Tillage and mulch effects on some soil physical properties in shallow red brown terrace soils of Bangladesh

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Abstract

A field and laboratory experiment was conducted during 2000-2001 and 2001-2002 to estimate the tillage and mulch effects on physical properties of soil. The experiment was laid out in split-plot design with three replications. Four different tillage methods were used in the main plots: minimum tillage (MT), conventional tillage (CT), disc ploughing (DP) and chisel ploughing (Chp), and four different mulch treatments were used in the subplots including rice straw mulch (RSM), water hyacinth mulch (WHM), white polyethylene mulch (WPM) and no mulch (NM). The physical properties of the soil were markedly influenced by tillage and mulch. The bulk density was significantly altered by different tillage practices. The lowest bulk density was observed in disc ploughing at the 0-10 cm-soil depth. The lowest value of soil strength was recorded in the ploughed zone, which used disc and chisel ploughing, and the highest values came from area of minimum tillage. Mulch had less effect on bulk density and soil strength. Marked differences in weekly mean and diurnal soil temperature under different mulch practices were observed. Polyethylene mulch showed the highest temperature and the lowest was observed under straw mulch. It was observed that minimally tilled plots showed the maximum level of soil temperature at the 10 cm depth throughout the day. Similar trends in the results were also observed for weekly mean soil temperature. The cumulative infiltration and infiltration rates increased with pulverization of soil and increasing depth of ploughing. Cumulative infiltration and infiltration rates were higher in disc and chisel ploughing and lower in minimum and conventional tillage methods.

Keywords: Soil, Physical Properties, Tillage and Mulch Effects

Introduction

Tillage physically manipulates soil and is intended to destroy weeds, incorporate crop residues and amendments into soil, increase infiltration and reduce evaporation, prepare seedbed and break hard layers to facilitate root penetration (Prihar, 1990). It has been an ancient innovation to alleviate soil-related constraints to crop production. Tillage has been used on shallow soils to increase the effective root volume, on soils with low infiltrability to improve water intake rate, on nutrient-deficient soil to turn under the crop residue and biomass, and on soils with low water holding reserves to increase surface retention capacity (Lal, 1990). Specific problems to be mitigated by appropriate tillage methods include:

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the establishment of good crop stand, creation of favorable soil temperature and moisture regimes, avoidance of soil compaction, enhancement of effective rooting volume, prevention of runoff and erosion, enhancement of soil structure and soil productivity, and minimization of soil degradation (Hillel, 1971). The nature and magnitude of tillage varies with the soil type, climate and crop. There is no single tillage method that can be universally applicable to all soils, crops, climate types, cropping systems and socioeconomic conditions.

Relationships between soil tillage methods and soil physical properties and, consequently, crop response in different soils have been reported by many authors (Acharya and Sharma, 1994; Sharratt, 1996). Pelegrin *et al.* (1990) observed different soil physical properties, e.g. penetration resistance, bulk density, hydraulic conductivity, and infiltration rate owing to different tillage treatments applied. Lal (1974) mentioned that an important factor in continuous productivity of tropical soils is the maintenance of soil physical characteristics at an optimum level. Once it is achieved, the production capacity of these soils can be substantially improved by the use of fertilizers. Total porosity and size of pore distribution are also important parameters in tilled soil. As a soil mass is compressed, its bulk density increases and the pore volume decreases. Water retention, hydraulic conductivity, and diffusivity of soils are affected by the intensity of land preparation done by different tillage methods. Thus, the types of tillage practices used plays an important role in rainfed or irrigated agriculture, proper choice of implements, timely operations. Additionally, the methods tillage to be used must be specifically selected for different agroclimatic zones. Hard setting soil, that have root restricting layers, need some form of loosening through deep tillage to conserve soil and water and facilitate crop growth (Lal, 1989). Tillage levels and soil physical conditions modify the root systems (Singh and Singh, 1996). Tillage can affect the amount, size and pattern of crop roots by altering the soil physical properties such as pore size distribution, bulk density and soil strength.

Mulches comprised of crop residue are effective in reducing evaporation and, in turn, aid in conserving soil moisture. Mulches have been known to modify the hydrothermal regime of soil (Bhagat and Acharya, 1988). It is most effective in water conservation during the first stage of evaporation. The overall effect of mulch depends on the magnitude of water saving during the first stage and on the duration of the dry period (Lal, 1990). Mulch also favourably affects root growth (Bhagat and Acharya, 1988). Acharya and Sharma (1994) concluded that mulching with pine needles under both conventional and no tillage practices favourably moderated the soil environment for better root growth resulting in a more efficient utilization of nutrients. Considering the above facts, the present investigation was carried out to study the effects of tillage and mulch on the physical properties of the shallow red brown terrace soils of Bangladesh.

Materials and Methods

The experiments were conducted at the research field of Banglabandhu Sheikh Mujibur Rahman Agricultural University, Salna Gazipur from November, 2000 to May, 2002. The experimental station is situated at about 24.05° north latitude and 90.16° east longitude; having a mean elevation of 8.4 m above sea level.

The climate of the location is tropical monsoon characterized by three distinct seasons (Ahsan and Karim, 1988). Highest and lowest mean monthly temperatures of the warmest and coldest temperature of the coldest months were recorded in April (33°C) and January (15°C), respectively. The mean daily open pan evaporation occurring the crop growing period ranged between 2.29 and 4.46 mm in 2000–2001 and 2.21 and 3.45 mm in 2001–2002.

