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Effect of Deep Tillage on Soil Physical Properties in Rice Wheat Cropping System

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Abstract

Rice-wheat cultivation is a prevalent agricultural practice in many regions of the world, feeding millions of peoples. Excessive tillage in conventional agriculture systems may cause plough pan, which alters soil physical properties, and thus adversely affects the crop growth and productivity. The effect of tillage practices and soil depth on soil physical properties in rice wheat cropping system was studied during Rabi season of 2022-23. The purpose of this research is to look at the impact of deep tillage on soil physical qualities in the context of a rice-wheat cropping system. The deep tillage practices significantly reduce soil resistance (kPa) in 15-60 cm soil depth. The conventional, rotary and conservation tillage practices do not have any impact on soil resistance (kPa) at any soil depth. The deep tillage practices significantly decreases bulk density (g cm^{-3}) at all soil depth, however no effect of other tillage practices was observed on bulk density at any depth. The deep tillage resulted in significantly improvement in soil moisture content (%) in deeper soil layer (45-90 cm) as compared to other tillage practices. The deep tillage resulted in significantly improvement in water infiltration rate (cm min^{-1}), mainly in 15-30 cm soil depth as compared to other tillage practices.

Keywords: Deep tillage, Bulk Density, Infiltration Rate, Moisture Content and Soil Resistance.

1. Introduction

The rice-wheat cropping system prevalent in South Asia significantly impacts soil physical and chemical characteristics, thus influencing crop output (Ranamukhaarachchi and Begum, 2005). Low crop yields often stem from improper ploughing techniques and inadequate management of the cropping system. Changes in land use and cropping patterns frequently lead to alterations in soil fertility, exacerbated by intensive cropping without natural replenishment (Rahman and Ranamukhaarachchi, 2003). Utilizing green manure, particularly legumes, can restore crop productivity and soil fertility by replenishing organic matter (Ahmad et al., 2009). In regions like northwest India, under the rice-wheat cropping system, coarse textured soils are susceptible to subsurface compaction, impeding wheat root growth (Dhaliwal et al., 2022). The predominant farming system relies on small-sized four-wheeled tractors for various operations, leading to soil overexploitation, improper mechanical manipulation and thickening of the hard pan (Zhao et al., 2006; Salam et al., 2013). Consequently, shallow and compacted topsoil negatively impacts root growth, water and nutrient uptake, and crop yield (Etana and Hakansson, 1994; Shah et al., 2017). Moreover, poor soil properties reduce tolerance to abiotic stress and resistance against natural disasters (Wang et al., 1999). It's imperative to address these issues to sustain agricultural productivity and enhance soil resilience in the long term.

Deep tillage effectively breaks up plow pans in farming management (He et al., 2006; Qin et al., 2008b; Wang and Chen, 2007; Bogunovic et al., 2018), loosening compacted layers and deepening topsoil without inverting it, thereby enhancing soil permeability (Huang et al., 2006). It improves soil properties, promotes water storage, and increases rainwater use efficiency, crucial in arid areas (Comia et al., 1994; Ding and Hann, 1997; Evans et al., 1996). Subsequently, it minimizes drought effects and boosts crop yield (Gao & Li, 1995; Mohanty et al., 2007; Dhaliwal et al., 2022), optimizing the proportion of soil components and enhancing topsoil structure and characteristics (Evans et al., 1996; Abu-Hamdeh, 2003; Wang et al., 2008;

Sidhu and Duiker, 2006). The tillage depth significantly affects soil properties and crop yield, with shallow tillage hindering root growth and deeper tillage impeding nutrient absorption (Han et al., 2015).

Deep tillage fosters an ecological environment conducive to root development and enhances plant stress resistance (Song et al., 2000; Qi et al., 2012), leading to considerable yield improvements (Gao and Li, 1995; Mohanty et al., 2007; Guan et al., 2014). Compared to traditional tillage, subsoiling increases winter wheat yield by 703.6 kg ha^-1 and water use efficiency by 16.8% (Wang et al., 2004). It's noted that annual subsoiling may not be necessary in no-tillage fields (He et al., 2006). Furthermore, subsoiling treatments significantly reduce soil resistance and bulk density while increasing water content (Akinci et al., 2004; Gao and Li, 1995). Keeping this in view, the present study was planned with the objective to study the effect of deep tillage on soil physical properties in rice-wheat system.

