



Research Article

Effect of Different Mulches and Nitrogen Doses on Nutrient Transport under Field Soil Condition I. Modification of Hydrothermal Regimes and its Impacts on Hydraulic Parameters

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ABSTRACT

A field study was carried out to evaluate the water 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. Different soil hydraulic parameters like, soil water content, saturated and unsaturated hydraulic conductivity and soil water flux were monitored under different mulching and nitrogen treatments at different soil depths. The temperature under black polythene mulch increased by about 2°C where the soil was relatively cooler under rice husk by about 1°C compared no mulch. Both the mulches could conserve water in soil to a significant extent. Soil water flux was conserved in soil to the maximum extent and for longer duration under black polythene followed by rice husk mulch. Overall, both rice husk and black polythene mulch could perform well in arresting loss of soil moisture in soil profile and making it available to crop for a longer period of time.

Key words: Rice husk, Polythene, Soil temperature, Hydraulic conductivity, Soil water flux

Introduction

High demographic population growth and rapid development of economic activity have resulted in an intensification of agricultural process to increase food production (Cirelli *et al.*, 2009). Of all the natural resources needed for economic and agricultural development, water is usually the most important, particularly in arid and semi-arid regions (Gercek *et al.*, 2010). Corresponding increase in demand of fresh water

for drinking water supply or in industry and agriculture imposes a key role of groundwater as one of main water resource. A sound understanding of soil processes is therefore necessary to enable better management of human activities which will result in minimising contamination of groundwater and surface water (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 to modify the soil hydrothermal regime, which has a direct impact on soil water transport within soil profile. Polythene mulch conserves soil moisture by reducing evaporation losses, particularly during the dry season (Li, 2004; Zhang, 2000). In

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addition, polythene mulch increases soil temperature during early spring and winter, when soil temperatures are usually low (Wang, 2003; Barton, 2000). The use of polythene mulch thus favours early crop establishment by conserving soil water and fertility of the land with increased crop yield (Huang, 2001; Wang, 2003; Barton, 2000). On the other hand, biological mulches like rice husk are also known to reduce evaporation, increase soil water, decreases diurnal soil temperature variations and increase in saturated hydraulic conductivity (Bristow and Campbell, 1986; Dahiya *et al.*, 2003).

The physical processes of water transport under different hydrothermal regimes as modified by the application of mulches are still not well documented due to the lack of knowledge of transport parameters under the modified environment, which are difficult to determine experimentally under field conditions. There exists therefore an information gap in literature 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 soil water movement by modifying soil hydrothermal regimes.

Materials and Methods

Study area

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

The climate of Delhi is semi-arid, subtropical with extreme hot summer and cool winter. The mean monthly maximum temperature ranges from 43.9 ° to 45°C in June, and the mean monthly minimum temperature varies from 2 to 6°C in the month of January. The mean annual rainfall of Delhi is about 652 mm, 84 per cent of which is normally received during July to September.

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

A field study was conducted to investigate the effect of mulch induced hydrothermal regimes on movement of water in soil profile. The experiment was laid out in a randomized block design with two replications under different mulching practices and nitrogen treatments in a bare soil to eliminate the crop uptake part. 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. 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 water and nitrogen movement in the profile for 21 days. 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 the second irrigation. First and second irrigation cycles were between 30th Dec'05 to 19th Jan'06 and 20th Jan to 20th Feb'06, respectively.

Data collection

The maximum and minimum temperatures and monthly total rainfall were recorded from the meteorological observatory of the Indian Agricultural Research Institute, New Delhi.

Soil temperatures were recorded by automated recorder at 7.5 and 22.5 cm soil depth at three days interval throughout the experimental period. The temperature data were recorded at 0700 and 1400 hrs for minimum and maximum temperature, respectively.

Soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm depths by screw auger (disturbed) and core sampler (undisturbed) 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 bulk density and hydraulic conductivity. Disturbed samples were used to determine the volumetric moisture content in the soil. Whereas, soil moisture content and dry bulk densities of the samples were determined gravimetrically and by core method (Blake and Hartge, 1986), respectively.