The soil of the experimental site belongs to Salna series and has been classified as Grey Terrace Soils in the Bangladesh soil classification system, which falls under Inceptisol in Soil Taxonomy (Brammer, 1980 and FAO, 1988). This soil of Madhupur Tract (AEZ No. 28) occupying an area of about 1600 square miles between the Brahmaputra and Meghna rivers is characterized by heavy clays within 50 cm from the surface, and are so compact that internal drainage and root penetration of crops is seriously impeded. The soil has poor physical and chemical properties. The detailed information about the physical characteristics of the soil are presented in Table 1.

The experiment was laid out in split-plot design with three replications. Four different tillage methods were used in the main plots and the four different mulch treatments in the sub-plots. The dimensions of individual plots were 4.5 m × 4.0 m. The distance between plots was 1.5 m and that between the blocks was 2 m. The main plots were treated with minimum tillage (MT): seeds were sown in furrows (shallow depth of 3–4 cm) made manually by pulling a curved iron rod (tyne). The soil between the rows was left undisturbed; conventional tillage (CT): ploughed four times by country plough (8–10 cm depth) followed by laddering three times for land preparation; disc ploughing (DP): land was opened (16 –20 cm in depth) by a tractor drawn disc plough. The soil was then pulverized using a rotavator. Finally, the land was leveled using a bullock drawn wooden ladder and chisel ploughing (Chp): land was cut by tractor drawn chisel plough (25–30 cm in depth). The soil was then powdered using a rotavator. Finally, the land was leveled by laddering.

The sub-plot treatments were rice straw mulch (RSM): rice straw was spread to cover the soil in between the plant rows at the rate of 7.5 ton ha^{-1}; water hyacinth mulch (WHM): water hyacinth was spread to cover the soil in between the plant rows at the rate of 7.5 ton ha^{-1}; white polyethylene mulch (WPM): polyethylene sheets were spread to cover the soil in between the plant rows, and no mulch (NM).

The land was prepared according to the prescribed tillage treatments. Wheat seeds were treated with vitavex-200 at 0.25 % prior to sowing in the second year and then planted in rows at 120 kg ha^{-1} with 20 cm spacing between each row. Seeds were placed at a depth of approximately 5 cm. In mini-

Table 1. Some physical properties of soil

Soil depth (cm)	Particle size (%)			Textural class	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Saturated hydraulic conductivity (cm hr^{-1})	Field capacity (cm^3 cm^{-3})	pH	Organic carbon (%)	CEC (meq/ 100 g)
	Sand	Silt	Clay								
0–7.5	44.1	20.0	35.9	Clay Loam	1.48	2.60	1.36	0.37	6.6	0.82	10.59
7.5–15	38.1	20.0	41.9	Clay	1.57	2.67	0.86	0.38	6.6	0.63	12.38
15–30	30.4	21.7	47.9	Clay	1.60	2.69	0.48	0.39	7.4	0.26	14.32
30–45	30.1	22.0	47.9	Clay	1.64	2.70	0.27	0.39	7.2	0.23	14.12
45–60	30.2	20.0	49.8	Clay	1.67	2.70	0.25	0.39	6.8	0.22	16.41

mum tillage treatment, furrows were made 20 cm apart. After the seeds were sown in the furrow they were covered with soil by hand. Rice straw and water hyacinth was applied at the rate of 7.5 ton ha^{-1} after the first irrigation and weeding was done at the CRI stage. White polyethylene sheet was placed between two rows of wheat after first irrigation.

During the wheat-growing period various soil and crop parameters were measured in the field. Soil samples were collected at different time intervals for measuring soil physical and chemical properties.

Bulk density of soil

Bulk density was determined by obtaining undisturbed soil cores of known volume and dividing the oven dry soil mass by the core volume of the sample. To determine the bulk density of four different layers, undisturbed soil cores 5 cm long and 5 cm in diameter were collected from the mid point of different layers (0–10, 10–20, 20–30 and 30–40 cm) with the help of a manually operated core sampler. Precautions were taken to avoid soil compaction inside the core sampler. The collected soil cores were trimmed to the exact volume of the cylinder and oven dried at 105°C (Black, 1965).

Soil strength

Soil strength was measured with the help of a pocket penetrometer. In each treatment three spots were chosen for the measurement of soil strength up to a depth of 40 cm at an interval of 5 cm. The mean values were used for preparing the graph. During the measurement of soil strength, soil moisture content was also determined.

Soil temperature

Soil temperature was recorded using soil thermometers after the establishment of the crops. The thermometers were installed at a depth of 10 cm in each of the experimental plots. Temperature reading was recorded at 13 hours every day. Besides this, diurnal temperature fluctuations were recorded at a depth of 10 cm from 6 to 18 hours at 60 days after sowing for both the years.

Saturated hydraulic conductivity

Saturated hydraulic conductivity (K_{sat}) was measured by the "Falling-Head" method, because the permeability of the soils was estimated to be low. Apparatus for the falling-head method of Daiki Rica Co. Ltd. (Dik-4000) was used and the saturated HC was calculated according to the following equation:

$$K_{sat} = \frac{2.3\,al}{At} \log_{10} \frac{h^1}{h^2}$$

Where, K_{sat} = Saturated hydraulic conductivity (cm s^{-1})

a = Cross sectional area of stand pipe (cm^2)

l = Thickness of soil sample i.e. height of the core sampler (5.1 cm)

A = Cross sectional area of soil sample (19.6 cm^2)

t = Time of water falling from the top line to the bottom line of the stand pipe (s)

h^1 = Height from the water surface in the vessel to the top line of the standpipe (17 cm)

h^2 = Height from the water surface in the vessel to the bottom line of the standpipe (7 cm).

