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Effect of long-term conservation agriculture on physical properties of soil in north Bihar condition

SK Nirala, Anshu Kumar and R Suresh

Abstract
A research work entitled "Effect of long-term Conservation Agriculture on Soil Physical Properties" was conducted at R.P.C.A.U, Pusa (Samastipur), Bihar. The experiment was carried out with five treatments, namely T_1 - puddled transplanted rice+ conventional tillage shown wheat (PTR-CTW); T_2-puddled transplanted rice + zero tillage shown wheat (PTR-ZTW); T_3 - zero tillage rice + zero tillage shown wheat + crop residues (ZTR-ZTW+R); T_4 - zero tillage rice- zero tillage shown wheat and without crop residues(ZTR-ZTW-R) and T_5 -permanent bed direct seeded rice+ permanent beds direct shown wheat +crop residues (PBDSR-PBW+R). It was found that the physical properties of soil were superior in treatment T_5 and inferior in treatment T_1. At 0-5 cm soil depth the dry bulk density was lowest in treatment T_5 (1.104g/cm^2) and highest in treatment T_1 (1.357g/cm^3); at 5-15cm soil depth it was lowest in treatment T_3 (1.246g/ cm^3) while highest in treatment T_1 (1.398g/ cm^3). At the depth 5- 15cm the dry bulk density was noticed in T5 (1.25g/cm3) and slightly higher than the treatment T3. In regard to variation in soil porosity it was found that the porosity was decreasing in trend with increase in soil depth. At the depth of 0 - cm it was highest about 10.30% in treatment T1 and at the depth 5 -10cm it was 2.97% in treatment T5 over conventional treatment T1, and so on. Amongst all five treatments the highest infiltration rate 3.0cm /h was in treatment T5. Similarly, the variation in field capacity was noticed to be highest in treatment T5 to the tune of 36.0%.

Keywords: Conservation agriculture, soil physical properties, infiltration and field capacity

Introduction

It is very essential to increase the food production from the existing 203 million tone to 400 million tones by the year 2025 to meet the requirement of ever-increasing population of country and to achieve food security. This task could be achieved by developing a sustainable agricultural system. To achieve food security, it is necessary to increase production per unit land area per unit time. Conventional farming is a set of farming practices, which commonly focus on monoculture and consists intensive ploughing, heavy irrigation as well as using chemical inputs. Ploughing is the main operation in the conventional farming practices. It reduces weed problem and facilitates to sow seeds. In the long-term unsustainable use of land resources and improper agricultural management lead to the land degradation. Consequently, it negatively affects yields, soil qualities and makes soil erodible, and there is inequality between agricultural productivity and world population growth, for this reason, there is need to use an approach, which maximizes the production in an environmental friendly manner at the same time without increasing the production cost.

Conservation farming is an approach to managing agro-ecosystem for improved and sustainable productivity, increased profits and food security while preserving and enhancing the resource base and the environment. It is more integrated approach, which is seen as being able to reduce land degradation and increased food security in a more sustainable way. According to Food and Agriculture Organization," Conservation Farming is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production level while concurrently conserving the environment". It is achieved through improved management and application of three key principles. These principles are minimal soil disturbance, cover crop and crop rotations. In conservation farming, crops are planted directly into unploughed soils. Minimal disturbance of the soil allows the retention of soil organic matter, which is lost through conventional agriculture. This not only provides more nutrients for the growing crop, but also stabilizes the structure of the soil, making it less vulnerable to crusting, compaction and erosion. Less moisture is lost through evaporation than happens in a conventionally ploughed field. More carbon is sequestered in the soil and carbon dioxide emissions can be reduced in mechanized farming systems as significantly less fuel is used than would be required for ploughing. Crop residues are retained in the field as mulch and/or cover crops are grown throughout the year. Covering the soil protects it from the physical impact of rain and wind and helps retain soil moisture and stabilize soil temperature in the surface layers. Insects, fungi, bacteria and other macro- and micro fauna and flora thrive in this environment. Their activity breaks down the mulch and incorporates it into the soil, improving soil fertility over time. Crops are planted in different associations and rotations with one another in space and over time. Growing crops in mixtures or rotations helps to control pests and diseases by breaking their cycles. Some crops help to suppress weeds and, if legumes are used, they can also fertilize the soil through the fixing of nitrogen. Soil structure is also improved through the penetration of different root systems into the soil.

