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Research Article

Effect of Conservation Agriculture on Root Distribution of Maize Crops

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ABSTRACT

This research concerns the influence of tillage practices and crop rotation on soil biological health under rice based cropping system. Maize base cropping system is advocated as the dominant system prevailing in India due to the better suitability to its landforms and climatic conditions. The tillage practices consisted of Zero Tillage (ZT), Permanent Bed (PB) and Conventional tillage (CT) in main plots and six diversified intensive maize based crop rotations namely, viz. Maize + Soybean-wheat, Maize-Wheat, Maize-winter maize, Maize- Mustard, Maize-Chickpea and Soybean-Maize. Out of these six cropping system three cropping system viz C1- Maize-winter maize, C2- Maize-Wheat, and C3- Maize-Chickpea were chosen for the present study. Computer aided root length scanning system 'RHIZO' was used to study rooting characteristics. Analysis showed that root characteristics including root length density (RLD), root mass density (RMD) and root volume of maize were significantly higher in zero tillage but at par with PB followed by conventional tillage system. Average RLD is computed by dividing the integral of polynomial function fitted to the horizontal root distribution (in the unit soil strip) with its length. The average RLD, thus, obtained is interpolated on the curve between root length density and horizontal distance from the plant base (d) in the representative half of the unit soil strip. Under these condition the response of application of some of the nutrients on cation-exchange capacity of roots is highly imperative, which eventually may affect the crop yield. Root CEC was found significantly higher in ZT under maize-chickpea.

Key words: Conservation agriculture, Root distribution, Maize

Introduction

Roots are the only parts of the plants that provide direct contact with the soil, which is their source of nutrients and moisture. The spatial configuration of a root system in the soil, is used to describe the shape and structure of root systems. A large number of studies confirm that deeper root systems enable plants to access water not available to shallow rooted plants, and to balance high rates of transpiration during water deficit. A range of root traits are linked to plant performance in specific environments (Lynch and Brown, 2012). Root architecture is an important plant morphological character which control growth and development of the entire plant. Root architecture refers to the spatial configuration and distribution of root systems up to effective root depth, including root length, root diameter and root surface areas which enable to bring the nutrients from deeper layer to upper surface layer. On the other hand root cation exchange capacity

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(CEC) play a major role in ion-uptake. This property of root in a qualitative way as a possible explanation of the differential uptake of mono and divalent cations by different plant. Hence, root architecture play pivotal role for governing the plant growth and yield of crops. Root growth is determined both by plant genetic characters and by soil physical and chemical properties (Muñoz-Romero *et al.,* 2010). Maize based cropping system having monocot types of root geometry, which enable to better understand the root architecture and growth dynamics, become more efficient towards applied nutrients.

Conservation agriculture is a crop production system that retains a permanent soil cover through retention of crop residues on soil surface with no till/zero and reduced tillage in order to enhance the natural biological processes above and below the ground. It is one of the best way to maintain soil health. Tillage systems which enhance water infiltration, increase soil moisture storage and improve hydro-physical properties are important to sustain agricultural practices (Brady and Weil 1999). Root growth in soil can be limited by physical, chemical, and biological properties of the soil. In terms of physical limitations to root growth, water stress (too little water for root growth), hypoxia or anoxia (too little oxygen), and mechanical impedance (soil that is too hard for roots to penetrate rapidly) are the major causes of poor root system growth and development (Bengough *et al*., 2010).

Kahlon *et al.* (2012) observed maximum penetration resistance (PR) under CT and least under NT at 15-30 cm depth and no significant difference was observed for surface soil layer. Martinez *et al.* (2008) reported higher RMD under NT in comparison with CT due to improved soil structure, more water availability and increased SOC due to continuous addition of crop residues. Under these condition the response of application of some of the nutrients on cation-exchange capacity of roots is highly imperative, which eventually may affect the crop yield. The aim of this experiment was to show the effect of some systems of soil tillage on the development of maize roots.

Materials and Methods

Study sites and soil properties

Research was carried out during 2018 in *kharif* season on the ongoing experiment of conservation agriculture entitled "Resource conservation technologies for stabilizing yield under different cropping system" laid out at Bihar Agricultural University Sabour, Bhagalpur, Bihar in the year 2011. The geographical location of Bhagalpur comes under the Middle Gangetic plain region of Agro-climatic Zone IIIA. It is situated between 25°50' N latitude and 87°19' E longitude and at an altitude of 52.73 meters above mean sea-level.