Measurement of infiltration

The infiltration rates in all the tillage treated plots were measured using a concentric cylinder infiltrometer which measured the fall of water over time by a point gauge. The details of the procedure are as follows:

Two metallic rings, each 60 and 30 cm in diameter, respectively, were driven concentrically into the soil to a depth of about 15 cm by keeping an iron sheet and a thick rubber pad over both the rings and hammering uniformly and slowly. Water was added to the circular compartment between the two rings, which acted as a buffer.

To avoid disturbing the soil, a polyethylene sheet was placed on the soil surface inside the inner ring and then water was added to about a height 20 cm, and the polyethylene sheet was removed carefully. The initial reading was taken five minutes after the addition of water in the inner cylinder. The infiltration measurements were taken at intervals of 5, 10, 20, 30 and 60 minutes and continued up to 360 minutes. Cumulative infiltration and infiltration rates were computed and plotted in graphs.

In the analysis of infiltration data, it was assumed that infiltration characteristics of soil could be adequately represented by the equation

$$I = at^n$$

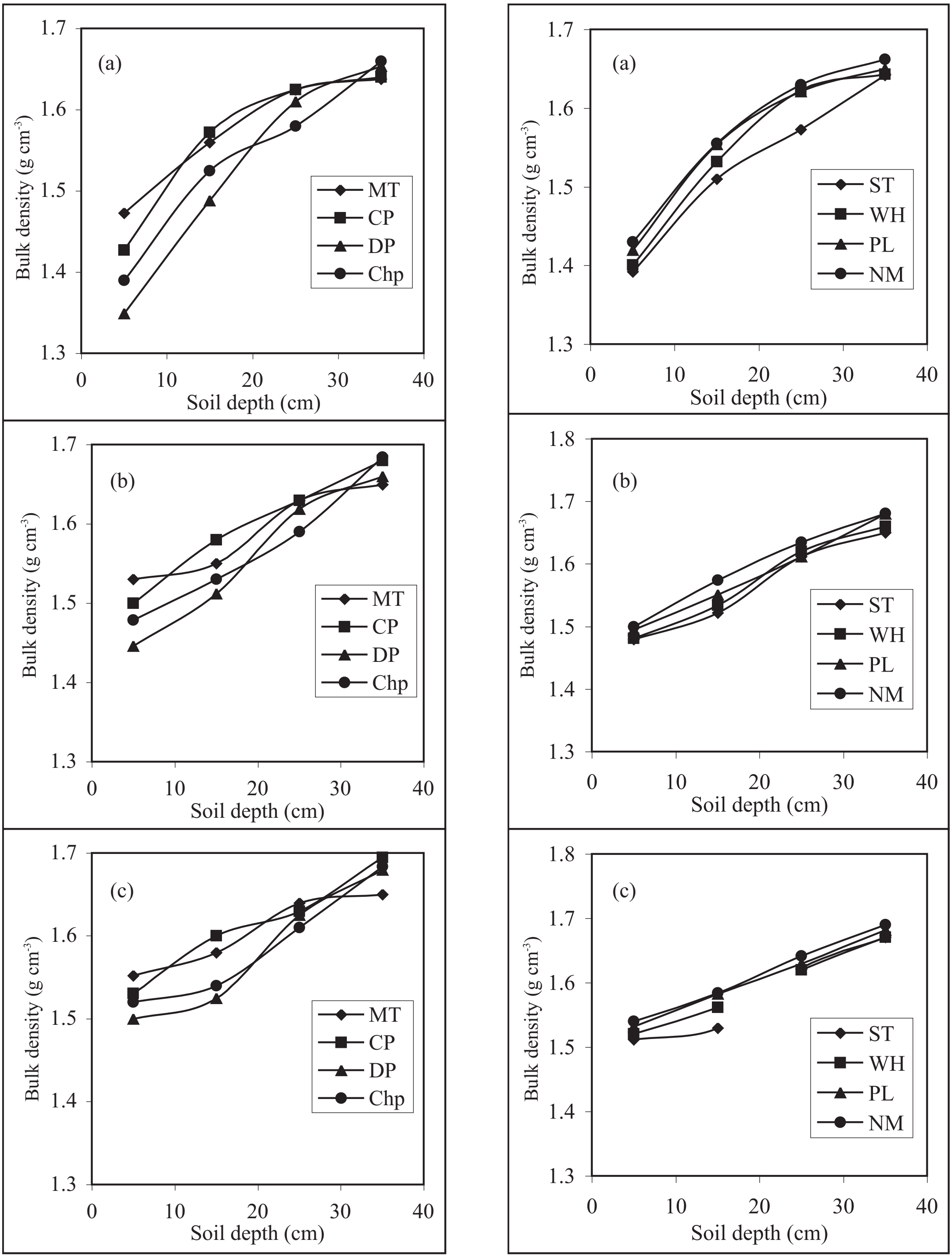
Where, *I* is the cumulative infiltration, *t* is the elapsed time and ‘*a*’ and ‘*n*’ are the constants.

Results and Discussion

The influence of different tillage methods and mulch application on various soil physical properties and their relation to crop production are discussed below.

