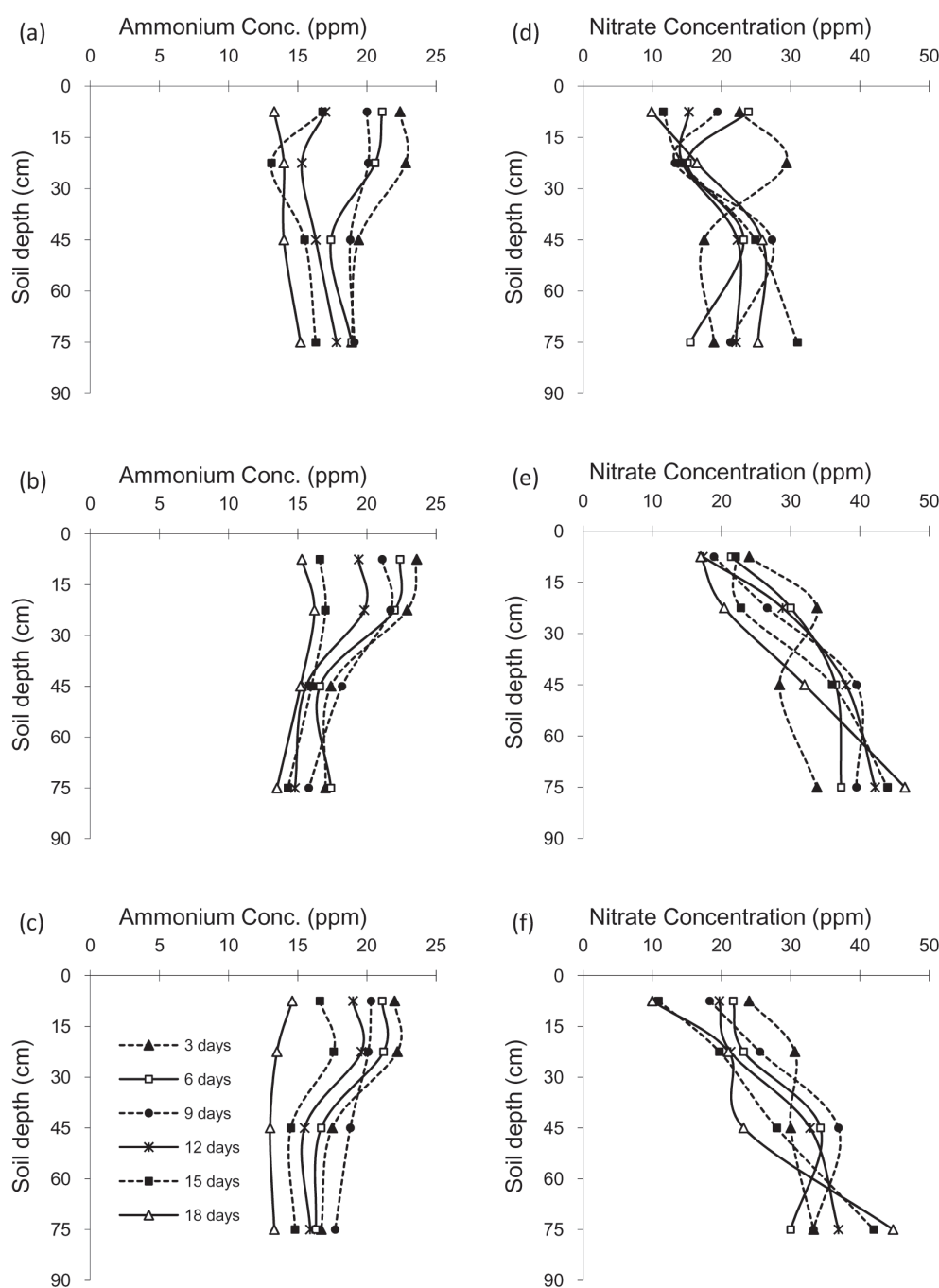


Fig. 1. Concentration (ppm) profiles for different days after saturation under M_0N_{120} , M_BN_{120} and M_HN_{120} for Ammonium-N (a-c) and Nitrate-N for (d-f) cycle during first irrigation.

NH_4 -N through nitrification, it depleted faster beyond 30 cm within 6 days after saturation, whereas this depletion was delayed due to slow release of nitrate. M_B and M_H followed a similar trend in NO_3 -N transport, throughout the experimental period in whole profile.

Urea applied to the soil undergoes hydrolysis and nitrification turning over to nitrate-N. These processes are reported to be temperature dependent (O' Toole *et al.*, 1982; Brady, 1983). But as the temperature under different mulches were not significantly different, we can conclude

Table 1. Biomass and LAI at 30, 60 and 75 days stage and N-uptake and yield at maturity under different treatments

Treatments	30 days stage		60 days stage		75 days stage			
	Biomass (t ha ⁻¹)	LAI	Biomass (t ha ⁻¹)	LAI	Biomass (t ha ⁻¹)	LAI	N-uptake (kg ha ⁻¹)	Yield (t ha ⁻¹)
M0-N0	1.02	0.74	3.3	1.5	4.5	2	49.4	2.14
M0-N120	1.5	0.91	5.1	2.25	8.4	2.75	67.7	3.91
MB-N0	1.1	0.77	3.4	1.7	5.1	2.25	55.1	2.4
MB-N120	1.6	1.16	5.3	2.47	8.9	3.05	75.6	4.28
MH-N0	1.1	0.74	3.7	1.65	5.8	2.2	52.6	2.76
MH-N120	1.8	1.11	5.5	2.39	9.4	2.9	73.8	4.51

that, in our experiment, different thermal regimes established by applying different types of mulches, were not playing a significant role in N-transport.