This study contributes to a deeper knowledge of the impacts of deep tillage on soil physical attributes in the rice-wheat cropping system, providing significant insights for farmers and agricultural practitioners looking for sustainable and productive methods to manage their soils. The findings might help drive soil management practices targeted at increasing the productivity and resilience of this critical agricultural system while improving long-term environmental sustainability.

2. Materials and Methods

The experimental study on “Effect of deep tillage on soil physical properties in rice wheat cropping system” was planned and conducted during Rabi (winter season) of the year 2022-

23. The materials and methods used for the study have been presented in this paper under the following sub headings:

1. General description of the experimental site
2. Treatment details of the experiment
3. Soil physical properties

2.1. General description of the experimental site

2.1.1 Climate and rainfall

The region has a semi arid climate, with hot and dry spell in April to June to wet summer spell in July to September and a cool and dry winter spell in October to March. The maximum and minimum temperature varied between 14.6 to 37.3oC and 3.6 to 17.3oC, respectively. The total rainfall received during the experimental period was 18.7 mm. The daily rainfall, PAN evaporation, maximum and minimum temperature, relative humidity and wind speed during crop season (November 22, 2022 to April 10, 2023) are plotted in Fig.1.

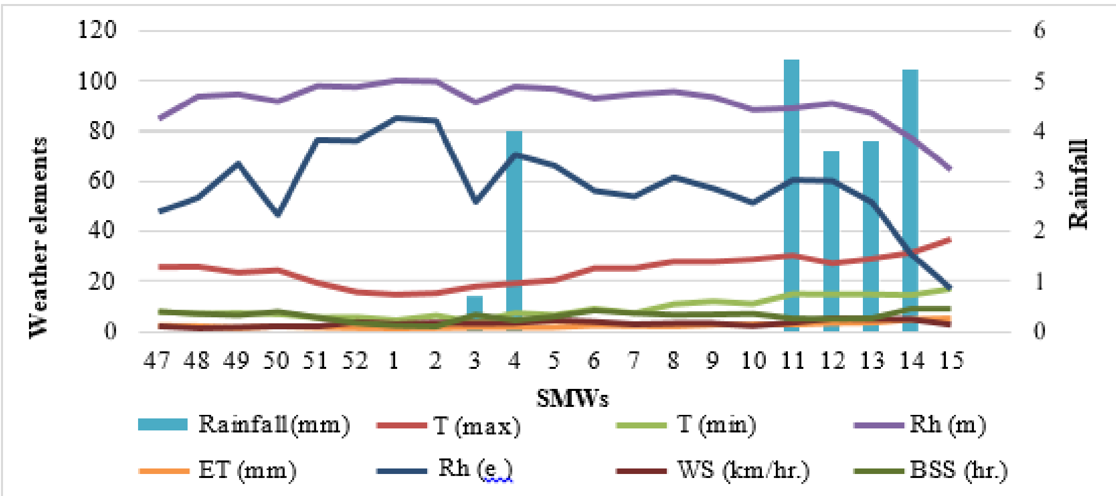

Figure.1. Mean weekly values of weather parameters during *Rabi* 2022-23

2.1.2 Description of soil

The representative soil samples were collected from five randomly selected places of the experimental field. Samples were collected from 15 cm plough depth. Texture analysis of the soil was carried out with the International pipette method (Piper, 1950) using sodium hex meta phosphate as dispersing agent. The texture classes were determined using the triangular textural diagram of USDA. The soil testing was done in the soil testing laboratory of College of Agriculture, CCS HAU, Hisar. The soil texture at the experimental site was classified as sandy loam (sand 67.6%, silt 11.1%, clay 21.3%) in texture, non-saline (EC 0.56 dS m-1), alkaline in reaction (pH 8.0), low in available N (170.2 kg ha-1), medium in available P (14.6 kg ha-1) and high in available K (311.8 kg ha-1).

2.1.3 Cropping history

The experimental field was under rice-wheat cropping system for last 10 years.

The experiment consists of 4 main treatment (Tillage practices) and 5 sub treatments (Soil depth).