Taxonomically, the soils of the study area fall in the order "Inceptisols" and sub group "Typic Ustifluvents". In the genetic system of classification, the soils of the area are of recent alluvium in origin and deep, mostly medium to coarse textured, white to light grey coloured deposited by river Ganga. These soils owe their origin to rocks like granite, amphibolites, schists, quartzites and gnessis. These soils are slightly alkaline in reaction.

Experiment design and crop cultivation

The experiment was laid out in split plot design having three establishment methods of maize in main plots, i.e. Zero tillage (ZT), Permanent bed (PB) and Conventional tillage (CT) and three cropping systems in sub-plot i.e. maize-maize, maize-wheat, and maize-chickpea. The field was prepared by ploughing and followed by 2-3 harrowings or 3-4 inter crossing ploughing with the local plough in conventional plots. Planking was done after each ploughing. Then layout of the field was done as per plan of the experiment for allocation of treatments. Channels and bunds were also made concurrently. Finally, a seedbed was prepared for sowing of maize seeds. In ZT and PB, sowing of maize was done without ploughing.

The maize seed was shown on 3rd July, 2018 with a seed rate of 20 kg ha-1. One seed was planted at every 60 cm in rows 20 cm apart in conventional and ZT plots. 10-20% more seeds than the desired plant population were planted to compensate for various field losses. The in- situ and laboratory determinations were made for various root characteristics at the end of the experiment i.e. after maize harvesting. The images were analyzed using the software WinRHIZO version 5.0 (Regent Instruments Inc., Quebec, Canada). After calculation, the total root length of the whole root sample was obtained. The root length density (RLD) was calculated by dividing the total root length by the volume of the corresponding soil-core section (Qin *et al.,* 2006). Root volume was calculated by water displacement method. Root mass density (RMD) was calculated by dividing root mass by volume of the corresponding soil-core section (Musick *et al.,* 1965).

The root distribution was measured at 75 DAS. For root sampling, the soil cores were taken with the help of core sampler of 5 cm diameter. Samples were taken in between the plant rows. The root-soil cores were then collected and washed in plastic nets. Roots were carefully separated from the soil by washing the nets under water. The washed roots were further cleaned to remove any leftover weed roots, seed and other organic debris. The RLD (cm cm^{-3}) was calculated from the total length of roots measured by scanner to the volume of the core. These roots were then dried in an oven at 60° C and were weighed on precision balance to calculate the RMD (µg cm^{-3}). Root CEC was founded with help of Crook (1964) method according to that first loosen and lift a soil block containing as much as possible of the root system of the plant being studied and free the roots from the bulk of the soil by gentle jets of water. Final separation was achieved by placing roots on sieve under running water and using combination of gentle agitation and flotation. Roots (or other plant tissue) were dried overnight at 80°C and milled to pass 0.7-1.0 mm sieve. After thorough mixing, sub samples of 200 mg (monocots) was withdrawn for C.E.C. measurement. Milled roots were placed in a 400 ml beaker, and moistened with a few drops of distilled water and allowed to become thoroughly wet. This prevents root material floating on the surface during the next stage. 200 ml0.01 N HCL was added and stirred intermittently for 5 minutes. Root material was allowed to settle out. Then quickly bulk of roots was decanted through filter funnel (18.5 cm Whatman No. 1). Roots were washed into funnel using jet of distilled water and continued to wash with water until washings are free of chloride (300 ml is generally adequate). Filter paper was pierced and washed root material into 250 ml beaker using a total of 200 ml 1 M KCL (adjusted to pH 7.0). pH of root-KCL suspension was determined using glass electrode and enough 0.01N KOH was added while stirring inter-mittently to restore pH to 7.0 and it was maintained there during the arbitrary ó-minute titration time. The H-roots was titrated immediately or stored moist overnight for titration next day. C.E.C. as meq per100 g dry roots was expressed by :

$$Root\ CEC = \frac{A * N * 100}{\mathrm{W}}$$

A = Volume of 0.01N KOH used

W = Dry weight of root sample

N = Normality of KOH used

Statistical analysis. Means were calculated for the three replicates from each treatment. Analysis of variance (ANOVA) was conducted using SPSS v 16 software package.