Plant biomass under different mulch and fertilizer treatments

Table 1 shows the plant dry biomass (t ha⁻¹) under different mulch and fertilizer treatments at different growth stages of maize. The values of plant biomass were significantly variable under different treatment, throughout the crop period. At 30 DAS, the nitrogen treatments showed a significant variation in biomass, over no nitrogen treatment. But no significant effect of mulch was observed at 30 DAS. The plant biomass under M_H was higher than that under M_B and M₀ throughout the crop period. At maturity stage both the M_B and M_H were having significantly higher plant biomass than that of M₀. It was observed that at 30 DAS the average biomass in N₁₂₀ plots was 1.5 times than in the N₀, but this increased to 1.6 and 1.7 at 60 and 75 Das, respectively (Table 1). The rate of increase in biomass from 30 to 60 DAS was 2.232 and 2.25 in N₀ and N₁₂₀ respectively, which decreased to 0.48 and 0.68 from 60 to 90 DAS, respectively.

LAI under different mulch and fertilizer treatments

Leaf area index (LAI) values under different mulch and fertilizer treatments at different growth stages of maize crop have been presented in Table 1. Throughout the crop growth period, the LAI of

maize in N₁₂₀ was greater than that in N₀ plot under different mulch treatments. Under all growth stages, LAI in M_B was higher than M₀, both under N₀ and N₁₂₀ treatments. It was observed that at 30 DAS the average LAI of N₁₂₀ plots was 1.4 times of the N₀, but it was 1.46 and 1.35 at 60 and 75 DAS, respectively. This may be due to the fact that after a certain growth stages the rate of growth decreases. The rate of increase in LAI from 30 to 60 DAS was 1.16 and 2.37 in N₀ and N₁₂₀ respectively, which decreased to 0.33 and 0.22 from 60 to 90 DAS, respectively.

This data was supported by the result that application of 100% dose of fertilizer to maize recorded highest leaf area and dry matter at all the stages (Kumar *et al.*, 2004). Since with application of proper nitrogen fertilizer the fertility of soil increased, the growth as well as LAI also consequently increased. The similar result was reported by Kumar *et al.* (2005).

The increased LAI in M_B and M_H over M₀, was due to increased availability of soil moisture and nitrogen throughout the crop growth cycle.

Yield of maize under different mulch and fertilizer treatments

Proper nitrogen nutrition of a crop is vital for its productivity and maize is one of the most responsive crops to application of nitrogen in low N soils. Therefore, a significant variation in yield was observed between N₀ and N₁₂₀ under all mulch treatments (Table 1). It was observed that the average yield of the N₀ treatments was 1.8 times lower than that of the N₁₂₀ treatments. A

similar trend was also reported by Kumar *et al.*, (2005). The effect of mulch on yield in both N_0 and N_{120} was highest under M_B followed by M_H and M_0 . In M_B treatments, the yield was 10% more than M_0 , whereas in M_H it was 7% more than that in M_0 . The difference in yield between M_B and M_H was not significantly different.

N-uptake by maize crop under different mulch and fertilizer treatments

The effect of N-uptake by plant is reflected in its growth, biomass production and yield. Table 1 shows the N-uptake (kg/ha) by maize crop at harvesting stage. It was observed that the N-uptake was 1.12 and 1.06 times more in M_B and M_H than M_0 , in N_0 , respectively, whereas, it was 1.12 and 1.09 in N_{120} plots. N-uptake in N_{120} treatment was much more than the N_0 under different mulch treatments. Table 1 shows that the average N-uptake in N_{120} was 1.4 times more than N_0 treatments. Since with increase in fertilizer application the growth of plant increased, the uptake of N by plants also increased to meet the nutrient requirement of the crop.

As discussed in previous paper that the mulching has a positive effect on moisture conservation of soil (paper I), the availability of moisture increased to plant in M_B and M_H , as well as the restricted soil water flux under M_B and M_H , help in conservation of NO_3 -N concentration in the soil profile throughout the experiment. So, the plant growth, i.e. the biomass, LAI, yield and N-uptake also increased in mulched treatments over no mulch. As the effect of mulch on moisture and nutrient conservation was more significant at the later stage of irrigation and fertilizer application, the effect of mulch on plant biomass was also prominent at later stage of plant growth. Nitrogen application showed a direct relation with biomass production of maize under different hydrothermal regimes, because of the fact that the nitrogen application enhanced the root growth and root uptake by plants.

Conclusions

Mulches significantly affect the hydrothermal regimes. Based on the results of this study it can

be inferred that moisture conservation potential of black polyethylene mulch was higher, whereas, rice husk mulch partially conserved the soil moisture. This implies that water is more freely available for uptake by plant roots with the application of black polyethylene mulch. Hence, under limited water supply conditions the use of these mulches enhance and sustain the crop growth. The nitrate fluxes, which dominantly occurred as massflow also gets reduced under the mulched condition. This study concludes that black polyethylene mulch significantly reduced nitrate losses from the soil profile, thereby, increasing its sustained availability to plants. The affect by mulch application on ammonium transport was very less because the ammonium movement is mainly through diffusion process. However, during the initial period after irrigation there was less depletion of ammonium from the upper to lower layer under mulched condition. Mulching improved the crop growth, was evident from better LAI and yield, which were highest in black polyethylene followed by rice husk mulched soil. Application of the full recommended nitrogen dose coupled with better soil hydrothermal environment under mulched conditions have resulted in better crop growth and highest yield.

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