Table.1. Tillage practices (T)

T_1	Conventional tillage
T_2	Rotary tillage
T_3	Conservation tillage
T_4	Deep tillage

Table.2. Soil depth (S)

S_1	0-15 cm
S_2	15-30 cm
S_3	30-45 cm
S_4	45-60 cm
S_5	60-90 cm

3. Soil physical properties

3.1 Moisture content (%)

For determination of moisture content, the method recommended by the Indian Standards Institution (ISI), as set out in "IS: 2720(Part - II) - 1973: Methods of test for soils - Determination of Moisture Content." was followed. Soil samples were taken from three different locations of the field and oven dried at a temperature of 110 ± 5 ºCfor 24 hours to determine moisture content of the soil. The moisture content of the soil on the dry basis was determined by using equation.

Moisture content (%) = $\frac{W2-W3}{W3-W1}\ x\ 100$

Where,

W1 = weight of crucible, g,

W2 = weight of crucible + wet soil, g,

W3 = weight of crucible + oven dried soil, g

3.2 Bulk density (g cm^{-3})

The bulk density of soil was determined by the core cutter method as described by Blake, 1965. Soil samples were taken from three different locations of the field and oven dried at a temperature of 110 ± 5 ºC for 24 hoursand then weighted. The soil bulk density was calculated by the formula:

$\gamma = \frac{Ws-Wc}{Vc}$

Where,

γ = Bulk density of soil, g cm^{-3}

W_S = Weight of soil and core cutter,gW_C= Weight of core cutter, g

V_c= Volume of core cutter, g cm^{-3}

3.3 Water infiltration rate (cm min^{-1})

The infiltration rate was estimated by double ring infiltrometer using falling head method (Bertrand 1965) beforesowing and after harvest of crop. Two rings (inner and outer ring with a diameter of 26 and 39 cm, respectively)were inserted in 15 cm soil depth in each measurement. The purpose of outer ring was to restrict horizontal movement of water for precise measurement. A hammer and a wood block were also used to drive the double ring infiltrometer into the soil. Scale was used to measure the water head after filling up one-third of ring with water. The water head was measured after every 2 minutes and final reading was taken when the head was stabilized. The infiltration rate of deeper soils was measured by gently removing the upper soil layers. The infiltration rate was measured before sowing and after harvest of crop.

3.4 Soil resistance (kPa)

The digital electronic cone penetrometer was used to measure the soil resistance. A 60^{o} cone with a 1.5 cm^{2} crossection area was used with cone penetrometer. The computer data acquisition system recorded all the data during the penetration process. The soil cone index was measured before sowing and after harvest of crop.

Figure.2. Measurement of Soil bulk density, moisture content, soil cone index and water infiltration rate

3. Result

Keeping in view the specific objectives of the study; the effect of different tillage practices and soil depth on soil physical properties in rice wheat cropping system were studied in terms of soil resistance, bulk density, and moisture content of soil and water infiltration rate.

3.1. Soil Physical Properties

3.1.1 Effect of tillage practices and soil depth on soil resistance (kPa)

Data indicated that before the tillage practices the soil resistance at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth varied from 1820-1835, 2589-2614, 1830-1853, 1632-1657 and 1553-1582 kPa, respectively among different tillage treatments. The lowest soil resistance in 0-15, 15-30, 30-45, 45-60 and 60-90 cm soil depth were observed in conventional tillage, conservation tillage, deep tillage, conventional tillage and conservation field; however, the results were non-significant. In overall, the soil resistance increased up to 30 cm depth and then decreased in all tillage treatments. The soil resistance under different tillage practices at various depths were non-significant among treatments. However, the effect of soil depth on soil resistance in a particular tillage practice was significant. The interaction effect of tillage practice and soil depth was also significant. After tillage practices, the soil resistance in 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth varied from 1812-1832, 2319-2617, 1640-1842, 1473-1649 and 1526-1587 kPa among different tillage treatments.

In conventional tillage practice, the soil resistance at 0-15, 15-30, 30-45 and 45-60 cm depth decreased from 1820-1812, 2595-2582, 1853-1838, 1632-1627 kPa respectively whereas in 60-90 cm depth it slightly increased from 1582-1587 kPa, however, all the results were non-significant. In rotary tillage practice, the soil resistance in 0-15, 15-30 and 30-45 cm depth increased from 1830- 1832, 2610-2617 and 1835-1842 kPa and in 45-60 and 60-90 cm depth slight decrease was observed from 1640- 1635 and 1565-1562 kPa, however, all the results were non-significant. In conservation tillage practice, the soil resistance at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth decreased from 1826-1818, 2589-2571, 1848-1833, 1657-1649 and 1553-1548 kPa, respectively. However all the results were non-significant.