The mercury tensiometers were installed at 7.5, 22.5, 45 and 75 cm soil depth. The soil moisture suctions were recorded at three days interval throughout the experiment. Total soil moisture suction was then calculated by adding the gravitational potential with the matric potential, measured from the tensiometers. The matric potential was calculated by the equation;

$$\Psi_m = - (12.6 h_1 - h_2 - h_3) \quad (1)$$

where, ' Ψ_m ' is matric potential head (cm), ' h_1 ' is the height of Hg rise above the Hg surface in the Hg-cup (cm), ' h_2 ' is the distance between the Hg surface in the Hg-cup and table top (cm) and ' h_3 ' is the distance between the table top and centre of the tensiometer cup. The slope of the curve showing the total soil moisture potential vs. depth on Y and X- axis, respectively, is the soil moisture potential gradient.

The soil water flux was calculated by internal drainage method using the equation;

$$-\frac{dw}{dt} = a.t^{-b} \quad (2)$$

where, ' dw ' is depletion of volumetric moisture content from a soil layer, ' dt ' is increase in time, ' t ' = time (days) and ' a ' and ' b ' are constants.

The hydraulic conductivity was calculated using the Darcy's equation, i.e., hydraulic conductivity is equal to flux divided by hydraulic gradient.

Results and Discussion

The results obtained from the field investigations carried out to study the soil water 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 the soil thermal as well as water status.

Modification of soil thermal regime induced by mulch

Soil temperature in the two layers (0-15 and 15-30 cm) was measured to study the effect of different kinds of mulches on modification of soil temperature. Three-day average of the daily mean soil temperature under no mulch, black polyethylene and rice husk are presented in Figure 1(a) and (b) for 0-15 and 15-30 cm, respectively. It was observed that the soil temperature was higher in 0-15 cm compared to 15-30 cm soil

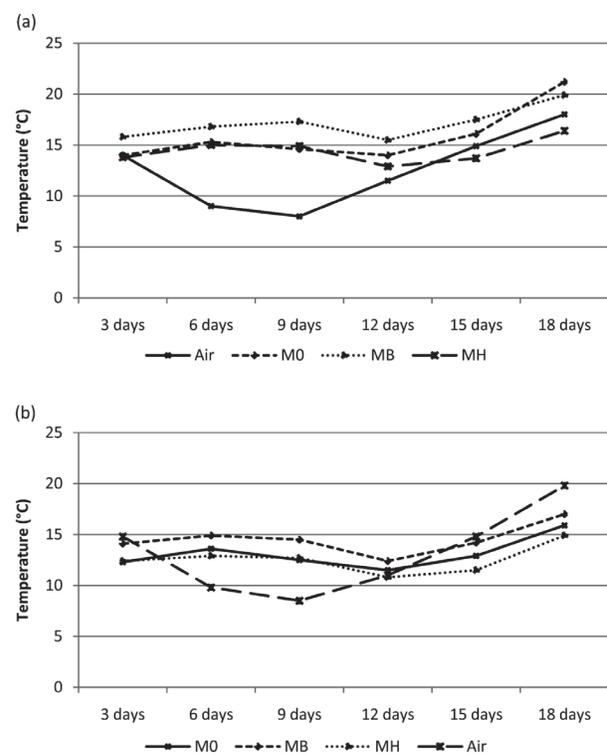


Fig. 1. Spatial and temporal variation of soil temperature ($^{\circ}\text{C}$) under different mulching treatments at (a) 0-15 cm and (b) 15-30 cm soil layer