Bulk density

One of the physical properties of soil that is almost always altered by tillage is bulk density (Cassel, 1982). The bulk density measured during the wheat-growing period at 25 day intervals after sowing in 2000–2001 is illustrated in Figure 1. The figure showed that, irrespective of growth period, tillage practices and mulch application, the bulk density at different soil depths increased with the increase of soil depth. After 25 days of sowing, comparison among the various treatments revealed that the minimum value (1.35 g cm^{-3}) was associated with the disc ploughing followed by chisel ploughing (1.39 g cm^{-3}) at the surface layer (0–10 cm). These results persisted throughout the growing season. After tillage, bulk density values of the upper 0–10cm soil layer became significantly lower for disc ploughing than for conventional tillage and chisel ploughing. This is presumed to be because disk ploughing pulverizes and loosens the soil to a greater extent than other tillage methods. It was revealed from the figure that in this layer (0–10 cm) the bulk density value reached a maximum (1.47 g cm^{-3}) in the minimally tilled plots, which gradually increased to 1.56 (10–20 cm), 1.63 (20–30 cm), and 1.64 g cm^{-3} (30–40 cm), respectively, with an increase in soil depth on the 25 day after sowing. This trend of increased bulk density with



(i) Tillage effects (ii) Mulch effects

Fig. 1: Schematic diagrams showing the effects of (i) tillage and (ii) mulch on soil bulk density at (a) 25, (b) 50, and (c) 75 days after sowing.

increased depth was similarly observed regarding other tillage methods. In conventional tillage treatment the lowest bulk density was 1.43 g cm^{-3} at the surface layer and the highest was 1.64 g cm^{-3} at the 30–40 cm depth. In this treatment, bulk density increased from the 10 cm soil depth because ploughing depth did not exceed 9 cm. Bulk density measured at 50 and 75 days of sowing showed the same trend as disc ploughing in which the lowest bulk density (1.45 and 1.50 g cm^{-3}) was followed by chisel ploughing (1.48 and 1.52 g cm^{-3}) at the 10 cm soil layer. Minimum tillage had the highest bulk density in this layer (1.53 g cm^{-3} in 0–10 cm and 1.65 g cm^{-3} in 30–40 cm). Bulk density gradually increased as time advanced, and irrespective of tillage treatment, attained a maximum value before harvesting although the magnitude of increase in bulk density varied appreciably depending on the tillage treatment.

The differences in bulk density values under different tillage treatments decreased with time or an increase in soil depth. Irrigation and subsequent drying of the clayish soil might have induced soil compaction irrespective of tillage treatment, which has led to higher and similar bulk densities. The decrease in bulk density associated with tillage treatment may be attributed to tillage that made the soil loose and more porous. Similar results were also reported by Aggarwal *et al*. (1992) and Carman (1997).

Mulching had no significant influence on bulk density. However, bulk density tended to decrease with mulch. It ranged from 1.30 g cm^{-3} in straw mulch to 1.43 g cm^{-3} in no mulch treatment at the 0–10 cm soil depth 25 days after sowing. Similar trends were also observed at 50 and 75 days after sowing.

Soil strength

Another physical property of soil which was modified by tillage is soil strength. The soil strength (kg cm^{-2}) measured at 30 days after wheat sowing is presented in Figures 2. The impact of different tillages methods on soil strength was similar to that of soil bulk density. Soil strength profiles indicated that soil strength increased with soil depth under both disc and chisel ploughing and decreased with minimal and conventional tillage. The maximum value (3.94 kg cm^{-2}) was recorded at the 5 cm depth for the minimal tillage followed by the 10 cm depth (3.55 kg cm^{-2}) also for minimal tillage. The dry unploughed surface layer of clay soil was very hard and attained the maximum strength. In disc and chisel ploughing a reverse trend was observed with the minimum soil strength being at the upper ploughed layer of the soil profile. In disc ploughing the strength varied between 0.62 and 0.70 kg cm^{-2} within the ploughing depth of 0 to 15 cm. Soil moisture in this region varied between 19.4% at 5 cm and 29.4% by volume at the 15 cm soil depth. The soil strength increased abruptly to as high as 1.62 kg cm^{-2} at the 20 cm depth (just below the ploughing depth) and increased further to the maximum value of 1.67 kg cm^{-2} at the 25 cm depth. The strength decreased again with further increase in soil depth and reached a lower value of 1.30 kg cm^{-2} at 40 cm. The soil moisture at this 20 to 40 cm depth increased from 31.2 to 37.4% by volume. It is revealed from this experiment that soil strength was influenced directly by ploughing and the moisture content of the soil. Disk ploughing up to a depth of 15 cm has made the soil softer and has led to the soil being of minimum strength in this region, while, increasing the soil moisture with an increase in depth beneath the ploughed layer has resulted in the soil becoming considerably softer. The impact of increased soil moisture on reducing the soil strength has been reflected in both minimal and conventional ploughing where maximum strength was attained under conditions of minimum moisture at the surface, and minimum soil strength under maximum moisture at the lower depth of the soil profile. In chisel ploughing the minimum strength of 0.70 to 0.72 kg cm^{-2} was confined to the soil within