In deep tillage practice, the soil resistance in 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth decreased from 1835-1825, 2614- 2319, 1830-1640, 1651-1473 and 1567-1526 kPa, respectively. In deep tillage practice, the soil resistance decreased significantly in 15-30, 30-45 and 45-60 cm depth, however in 0-15 and 60-90 cm depth the results were non-significant.

Soil resistance under different tillage practices at various depths before tillage practices and after tillagepractices are also depicted in Fig. 3-4.

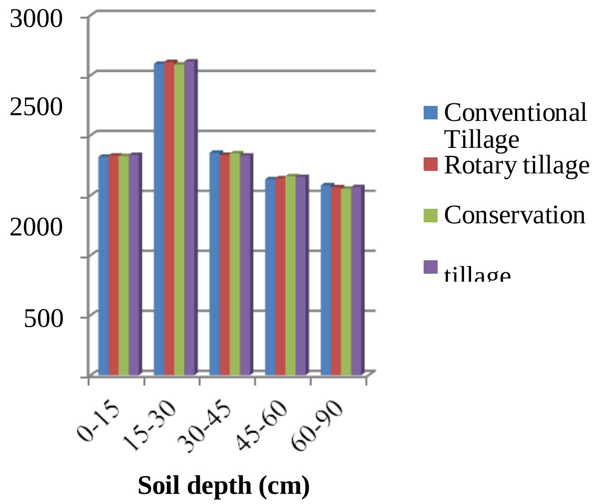

Figure. 3. Soil resistance (kPa) of experimental field before

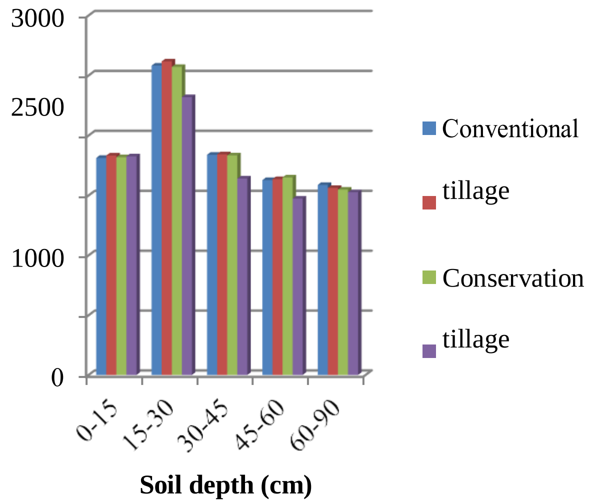

Figure.4. Effect of tillage practice and soil depth on soil resistance (kPa)

3.1.2. Effect of tillage practices and soil depth on bulk density (g cm^{-3})

Data indicated that before the tillage practices the bulk density at 0-15, 15-30, 30-45, 45-60 and 60-90 cm soil depths varied from 1.53-1.52, 1.51-1.52, 1.53, 1.55-1.56 and 1.57-1.58 g cm^{-3} respectively among different tillage treatments. The bulk density decreased as the depth increased from 0-15 to 15-30 cm in all the experimental fields. No variations were observed at 30-45cm soil depth. After 45 cm depth the bulk density starts increasing among all the tillage treatments. The effect of particular soil depth on bulk density among different tillage practice was observed to be non significant. The interaction effect of tillage practice and soil depth was also observed to be non-significant. However, the effect of soil depth on bulk density in a particular tillage practice was observed to be significant.

After tillage practices, the bulk density at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth varied from 1.51-1.53, 1.47-1.52, 1.47-1.53, 1.50-1.56 and 1.52-1.58 g cm^{-3}, respectively among different tillage treatments.In conventional tillage practice, the bulk density at all soil depths remains same except 15-30 cm depth, where bulk density slightly increased from 1.52 to 1.53 g cm^{-3} which was non-significant. Therefore, no effect of tillagewas observed on soil bulk density. In rotary tillage practice, the bulk density at 0-15 and 60-90 cm slightly decreased from 1.53-1.52 and 1.58-1.57 g cm^{-3} and slightly increased from 1.55-1.56 g cm^{-3} at 45-60 cm depth.