layer throughout the experimental period. The soil temperature in plots with recommended dose of nitrogen (N_{120}) was 15.8 and 13.8 °C and that in control (N_0) plot was 15.8 and 13.7 °C under M_B (black polyethylene) and M_H (rice husk), respectively, whereas it was 13.8 and 14.2 °C in N_{120} and N_0 under no mulched conditions. It can, therefore, be concluded that N-application has none or negligible effect as far as modification of soil temperature is concerned. Hence, the data was averaged over nitrogen treatments and the change in soil thermal regime under various mulch conditions was evaluated irrespective of nitrogen treatment. The mean temperature of soil was significantly different in all the three-mulch treatments during initial three days in 0-15 cm soil layer and initial six days in 15-30 cm soil layer from the days of irrigation. Though there were marked differences in soil temperatures between M_B with M_0 and M_H in both 0-15 and 15-30 cm soil layer throughout the duration of the experimental period, the differences were also found to be non significant. The value of the soil temperature was much higher in M_B (15.8° to 19.6 °C from 3rd to 21st day after irrigation) in 0-15 cm soil layer, whereas these variations were 14.0° to 18.4° C and 13.7° to 17.3° C in M_0 and M_H , respectively; no significant difference between M_H and M_0 treatments could be observed. The temperature under black polyethylene increased on an average by (2.7°C) as compared to no mulch in 0-15 cm layer. The maximum increase was on the 9th day after irrigation. The rice husk mulch decreased soil temperature on an average by 1°C in 0-15 cm layer. The maximum decrease (2.4°C) was observed on 15th days after irrigation. The rice husk mulched soil maintained comparatively lower temperatures than no mulched soil in both 0-15 and 15-30 cm soil layers. In general, the mean daily temperature in both the soil layers followed the order $M_B > M_0 > M_H$.

These findings are in agreement with those reported earlier by Kalaghatagi *et al.* (1988) and Sui *et al.* (1992). Mulching tends to reduce the thermal conductivity of surface soil, thereby decreasing the heat transfer between the soil surface and the lower layer. Rice husk increases

the albedo of the surface thereby also reducing the maximum soil temperature during day time. The black polythene, on the contrary, absorbs much of the radiation energy but transmits very little downwards in to the soil by conduction because the energy is lost through increased long wave radiation, thereby increasing soil temperature.

Effect of mulches on volumetric moisture content

Figure 2 shows the volumetric water content in different soil layers under the three mulch treatments during first and second irrigation cycle, respectively. The soil water depletion from different mulch treatments followed a common trend with time after irrigations. But the range of decrease of water content was different from one treatment to another. In 0-15 cm soil layer, compared to the control (M_0), water depletion between 3 and 21 days after irrigation was 25% and 75% less in the rice husk mulched soil (M_H) and black polythene mulched soil (M_B), respectively. The M_B treatment recorded 50% and 60% less depletion even for 15-30 cm and 30-60 cm deep soil layers respectively, compared to M_0 and M_H (Figure 2). However, no significant differences in water depletion were observed in 60-90 cm soil layer among the treatments.

Under no mulch, the soil water content in 0-15 and 15-30 cm decreased sharply during initial 6 days after irrigation. The lower layers (30-60 and 60-90 cm) could still retain some more water up to the 9th day after irrigation (Figure 2). However, a sharp decrease in soil water was observed 9 days after the irrigation, with the rate of depletion of water from upper to lower soil layer decreasing with time.

An interesting trend was observed under black polyethylene. The soil water was depleting from 0-15 cm soil layer, but below 30 cm the water content was very consistent and the rate of decrease of water was also very slow (Figure 2). After 9 days of irrigation some depletion of soil water took place from the soil profile but again the rate of decrease was not so high enough as in case of no mulched soil.