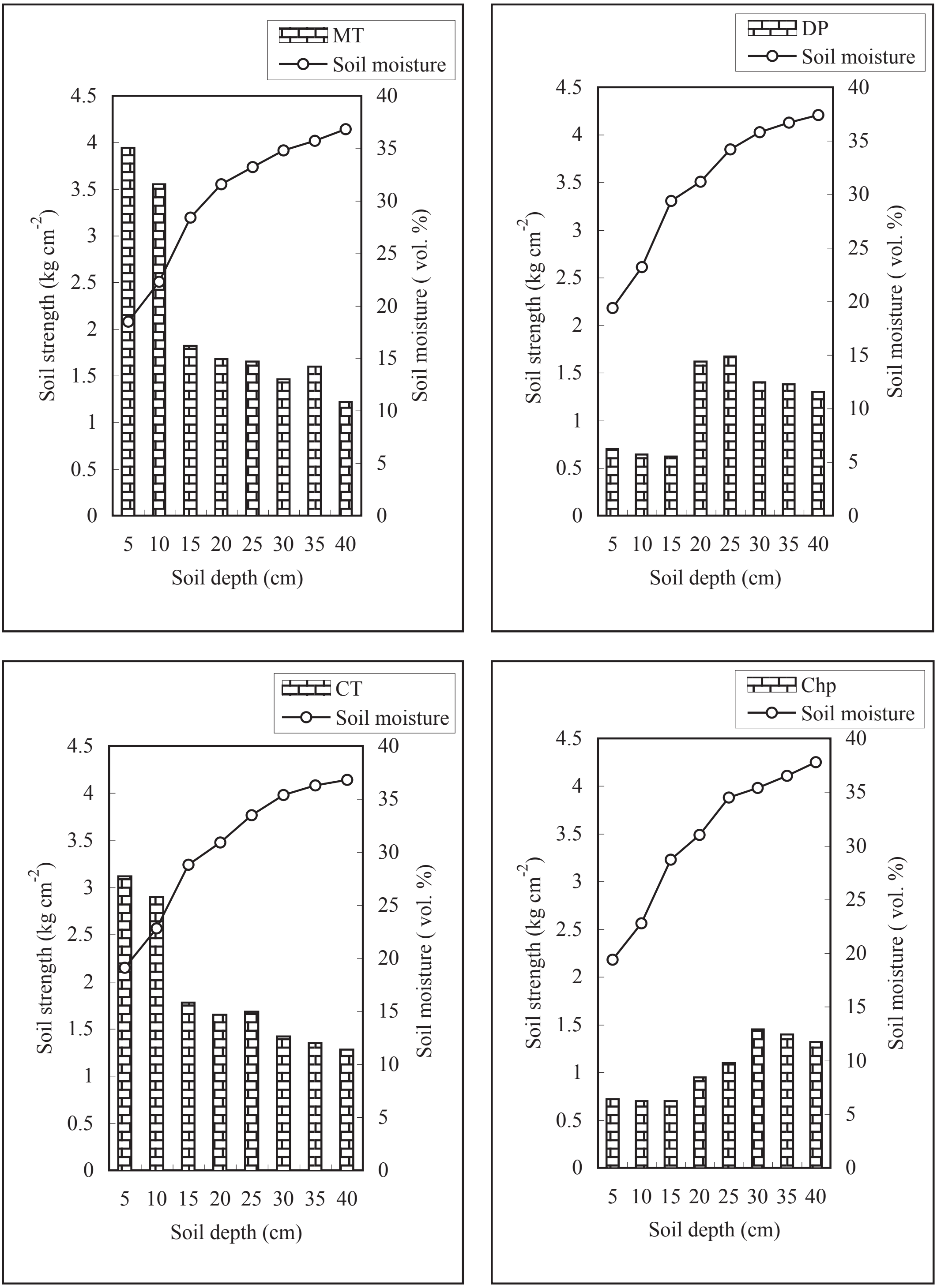


Fig. 2. Soil strength and moisture at different depths of the soil profile as influenced by minimum (MT) and conventional tillage (CT) as disc (DP) and Chisel ploughing (Chp).

the 5 to 15 cm depth range, which increased remarkably to 0.95 kg cm^{-2} at 20 cm and increased further to the maximum value of 1.45 kg cm^{-2} at the 30 cm depth. Below this layer the strength of soil started declining to 1.40 kg cm^{-2} at the 35 cm and finally to 1.32 kg cm^{-2} at the 40 cm depth of the soil profile. The moisture content of the soil profile increased linearly from 19.4% at the surface to as high as 37.8% at the depth of 40 cm.

It is important to note that the soil strength at the upper zone of the soil profile (0–15 cm) under disc ploughing was slightly lower than that under chisel ploughing, which exceeded 30 cm in depth. Although, the depth of disk ploughing was considerably lower than that of chiseling, the soil was completely inverted during disk ploughing and pulverized very well by rotavator to make the soil very soft and pliable up to a 15 cm depth. From this study it may be inferred that soil strength is highly influenced by the method of tillage applied. Different tillage treatments created a plough zone of variable depths. Soil strength increased greatly in the soil below the plough zone. Similar results were reported by Hamblin (1982). This was attributed to variations in bulk density. Soil strength was found to be higher in untilled than tilled treatments, which explains that deep ploughing and sub soiling decreases mechanical resistance compared with no tillage and shallow tillage (Francis *et al*. 1987).