The bulk density at 15-30 and 30-45 cm depth remains unchanged *i.e.* 1.52 and 1.53 g cm^{-3}, respectively. However, the all the results were non-significant. In conservation tillage practice, the bulk density at 0-15 and 60-90 cm depth slightly decreased from 1.52-1.51 and 1.57-1.56 g cm^{-3}, respectively whereas slightly increasedfrom 1.55-1.56 g cm^{-3} in 45-60 cm depth. The bulk density at 15-30 and 30-45 cm depth remains unchanged *i.e.*1.53 g cm^{-3} however all the results were non-significant. In deep tillage practice, the bulk density at 0-15, 15-30,30-45, 45-60 and 60-90 cm depth decreased from 1.52-1.51, 1.51-1.47, 1.53-1.47, 1.56-1.50 and 1.58-1.52 g cm^{-3} respectively. In deep tillage practice, the bulk density decreased significantly at 15-30, 30-45, 45-60 cm and 60-90 cm depth, however in 0-15 cm depth the results were found to be non significant.

Soil bulk density under different tillage practices at various depths before tillage practices and after tillage practices are also depicted in Fig 5-6.

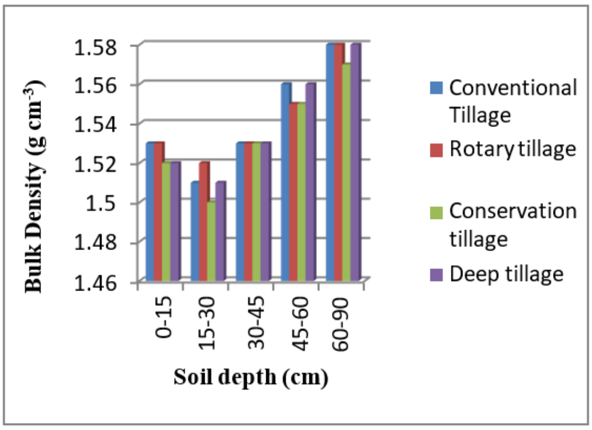

Figure.5. Bulk density (g cm^{-3}) of experimental field before tillage

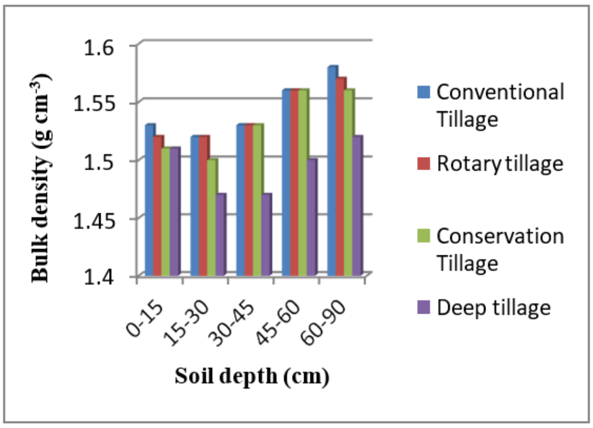

Figure.6. Effect of tillage practice and soil depth on bulk density (g cm^{-3})

3.1.3 Effect of tillage practices and soil depth on soil moisture content (%)

Data presented in Table 4 indicated the effects of tillage practice and soil depth on soil moisture content.Data indicated that before the tillage practices the moisture content at 0-15, 15-30, 30-45, 45-60 and 60-90 cm soil depths varied from 15.09-15.16, 16.15-16.62, 17.86-18.14, 18.97-19.23 and 17.88-18.92 per cent, respectively among different tillage treatments. The moisture content increased as the depth increased from 0- 15 to 45-60 cm. After 45-60 cm depth the moisture content starts decreasing among all the tillage treatments.

After tillage practices, the moisture content at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth varied from 4.52-4.80, 8.15-8.85, 12.19-13.25, 14.64-16.18 and 14.64-16.12 per cent, respectively among different tillage treatments. In conventional tillage practice, the moisture content at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth decreased from 15.09-4.72, 16.24-8.24, 17.93-12.37, 18.97-14.64 and 17.88-14.70 per cent, respectively among all soil depths. The moisture content in rotarytillage at various soil depths decreased significantly. In conservation tillage practice, the moisture content at 0-15, 15-30, 30-45, 45-60 and 60-90 cm were also decreased from 15.12-4.80, 16.15-8.85, 17.86-12.78, 19.12-15.25 and 18.76-15.23 per cent, respectively. The moisture content in conservation tillage at various soil depths decreased significantly. In deep tillage practice, the moisture content in 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth decreased from 15.14-4.52, 16.48-8.15, 18.02-13.25, 19.18-16.18, 18.92-16.12 per cent, respectively. In deep tillage practice, the moisture content decreased significantly.