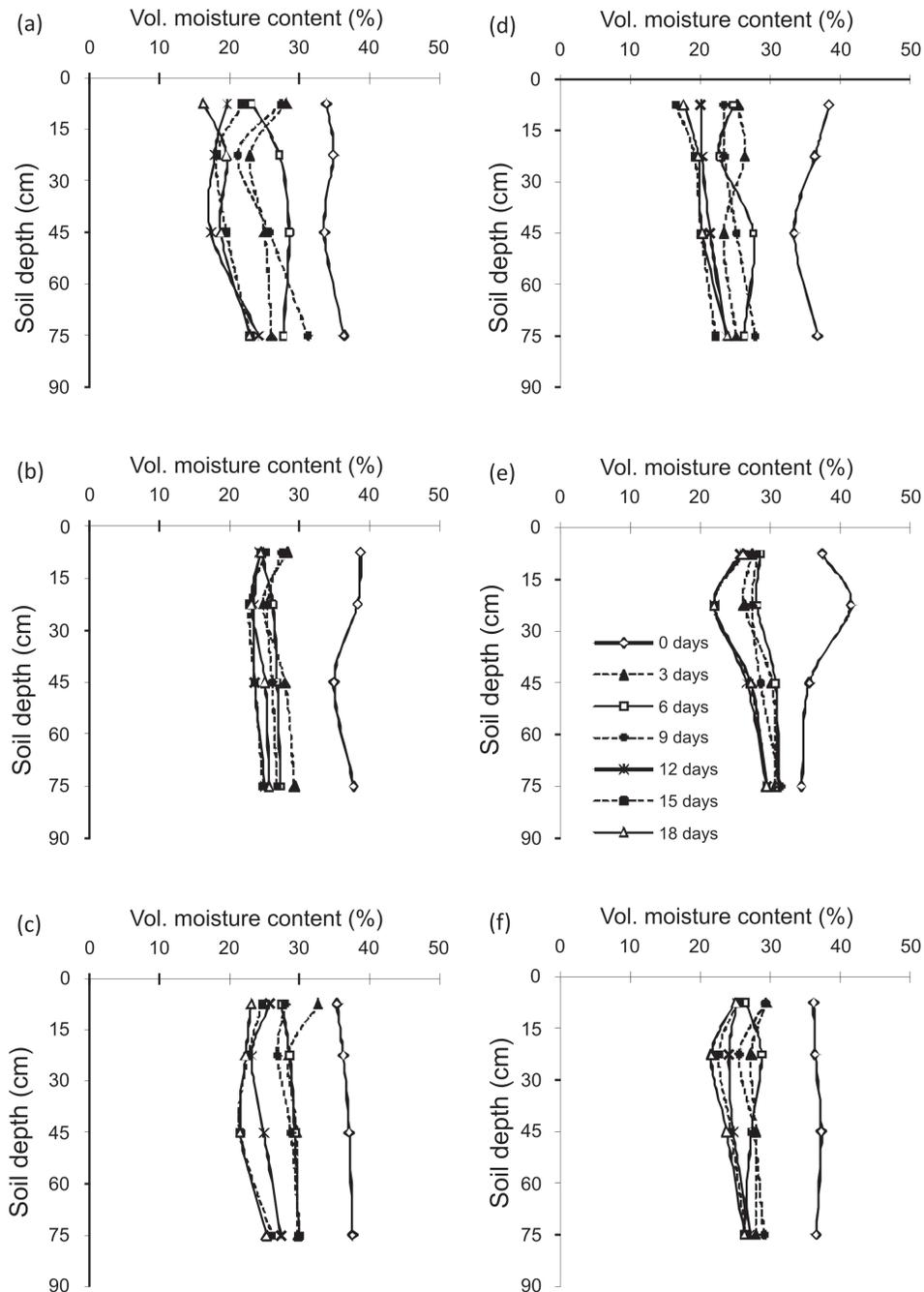


Fig. 2. Spatial and temporal variation in volumetric soil water content (%) under (a) M_0N_0 , (b) M_BN_0 , (c) M_HN_0 , (d) M_0N_{120} , (e) M_BN_{120} and (f) M_HN_{120} treatments during first irrigation cycle

Similar to M_B , in M_H there was little variation in soil water content in the lower layers, though the upper (0-15 cm) soil dried up (Figure 2). The rate of decrease in soil moisture after 9 days of irrigation in M_H was less than M_0 but more than in case of M_B . The trends were similar in the

second irrigation cycle, but only after 21 days of irrigation, the soil moisture sharply decreased in the soil profile. The comparative performance of different mulches in conserving soil water under both the irrigation cycles followed the trend of $M_B > M_H > M_0$.

Under rice husk mulch, evaporation was reduced due to the protection and isolation of soil surface from insolation, interruption in downward heat flow and obstruction to the diffusion of vapour. Rice husk mulch was less effective than the black polyethylene mulch because whatever amount of water vapour was formed, it could escape through the porous husk layer, which was not possible in case of the polyethylene mulch. Similar results were also reported earlier by Fisher (1995). Polyethylene mulch proved to be more efficient physical barrier to prevent the loss of moisture to the atmosphere as compared to rice husk mulch. From the present study, it was evident that application of mulch reduced the actual evaporation rates in the initial days after irrigation (coinciding with early periods of plant growth). The water was thus conserved and could be used by the crop subsequently during the later period of its growth.