Soil temperature

Tillage and mulching, with or without crop cover, substantially affect time and depth variations of soil temperature. The seasonal and diurnal soil temperature was affected by the nature of tillage practices and mulch application during the crop growing seasons for both years this study was conducted. The hourly temperature variations at a depth of 10 cm, among soil treated with various tillage practices and mulch applications, were measured at 60 days after sowing, and two years mean temperature are presented in Figs. 3 and 4 The temperature of the minimally tilled plots maintained the maximum level all through the day followed by conventionally tilled plots. The minimum temperature was observed in disc ploughing. The maximum temperature variation between minimum tillage and chisel ploughing was 1.2°C at 14 hours. De Datta (1985) posited that the minimum soil temperature resulted from disc ploughing may be attributable to lower thermal conductivity from better land preparation, making the soil loose and porous.

There was considerable difference in diurnal soil temperature by the application of different mulch material (Figure 3). Application of polyethylene mulch showed the highest soil temperature followed by no mulch. Straw mulch showed the lowest temperature during the study period. The highest temperature (23.2°C) was recorded at 14 hours using polyethylene mulch. The maximum difference of soil temperature (4°C) was observed between polyethylene and straw mulch at 10 hours.

Weekly mean values of soil temperature as influenced by tillage and mulch treatments at a soil depth of 10 cm are shown in Figure 4 The seasonal soil temperature was affected by the nature of tillage practices during the cropping seasons. There was considerable difference between the minimum and deep tilled plots in terms of soil temperature. The temperature variation during the cropping season was greater in the unploughed treatment than in the ploughed ones. The temperature of the minimally tilled plots reached the maximum (23.36°C) at 15 weeks of sowing against 22.65°C in disc ploughing.

Mulching also influenced the weekly mean soil temperature. Soil temperature at 13 hours was consistently highest in plots receiving polyethylene mulch throughout the study period, followed by plots

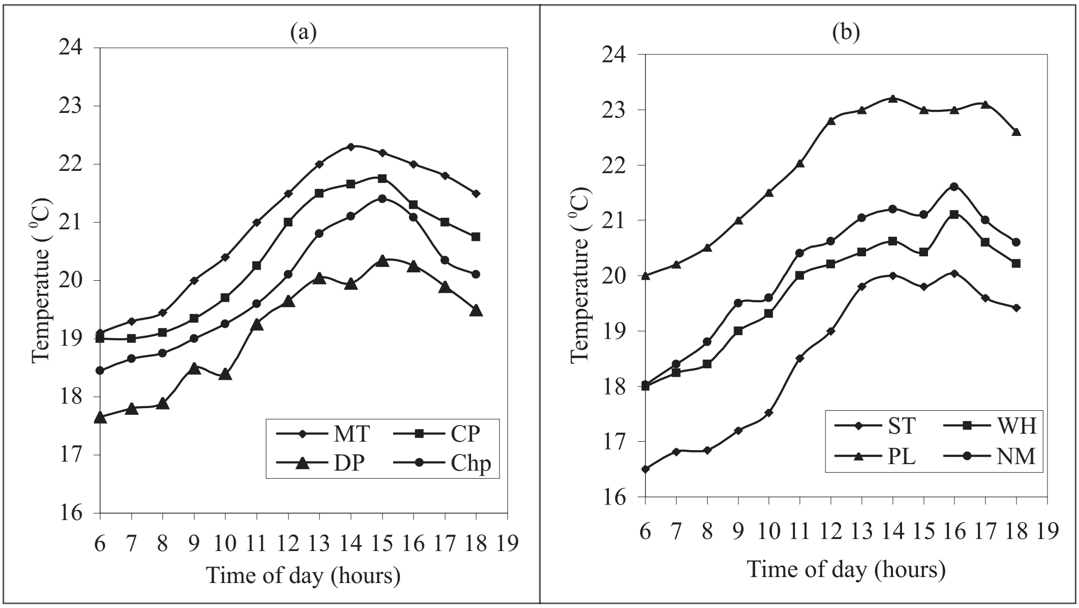


Fig. 3. Two years mean diurnal temperature fluctuation as influenced by (a) tillage and (b) mulch at 10 cm depth at maximum tillering stage (2000–2001 & 2001–2002).