Globally, conservation farming is being practiced on about 125 M ha. The major conservation farming practicing countries are USA (26.5 M ha), Argentina (25.5 M ha), Canada (13.5 M ha) and Australia (17.0 M ha). In India, conservation farming adoption is still in the initial phase. Over the past few years, adoption of zero tillage and conservation farming has expanded to cover about 1.5 million hectares. In India, efforts to adopt and promote resource conservation technologies have been underway for nearly a decade, but it is only in the past 4-5 years that technologies are finding acceptance by the farmers. The primary focus of developing and promoting conservation farming practices has been the development and adoption of zero tillage cum fertilizer drill for sowing wheat crop in rice-wheat system. Long term tillage impact on soil hydraulic conductivity and infiltration rate was found in ponded infiltration only. Total porosity, saturated hydraulic conductivity, and water retention among the treatment did not differ. Overall, soil hydraulic properties did not differ among tillage system except water infiltration Blanco-Canqui H *et al*. (2017) [2]. Six tillage practices were studied in an apple orchard located in the Losses Plateau from 2007 to 2009. The results showed that different tillage practices had varied effect on the water-holding properties. Subsoil tillage with straw mulching, plow tillage with straw mulching and no tillage with straw mulching showed a decrease in the soil bulk density and an increase in the soil porosity, soil saturated water content and soil moisture relative to plow tillage in bare soil Liu *et al*. (2013) [5]. Tillage practices comprised mouldboard ploughing to a depth of 15cm, deep mouldboard ploughing to a depth of 30cm, and chisel ploughing to a depth of 30 cm. Crop residues management included crop residue retained and crop residue removed. The results indicated that yields in deep mouldboard ploughing and chisel ploughing with residues increased significantly with respect to other practices and result were related to reduced bulk density, and soil penetration resistance, increased soil water content and improved root density. The crop residues of common cultivated crops are an important resource not only as a source of significant quantities of nutrients for crop production but also affecting soil physical, chemical and biological function. Ideally, crop residue management practices should be selected to enhance crop yields with minimum adverse effect on the environment. It has been suggested that in each cropping system, the constraints to production and sustainability should be identified and conceptualized to guide toward the best option Kumar *et al*. (1999) [3]. Soil porosity and water infiltration as influenced by tillage methods, the effect of long-term use of various tillage systems on pore size distribution, effective porosity and infiltration and conventional tillage soil had the greatest effect on porosity Lipiec *et al*. (2005) [4]. The comparative assessment of water infiltration of soils under different tillage systems compared with conventional ploughing, the steady state infiltration rate was greater but not significantly different under ripped Moroke *et al*. (2009) [6]. The soil retention capacity constant values at all the studied soil depth were higher under zero tillage than those observed under conventional tillage irrespective of the crop rotations. The values of soil bulk density under zero tillage were higher in 0-75 mm soil depth in all the crop rotations. Saturated hydraulic conductivity values in all studied soil depths were significantly greater under zero tillage than those under conventional tillage Bhattacharya *et al*. (2006) [1]. For excellent yield of crop moisture holding capacity, infiltration rate, permeability and other physical properties must be appropriate. Understanding the relations between different physical properties of soil induced by two different farming systems (conservation &conventional) is important in predicting storage and flow characteristics of water and solutes in the soil profile. Therefore, this study is carried out with following objectives. Effect of different farming practices on dry bulk density and porosity, field capacity and water infiltration rate.

Materials and methods

Location of experimental site

The experimental site is located behind the University Boys Hostel, Dr. R. P. C. A. U. Pusa. The experimental site is located in Samastipur district of North Bihar. It is at 25.98^0 N latitude, 85.67^{0}S longitudes and at about 59.92 m above the sea level. Climate is sub-humid-west monsoon. The annual rainfall in the area is about 1270mm, out of which 1026 mm (80.78%) is received during monsoon months (July-September) and rest during other seasons of the year. The average minimum and maximum temperatures during the hottest months of May to June goes up to 3-4 ^{O}C and 43-44 ^{O}C respectively.

Treatments

The field having each plot size 700m^2, five treatments are being applied since 2008.

- T1-Puddled transplanted rice- conventional tillage wheat (PTR-CTW)
- T2-Puddled transplanted rice- zero tillage wheat (PTR-ZTW)
- T3-Zero tillage rice- zero tillage wheat and keep residues (ZTR-ZTW+R)
- T4-Zero tillage rice-zero tillage wheat and remove residues (ZTR-ZTW-R)
- T5-Permanent beds direct seeded rice-permanent beds wheat and keep residues (PBDSR-PBW+R)

Layout of the field

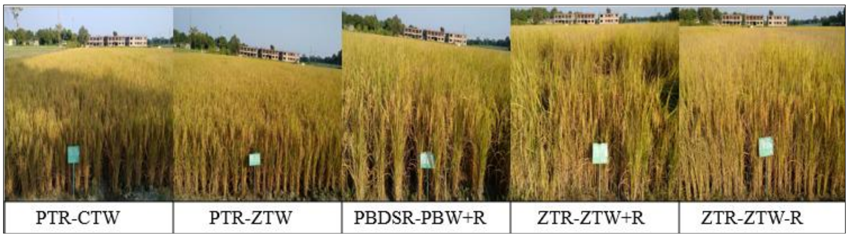

Fig 1: Layout of the field

Observations to be recorded

Dry bulk density and porosity of the soil at the depth 0-5 cm and 5-15 cm; Water holding capacity of the soil at depth 0-5 & 5-15 cm; and infiltration rate

Determination of dry bulk density by core sampler

While determining bulk density by core cutter method at first height and diameter of core cutter was measured with the help of tape.