Effect of mulch on soil water flux

As the soil profile was fully saturated, there was no significant difference in soil water content as well as soil water flux among the different treatments during initial stage of observation Figure 3. However with passage of time, soil moisture content changed, resulting in significant variation in fluxes among M_0 , M_B and M_H at 0-15 cm depth. As previously discussed, the soil moisture variation in M_B being minimum among all the treatments, the flux was also minimum in this treatment. In 0-15 cm soil layer the flux in M_B decreased from 0.059 to 0.011 cm day⁻¹ from 3 to 21 days after irrigation, whereas these values were 0.096 to 0.026 cm day⁻¹ and 0.158 to 0.048 cm day⁻¹ for M_H and M_0 , respectively under first irrigation cycle. Under second irrigation cycle in 0-15 cm soil layer, the flux in M_B decreased from 0.104 to 0.020 cm.day⁻¹ from 4 to 32 days after saturation, whereas such decrease were from 0.123 to 0.031 cm day⁻¹ and from 0.147 to 0.036 cm day⁻¹ for M_H and M_0 respectively (Figure 5). This indicates that the soil water flux was affected by the moisture conserving capacity of the mulches. At 30 cm soil depth, there was a significant variation in moisture flux among the different mulching treatments except during the

initial 3 days. In this layer also, the flux followed the same trend as in the upper depth. It was the lowest in M_B and highest in M_0 , whereas in M_H soil water flux values were intermediate.

There was no significant difference in flux among the treatments at 60 cm soil depth. However, the flux under M_B was lower than that of M_0 and M_H . The fluxes under the later two were close to each other (Figure 3). The reason may be the lesser variation of soil moisture in the M_B in comparison to M_H and M_0 .

It was observed that, the water flux in general increased as the soil depth increased. The flux followed the same trend at 90 cm depth as at 60 cm depth, whereas, the fluxes under M_B were markedly different from those under M_H and M_0 , which were not significantly different from each other in respect of their soil water fluxes (Figure 3).

There is no significant initial variation in moisture content among the mulching treatments, but with time, the depletion of moisture content increased, which was maximum in M_0 , followed by M_H and M_B , possibly due to moisture conservation potential of M_H and M_B . As a result of this, the variation of flux values among different treatments became significant with increase in time at the upper 15 and 30 cm soil depth. But the variation was not significant in the lower soil profile below 30 cm, due to lesser depletion of soil moisture content in these layers.

Effect of mulch on unsaturated hydraulic conductivity

Hydraulic conductivity is the most important soil physical parameter used to study the soil water and nutrient transport mechanisms. According to Darcy's law, the hydraulic conductivity is the flux at unit hydraulic gradient. Using this concept, the unsaturated hydraulic conductivity of soil in field condition was computed, under different mulching treatments. Since the hydraulic conductivity is directly related to water flux, the effect of mulches on hydraulic conductivity followed the same trend as the water flux in both the irrigation cycles. With increase in time from the days after irrigation, the