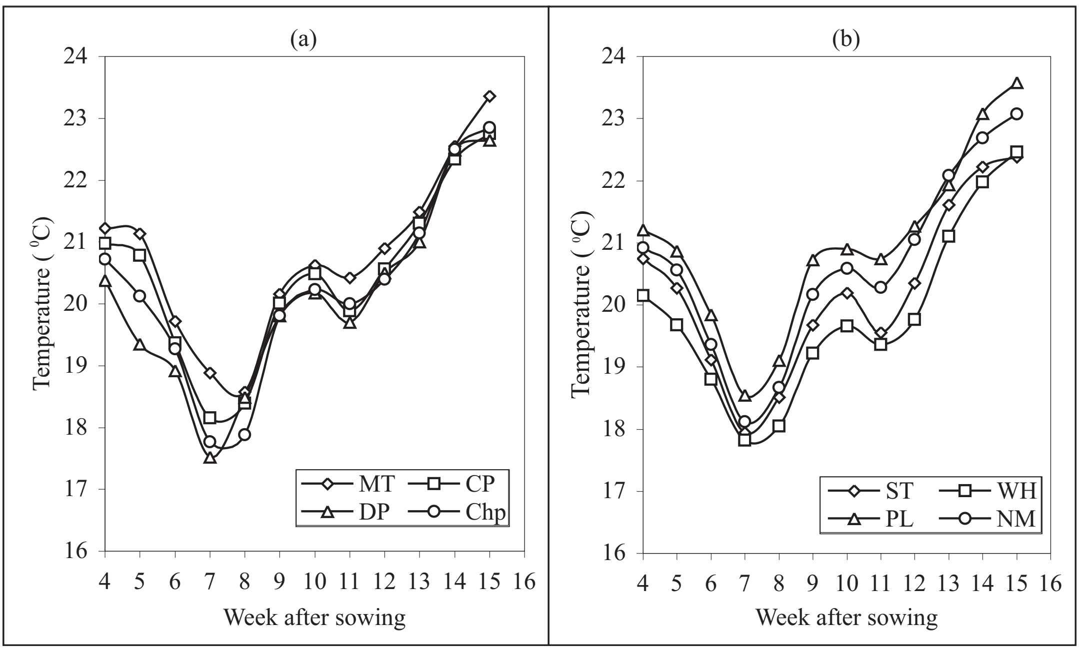


Fig. 4. Two years mean weekly mean soil temperature as influenced by (a) tillage and (b) mulch at 10 cm depth during growing season (2000–2001 & 2001–2002)

receiving no mulch. Soil temperature was lowest in plots receiving straw and water hyacinth mulch. Polyethylene raised the soil temperature by 1.2°C at 15 weeks after sowing, as compared to water hyacinth mulch. Such an increase in soil temperature under transparent polyethylene is attributed to its greenhouse effect. Conversely, proper shading against the sun together with well ventilated straw and water hyacinth mulch managed to maintain a low soil temperature.

Saturated hydraulic conductivity

Saturated hydraulic conductivity of the soil as affected by applied tillage method and mulch application is presented in Table 2. It was observed that saturated hydraulic conductivity (K_{sat}) was affected by tillage practices and the depth of ploughing. The overall Ksat of soils was very low ranging from 2.57 × 10^{-7} cm s^{-1} in conventional tillage with polyethylene mulch at a 20–30 cm depth, to 9.45 × 10^{-2} cm s^{-1} in disc ploughing with straw mulch at a 0–10 cm soil depth.

Deeper or more intensive tilling leads to better transmission of water at each soil depth studied. Disc ploughing and chisel ploughing gave higher K_{sat} values compared to the other two tillage methods, with the smallest value coming from minimum tillage. The surface layer (0–10 cm) continuously had the maximum K_{sat} and the bottom layer (20–30 cm) the least. Deeper and better land preparation by disk ploughing or chiseling made the soil porous and led to higher conductivity of water. The surface soil, having relatively higher organic matter content, was less compact compared to the subsurface soils, which resulted in the easy passage of water through it. This result is in agreement with the findings of Ogunremi and Lal (1986) who found that soil compaction decreased the saturated hydraulic conductivity. Generally the higher the transmission porosity, the greater the K_{sat}, but the magnitude and ratio would depend on the clay mineralogical make up, soil texture and other variables.

Infiltration

Tillage affects infiltration rate to a great extent. The cumulative infiltration values versus elapsed time as influenced by different tillage practices were plotted on log-log scale and are presented in Figure 5. From the cumulative infiltration data, water intake rates at different times were calculated and plotted on a natural scale and are presented in Figure 6.

Table 2. Tillage and mulch effects on saturated hydraulic conductivity at different soil depth.

Particle size (%)		Saturated hydraulic conductivity (cm sec^{-1})		
		Soil depth (cm)		
		0–10	10–20	20–30
Tillage	Minimum	6.28 × 10^{-3}	3.11 × 10^{-4}	3.61 × 10^{-6}
	Conventional	1.43 × 10^{-2}	2.01 × 10^{-4}	2.61 × 10^{-6}
	Disc plough	8.57 × 10^{-2}	4.60 × 10^{-4}	1.82 × 10^{-5}
	Chisel plough	1.64 × 10^{-2}	5.00 × 10^{-4}	2.99 × 10^{-5}
Mulch	Straw	3.78 × 10^{-2}	5.86 × 10^{-4}	1.71 × 10^{-5}
	Water hyacinth	3.21 × 10^{-2}	4.35 × 10^{-4}	1.46 × 10^{-5}
	Polyethylene	2.75 × 10^{-2}	3.04 × 10^{-4}	9.80 × 10^{-6}
	No-mulch	2.52 × 10^{-2}	1.48 × 10^{-4}	9.46 × 10^{-6}