Height of core sampler (h) = 5 cm and 10 cm

Diameter (d) = 4.2 cm

$V = (\pi/4) \times d^{2\times}h$ …1

V = volume of core cutter or bulk volume of soil sample, (m^3)

d = diameter of core cutter, (m)

h = height of core cutter, (m)

Volume of core sampler = 69.237m^3 and 138.474m^3

The cylinder of core sampler which has cutting edge was driven into the soil and an undisturbed sample of soil was obtained within the core sampler. The samples were carefully trimmed off at both ends of core sample and it was dried in oven for 24 hours at the temperature 105 ^{O}C. Weight of dried soil sample with core cutter and weight of empty core cutter was taken. Ultimately, we got weight of dry soil sample and bulk volume of sample is equal to volume of core cutter. Dry bulk density was determined by using following formula:

$$\textbf{Bulk density} = \frac{\textbf{Mass of dry soil sample}}{\textbf{Bulk volume of soil sample}} \quad \ldots 2$$

Determination of porosity

For determining porosity soil sample from field was taken without disturbing its structure with the help of core sampler and it was made fully saturated by pouring water and weight of fully saturated soil sample (m_1) was taken. Saturated sample was dried in oven for 24 hours at temperature 105 ^{O}C and weight of dried product (m_2) was taken and difference between weight of saturated and dried sample (m_1-m_2) gave the maximum weight of water that can be hold in pores of soil and porosity was evaluated by formula

$$\textbf{Porosity} = \frac{\textbf{m1}-\textbf{m2}}{\textbf{density of water}\times\textbf{volume of core sampler}} \quad \ldots 3$$

Determination of field capacity on weight basis

While determining field capacity of the soil a core sampler of diameter 7.5 cm and length 20cm was installed at the depth 15cm and rest part was filled with water to make it saturated. After 24 hours soil sample at the depth 0-5 cm and 5-15 cm was taken with the help of auger and its moisture content was determined by oven dry method. Moisture content of the sample gave field capacity.

Measurement of infiltration rate of soil

For measuring the infiltration rate, the double ring infiltrometer was installed in concentric way at a depth of 15cm in the soil. Side of the ring was kept vertical and measuring rod was driven into the soil, keeping 12cm is left above the ground. Water was filled in the both (inner and outer) compartments for 12cm depth. Measurements were recorded from inner cylinder on measuring rod. The measurement includes the depth of water in infiltrometer above the ground after the passes of time.

Fig 2: Double ring infiltrometer installed at experimental site

Results and Discussion

Dry bulk density & porosity

Dry bulk density and porosity has been significantly affected by different type of tillage and residue management. At the depth 0-5 cm dry bulk density is lowest in the treatment PBDSR-PBW +R (1.104 g/cm^3) and highest in the treatment PTR-CTW (1.357 g/cm^3). At the depth 5-15 cm it is lowest and highest in ZTR-ZTW +R (1.246 g/cm^3) and PTR-CTW (1.398 g/cm^3) respectively. In the treatment PBDSR-PBW +R at the depth 5-15 cm dry bulk density (1.252 g/cm^3) is slightly higher than the treatment ZTR-ZTW +R.

As dry bulk density, porosity is also affected by different treatment. At the depth 0-5 cm and 5-15 cm for the treatment PBDSR-PBW +R porosity is highest (66.28% at the depth 0-5 cm and 59.42% at the depth 5-15 cm) and it is lowest for the treatment PTR-CTW (48.46% at the depth 0-5 cm and

47.02% at the depth 5-15 cm). Average dry bulk density and porosity given in table 1and table 2.