Soil moisture content under different tillage practices at various depths before tillage practices and aftertillage practices are also depicted in Fig.7-8

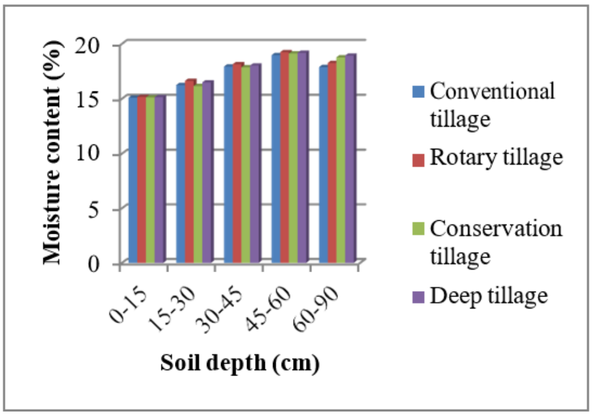

Figure.7. Moisture content (%) of experimental field before tillage

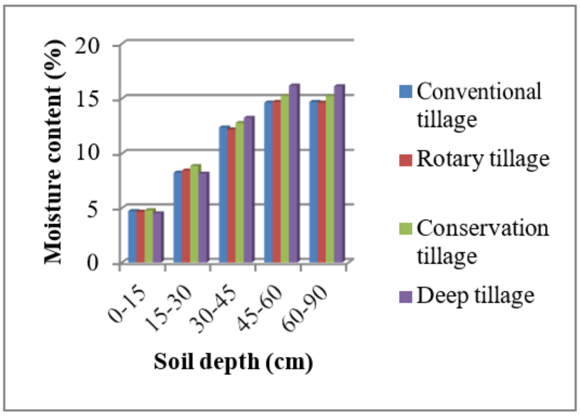

Figure.8. Effect of tillage practice and soil depth on moisture content (%)

1.4 Effect of tillage practices and soil depth on water infiltration rate (cm min^{-1})

Data presented in Table 5 indicated the effects of tillage practice and soil depth on water infiltration rate. Data indicated that before the tillage practices the infiltration rate at 0-15, 15-30, 30-45, 45-60 and 60-90cm soil depths varied from 1.11-1.13, 0.91-0.94, 1.10-1.11, 1.05-1.06 and 0.97-0.98 cm min^{-1}, respectively among different tillage treatments. The infiltration rate decreased as the depth increased from 0-15 to 15-30 cm. After 15-30 cm depth the infiltration rate increased up to 30-45 cm depth among all the tillage treatments. After30-45 cm depth the infiltration rate again decreased up to 60-90 cm soil depth. The effect of soil depth on infiltration rate was significant. The interaction effect of tillage practice and soil depth was non-significant. Also, the tillage practices were observed to be non-significant among themselves. After tillage practices, the infiltrationrate at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth varied from 1.12-1.13, 0.92-1.12, 1.10-1.23, 1.05-1.18 and 0.97-1.02 cm min^{-1}, respectively among different tillage treatments. In conventional tillage practice, the infiltration rate at 0-15 cm depth was slightly increased from 1.11-1.12 cm min^{-1} whereas at 15-30, 30-45 depthwater infiltration rate remains unchanged as there is no effect of tillage on infiltration rate.

At 45-60 cm soil depth infiltration rate was slight decreased from 1.06-1.05 cm min^{-1}. However, all theresults were non-significant. In rotary tillage practice, the infiltration rate at 0-15, 15-30, 30-45 and 60-90 cm were decreased from 1.13-1.12, 0.94-0.93, 1.11-1.10 and 0.98-0.97 cm min^{-1}, respectively. At 45-60 cm soil depth water infiltration rate was remains unchanged. However, the results were non-significant. In conservation tillage practice, the infiltration rate at 0-15, 15-30, 30-45, 45-60 and 60-90 cm were increased from 1.12-1.13, 0.94-0.95, 1.10-1.11, 1.05-1.06 and 0.97-0.98 cm min^{-1}, respectively. In deep tillage practice, the infiltration ratein 0-15 cm depth was remains unchanged. However, at 15-30,30-45,45-60 and 60-90 cm soil depth the infiltration rate were increased from 0.91-1.12, 1.10-1.23, 1.05-1.18, 0.97-1.02 cm min^{-1}, respectively. The water infiltration rate in deep tillage at various tillage depths were observed to be significantly increased after 15 cm soil depth.