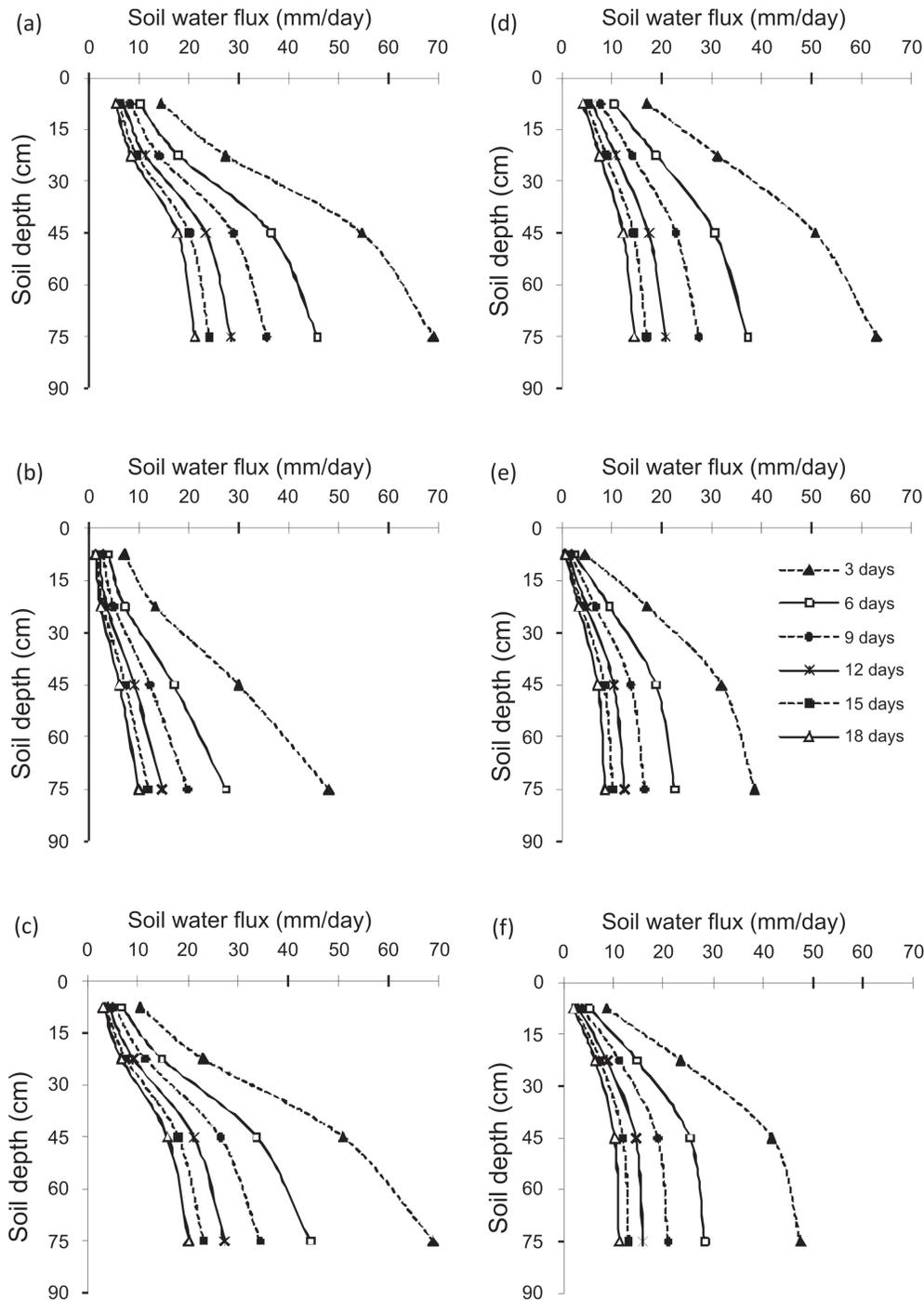


Fig. 3. Spatial and temporal variation in soil water flux (mm/day) under (a) M_0N_0 , (b) M_BN_0 , (c) M_HN_0 , (d) M_0N_{120} , (e) M_BN_{120} and (f) M_HN_{120} treatments during first irrigation cycle

hydraulic conductivity decreased (Figure 4). In 0-15 cm soil layer, hydraulic conductivity was maximum in M_0 followed by M_H and M_B .

The decrease in hydraulic conductivity with time was mainly due to the decreasing in moisture

content. This could be associated with the disappearance of capillary water to an increase soil moisture tension with the consequent change from capillary flow to molecular flow. The sharp decrease in hydraulic conductivity with a decrease