Table 1: Average dry bulk density (g/cm^3) at different depth

Treatments	Dry bulk density (g/cm^3)	
	0-5 cm	5-15 cm
PTR-CTW	1.357	1.398
PTR-ZTW	1.292	1.364
PBDSR-PBW+R	1.104	1.252
ZTR-ZTW+R	1.172	1.246
ZTR-ZTW-R	1.225	1.369

Table 2: Porosity (%) of soil at different depth

Treatments	Porosity (%)	
	0-5 cm	5-15 cm
PTR-CTW	48.46	47.02
PTR-ZTW	52.63	50.97
PBDSR-PBW+R	66.28	59.42
ZTR-ZTW+R	61.84	58.45
ZTR-ZTW-R	55.37	52.31

Field capacity and specific retention

Field capacity and specific retention capacity for different treatments it has been found that field capacity are considerably different. As dry bulk density and porosity, field capacity is also excellent for the treatment PBDSR-PBW +R and lowest for the treatment PTR-CTW. For sandy clay loam soil and excellent structure field average field capacity is 36%. In the case of PBDSR-PBW +R it is 46.28% i.e. 28.55% higher than average capacity, in the case of ZTR-ZTW +R it is 42.93% i.e. 19.25% higher than average capacity. This increase in value occurs only due to residue presence of previous crop residue. While in case of PTR-CTW it is 30.45% i.e. 15.41% lower.

Specific retention was found highest for the treatment ZTR-ZTW +R (55.86%), n treatment PBDSR-PBW +R it was slightly lower (55.56%). It was lowest in treatment PTR-CTW (42.13%).

Table 3: Field capacity of soil for different treatments

Treatments	Field capacity (%)
	0-15 cm
PTR-CTW	30.45
PTR-ZTW	32.62
PBDSR-PBW+R	46.28
ZTR-ZTW+R	42.93
ZTR-ZTW-R	41.60

Table 4: Specific retention and specific yield of soil for different treatments

Treatments	Specific retention (%)	Specific yield (%)
PTR-CTW	42.13	5.35
PTR-ZTW	43.68	7.84
PBDSR-PBW+R	55.56	6.14
ZTR-ZTW+R	55.85	3.72
ZTR-ZTW-R	47.10	6.22

Infiltration rate

Rate of water infiltration during experiment is found to be different for different field. Time to reach steady state for treatment PBDSR-PBW+R was less than the conventional treatment PTR-CTW. For the treatment PBDSR-PBW+R it was 150-180 minutes and for the treatment PTR-CTW it was 210-240 minutes. Steady infiltration rate for the treatment PBDSR-PBW+R and PTR-CTW was 3 cm/h and 1.8 cm/h. Total water depth at the end of measurement (330 minutes) was 16.5 cm and 26.8 cm for the treatment PTR-CTW and PBDSR-PBW+R respectively. Rate of infiltration in PTR-CTW and PBDSR-PBW+R are given in table 5.

Conclusions

During experiment it was found that physical properties of soil was excellent for the treatment PBDSR-PBW+R and poor in conventional treatment PTR-CTW. At 0-5 cm soil depth the dry bulk density was lowest in treatment T_5 (1.104g/cm^2) and highest in treatment T_1 (1.357g/cm^3); at 5-15cm soil depth it was lowest in treatment T_3 (1.246g/ cm^3) while highest in treatment T_1 (1.398g/ cm^3). At the depth 5- 15cm the dry bulk density was noticed in T5 (1.25g/cm3) and slightly higher than the treatment T3. In regard to variation in soil porosity it was found that the porosity was decreasing in trend with increase in soil depth. At the depth of 0 - cm it was highest about 10.30% in treatment T1 and at the depth 5 - 10cm it was 2.97% in treatment T5 over conventional treatment T1, and so on. Amongst all five treatments the highest infiltration rate 3.0cm /h was in treatment T5. Similarly, the variation in field capacity was noticed to be highest in treatment T5 to the tune of 36.0%.

Table 5: Infiltration rate

Treatment: PTR-CTW			Treatment: PBDSR-PBW+R		
Time (minutes)	Infiltration depth (cm)	Infiltration rate (cm/h)	Time (minutes)	Infiltration depth (cm)	Infiltration rate (cm/h)
0-5	1.4	16.8	0-5	2.6	31.2
5-10	0.9	10.8	5-10	1.6	19.2
10-20	1.5	9.0	10-20	2.6	15.6
20-30	0.9	5.4	20-30	1.5	9.0
30-45	1.2	4.8	30-45	2.0	8.0
45-60	1.0	4.0	45-60	1.6	6.4
60-75	0.8	3.2	60-75	1.3	5.2
75-90	0.7	2.8	75-90	1.1	4.4
90-120	1.3	2.6	90-120	1.9	3.8
120-150	1.1	2.2	120-150	1.6	3.2
150-180	1.0	2.0	150-180	1.5	3.0
180-210	1.0	2.0	180-210	1.5	3.0
210-240	0.9	1.8	210-220	0.5	3.0
240-250	0.3	1.8	220-230	0.5	3.0
250-260	0.3	1.8	230-240	0.5	3.0
260-270	0.3	1.8			

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