Water infiltration rate under different tillage practices at various depths before tillage practices and aftertillage practices are also depicted in Fig.9-10.

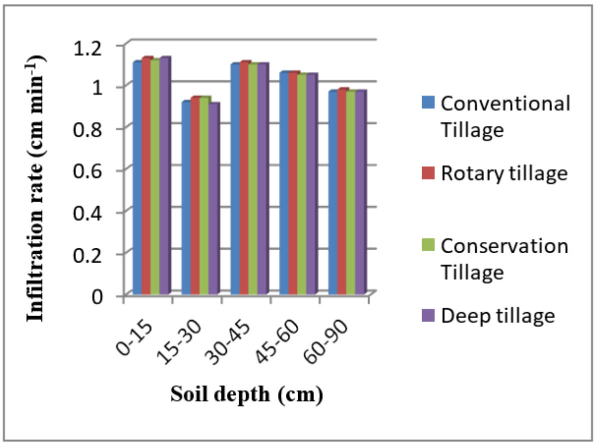

Figure.9. Water infiltration rate (cm min^{-1}) of experimental field before tillage

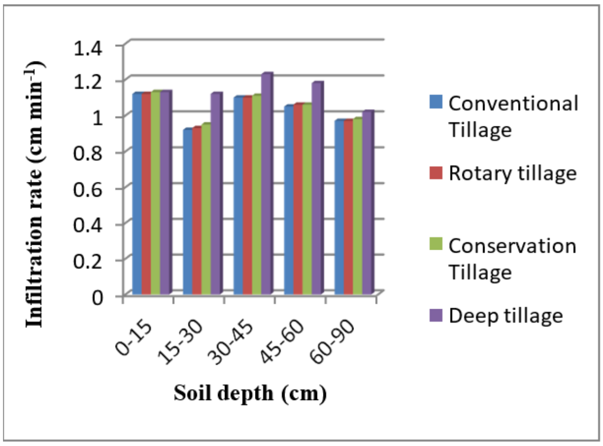

Figure.10. Effect of tillage practice and soil depth on water infiltration rate (cm min^{-1})

4. Discussion

The experimental findings of the investigation entitled "effect of deep tillage on soil physical properties in rice wheat cropping system" embodied in the preceding chapter are being discussed in the present chapter with the help of observations recorded in the present study. The results are discussed under following headings:-

4.1. Effect of tillage practices and soil depth on soil resistance (kPa)

The effects of tillage practice and soil depth on soil resistance are presented in Table 2 and Fig. 3-4. Data indicated that before the tillage practices the soil resistance at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth varied from 1820-1835, 2589-2614, 1830-1853, 1632-1651 and 1582-1567 kPa, respectively, however theresults were non-significant. In overall, except at 15-30 cm depth, soil resistance decreases with increase in soildepth. This might be due to the fact that in 15-30 cm layer a hard pan (compacted layer of soil) was developed due to continuous ploughing in 0-15 cm depth especially rotary tillage. The decrease in soil resistance after 15-30 cm depth was may be due to texture of field (sandy loamy) and the location of field (situated near the canal).The overall soil resistance of the soil after tillage practices (1473-2617 kPa) was lesser than the soil resistance of soil before tillage operation (1553-2614 kPa). It specially decreased (0.5-11.3 per cent) in deep tillage practice,the decrease in soil resistance might be due to breaking of hard pan in the plough layer, which affects gravimetricmoisture content, total porosity and air filled porosity (Xue *et al*., 2018). In conventional, rotary and conservationtillage practice, any significant effect on soil resistance was not observed at any depth. However, soil compactionunder conservation tillage practice was lower as compared to conventional and rotary tillage practice mainly because of absence of soil disturbance (Huang *et al*., 2013).