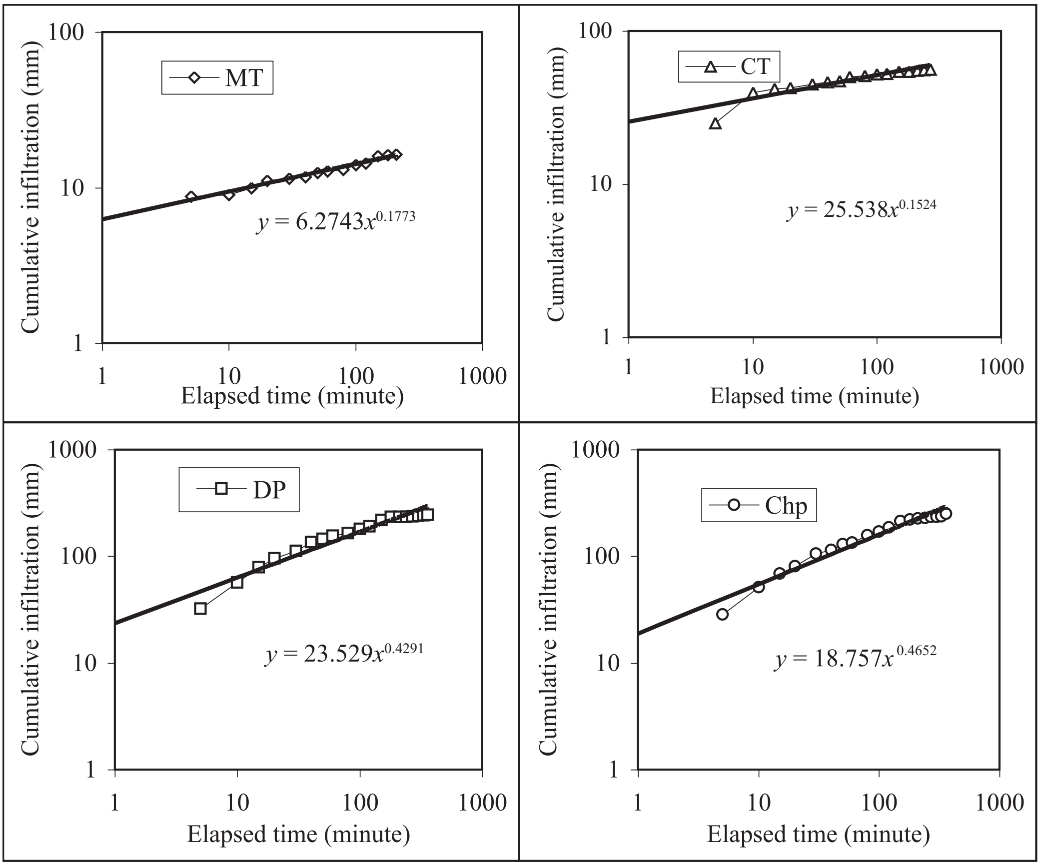


Fig. 5. Cumulative infiltration as influenced by tillage treatments a. minimum (MT), b. conventional (CT), c. disc (DP) and d. chisel ploughing (Chp)

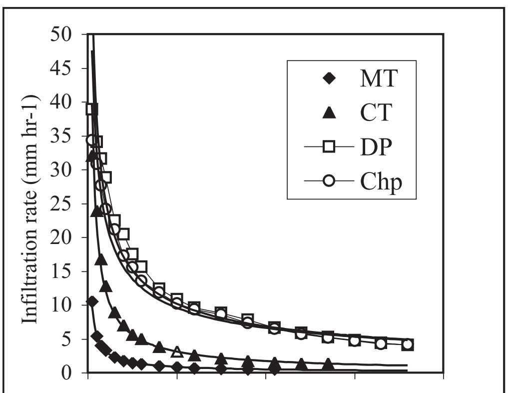


Fig. 6. Infiltration rate versus time relationship under different tillage methods

Rate of infiltration was affected by tillage treatment, which increased with the increase in tillage depth. The initial 5 minute infiltration rate (IR) in the minimally tilled plot was 105.6 mm h^{-1}, while 321.2, 388.8 and 343.2 mm h^{-1} infiltration rates were recorded with conventional tillage, disc ploughing and chisel ploughing, respectively. The infiltration rate in minimally and conventionally tilled plots reduced sharply to 54.4 and 239.5 mm h^{-1} within 10 minutes, but the rate of reduction is low in disc and chisel ploughing for the same elapsed time. The time of attaining steady state infiltration was different for different tillage treatments. In the minimum tillage treatment plot, steady state infiltration was attained within 210 minutes, while for conventional tillage plots, it was 270 minutes. Again, in both the disc and chisel ploughed plots steady state infiltration was attained within 330 minutes, indicating that a water is allowed to move very quickly due to the effect of increased tillage depth. The infiltration rates for disc and chisel ploughing after 100 minutes were comparable. In these treatments the rates at the end of the study period of 360 minutes were the same (41 to 42 mm h^{-1}). The high initial infiltration rate is in all probability attribuable to the dryness of the surface soil as well as slight cracking. As the infiltration processes continued, the soil pores approached saturation, soil water suction decreased and swelling of particles and clogging of pores occurred which reduced the cross sectional area available for downward movement of water. All of these events contributed in the reduction of infiltration rate with time and attainment of final steady rates.

The cumulative infiltration in minimum and conventional tillage was smaller than that for disc and chisel ploughing. The total amounts of water infiltrated into the soil were 16.4, 56.4, 246.2 and 252.0 mm in minimum, conventional, disc and chisel ploughing, respectively at the cumulative time of 210, 270, 360 and 360 minutes. Comparatively higher values of infiltration were observed in disc and chisel ploughing.

The effect of deep tillage in enhancing the infiltration characteristics of the soil was clearly evident. The cumulative infiltration and infiltration rate increased with the depth of tillage. The results of the infiltration measurements indicate that infiltration rates for minimum and conventional tillage was very slow. This may be attributed to the compactness of the sub soil that resulting in a substantial reduction of water flow through soil profile. The higher infiltration rates in the deep tilled plots, compared to minimum and shallow tillage, were attributed to the reduction in soil compaction that led to less obstructed water flow down through the soil profile. Linddstorm *et al*. (1984) also found a greater infiltration rate in tilled clay loam soil than non-tilled plots. In non-tilled plots, the impeding layer with higher bulk density was not disturbed. An impeding layer with higher bulk density might cause abrupt discontinuities in water content and hydraulic conductivity at inter layer boundaries thereby greatly reducing infiltration (Miller and Gardner, 1968).

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