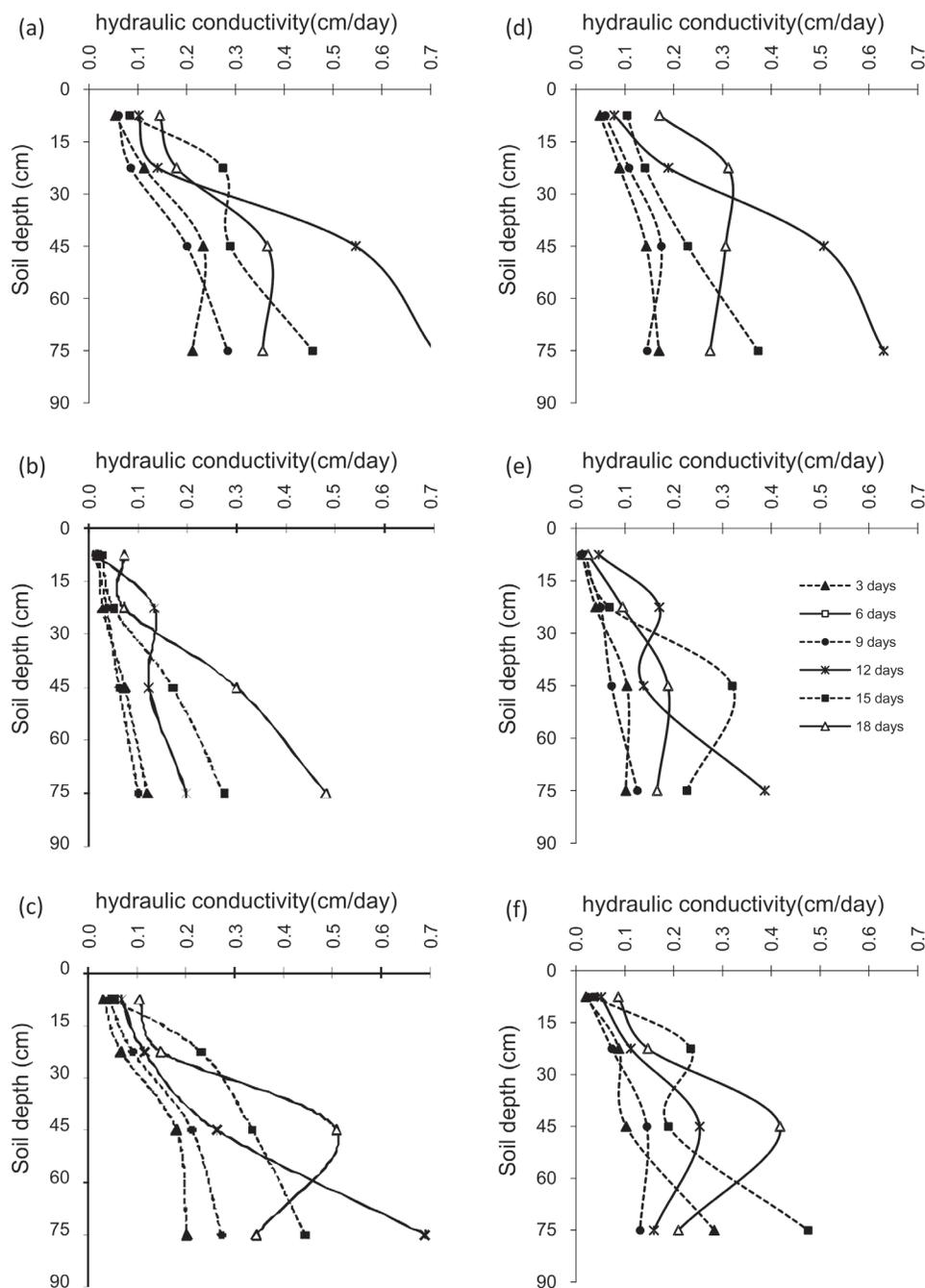


Fig. 4. Spatial and temporal variation in unsaturated hydraulic conductivity (cm/day) under (a) M_0N_0 , (b) M_BN_0 , (c) M_HN_0 , (d) M_0N_{120} , (e) M_BN_{120} and (f) M_HN_{120} treatments during first irrigation cycle

in moisture content is also widely reported in literature.

Conclusions

Application of mulches significantly affects the hydrothermal regimes of soil. They modified

the soil temperature upto 30 cm depth. The black polyethylene mulch was effective in increasing the soil temperature of the top layer (0-15 cm) by about 2°C under sub-optimal air temperature condition. Whereas, the rice husk mulch slightly decreased the soil temperature of this layer by

about 1°C making the soil temperature more sub-optimal. Therefore, under sub-optimal air temperature condition, use of black polyethylene mulch is beneficial for crop growth. Based on the results of this study it can be concluded that moisture conservation potential of black polyethylene mulch was higher. Whereas, rice husk partially conserved the soil moisture. Hence, under limited water supply condition the use of these mulches enhance the crop growth. The use of mulches also reduces the hydraulic gradient in the profile, which in turn decreases the water fluxes under mulch condition. Hence, mulching is useful in reducing the loss of water fluxes out of the soil profile. Water is more freely made available for uptake by plant roots with the application of black polyethylene mulch.

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