4.2. Effect of tillage practices and soil depth on bulk density (g cm^{-3})

The effects of tillage practice and soil depth on soil resistance are presented in Table 3 and Fig. 5-6. Data indicated that before the tillage practices the bulk density at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depthvaried from 1.53-1.52, 1.51-1.52, 1.53, 1.55-1.56 and 1.57-1.58 g cm^{-3} , respectively among different tillage treatments. The bulk density decreased as the depth increased from 0-15 to 15-30 cm and then increased amongall the tillage treatments. However, the results were non significant. This might be due to the fact that the textureof field was sandy loamy and the field was situated near the canal. Zhai *et al.* (2021) also conducted that bulk density increases as we go to the deeper layers. The overall bulk density of the soil after tillage practices (1.47-1.58 g cm^{-3}) was lesser than the bulk density of soil before tillage operation (1.50-1.58 g cm^{-3}). It specially decreased (0.6-5.3 per cent) in deep tillage practice, the decrease in bulk density might be due to breaking of hard pan in the plough layer, which affects gravimetric moisture content, total porosity and air filled porosity (Xue *et al.*, 2018). In conventional, rotary and conservation tillage practice, any significant effect on bulk densitywas not observed at any depth, similar to the results reported by Anken *et al*., 2004, Pena-Sancho *et al.,* 2017 and Xue *et al*., 2018, however, bulk density under conservation tillage practice was lower as compared to conventional and rotary tillage practice mainly because of absence of soil disturbance (Huang *et al*., 2013).

4.3. Effect of tillage practices and soil depth on moisture content (%)

The effects of tillage practice and soil depth on soil moisture content are presented in Table 4 and Fig. 7-8. Data indicated that before the tillage practices the moisture content at 0-15, 15-30, 30-45, 45-60 and 60-90 cm soil depths varied from 15.09-15.16, 16.15-16.62, 17.86-18.14, 18.97-19.23 and 17.88-18.92 per cent, respectively among different tillage treatments. The moisture content increased as the depth increased from 0- 15 to 45-60 cm. In 60-90 cm soil depth the moisture content was slightly lower, but the results were non- significant. Before tillage treatment soil moisture content was observed maximum in deeper soil layers and minimum in top soil layers. The moisture content continuously increased as we go to the deeper layers. Qin *et al.* (2008b) also observed that moisture content was more in deeper soil layers as compared to top soil. After tillage practices, the moisture content at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth varied from 4.52-4.80, 8.15-8.85, 12.19-13.25, 14.64-16.18 and 14.64-16.12 per cent, respectively among different tillage treatments.

4.4. Effect of tillage practices and soil depth on water infiltration rate (cm min^{-1})

The effects of tillage practice and soil depth on water infiltration rate content are presented in Table 5 and Fig. 9-10. Data indicated that before the tillage practices the infiltration rate at 0-15, 15-30, 30-45, 45-60 and 60-90 cm soil depths varied from 1.11-1.13, 0.91-0.94, 1.10-1.11, 1.05-1.06 and 0.97 -0.98 cm min^{-1}, respectively among different tillage treatments. The water infiltration rate decreased as the depth increased from0-15 to 15-30 cm. After 30 cm depth the water infiltration rate starts increasing up to 45 cm depth among all thetillage treatments. After

45 cm depth the water infiltration rate starts decreasing up to 90 cm soil depth. After tillage practices, the water infiltration rate at 0-15, 15-30, 30-45, 45-60 and 60-90 cm depth varied from 1.12- 1.13, 0.92-1.12, 1.10-1.23, 1.05-1.18 and 0.97-1.02 cm min^{-1}, respectively among different tillage treatments. The water infiltration rate was higher in deep tillage practice after 15-30 cm soil depth upto 60-90 cm soil depthbecause of breaking of hard pan.

5. Conclusion

The deep tillage practices significantly reduces soil resistance (kPa) in 15-60 cm soil depth, however there was no effect of deep tillage on soil resistance was observed in 0-15 and 60-90 cm depth. The conventional, rotary and conservation tillage practices do not have any impact on soil resistance (kPa) at any soil depth. The deep tillage practices significantly decreases bulk density (g cm^{-3}) at all soil depth, however no effect of other tillagepractices was observed on bulk density at any depth. The deep tillage resulted in significantly improvement in soil moisture content (%) in deeper soil layer (45-90 cm) as compared to other tillage practices. The deep tillageresulted in significantly improvement in water infiltration rate (cm min^{-1}), mainly in 15-30 cm soil depth as compared to other tillage practices.

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