Result and Discussion

Root length density (RLD)

Table 1 represents the effect of different tillage and cropping system on RLD. At surface layer (0-15 cm), RLD (cm cm^{-3}) was found to be maximum under ZT (1.45) that was statistically at par with permanent raised bed system and least under conventional tillage. The highest RLD was observed in maize-chickpea cropping system and lowest in under maize-maize cropping system. Interaction effect was found non-significant.

Barley (1962, 1963) also reported that the elongation rate of roots growing into a zone of greater mechanical impedance has been observed to decrease with time.

Table 1. Effect of cropping systems and tillage practices on Root length density of soil after seven years under maize based cropping system

Treatment	Root length density (RLD)(cm cm^{-3})			
	0-15 cm			
	T1 : Zero Tillage	T2: Permanent Raised Bed	T3: Conventional Tillage	Mean
C1 : Maize – Maize	1.31	1.27	1.25	1.28
C2 : Maize – Wheat	1.48	1.39	1.34	1.41
C3 : Maize – Chickpea	1.52	1.45	1.42	1.47
Mean	1.44	1.37	1.34	
CD (P=0.05)	T : 0.059; C : 0.043; T × C : NS			

Table 2. Effect of cropping systems and tillage practices on Root volume of soil after seven years under maize based cropping system

Treatment	Root volume (m^3 m^{-3})			
	0-15 cm			
	T1 : Zero Tillage	T2: Permanent Raised Bed	T3: Conventional Tillage	Mean
C1 : Maize – Maize	22.6	21.4	18.3	20.77
C2 : Maize – Wheat	23.8	22.7	19.6	22.03
C3 : Maize – Chickpea	24.7	23.4	21.2	23.10
Mean	23.70	22.50	19.70	
CD (P=0.05)	T : 0.157; C : 0.221; T × C : 0.384			

Martinez *et al (*2008) also found that surface soil have greater Length density under NT than under CT (soil physical properties benefited by NT systems are increased soil water availability (Unger, 1994; Drury *et al.,* 1999), and increased number of biopores (Francis and Knight, 1993), that may facilitate root growth (Martino and Shaykewich, 1994).

Root mass density (RMD)

Table 2 represents the effect of tillage and cropping system on RMD. Maximum RMD (µg cm^{-3}) was found at 0-15 cm depth under ZT (1.62) followed by PB (1.59) and minimum under CT (1.42). Highest value of RMD was recorded in case of maize-chickpea cropping system (T1C3) under zero tillage (2.01) and minimum in case of maize-maize cropping system (T3C1) under conventional tillage. Interaction between tillage and cropping system was found to be significant.

Conventional tillage affects soil temperature (Dwyer *et al.,* 1996), soil mechanical impedance (Cox *et al.,* 1990), the continuity of macropores (Roseberg and McCoy, 1992; Shipitalo *et al.,* 2000), soil water availability (Cox *et al.,* 1990; Fuentes *et al.,* 2003), and the depth and distribution of roots (Dwyer *et al.,* 1996).

Martinez *et al*. (2008) reported higher RMD under NT in comparison with CT due to improved soil structure, more water availability and increased SOC due to continuous addition of crop residues.

Root volume

The table 3 represents the effect of tillage and cropping system on root volume. A critical insight into the data revealed that root volume was found to vary from 18.3 to 24.7 cm cm^{-3}. Under different cropping systems the root volume was found to be significantly higher under maize-chickpea system (23.10) as compared to maize-wheat (22.03) and maize-maize cropping (20.77) system. Highest root volume was recorded in case of maize-chickpea cropping system (T1C3) under

Table 3. Effect of cropping systems and tillage practices on Root mass density of soil after seven years under maize based cropping system

Treatment	Root mass density (RMD)(µg cm^{-3})			
	0-15 cm			
	T1 : Zero Tillage	T2: Permanent Raised Bed	T3: Conventional Tillage	Mean
C1 : Maize – Maize	1.16	1.06	1.04	1.08
C2 : Maize – Wheat	1.53	1.52	1.35	1.46
C3 : Maize – Chickpea	2.05	1.85	1.68	1.86
Mean	1.58	1.47	1.35	
CD (P=0.05)	T : 0.040; C : 0.055; T × C : 0.095			

zero tillage (24.7) and minimum in case of maize-maize cropping system (T3C1) under conventional tillage (18.30). The root volume content in zero tillage system (T1) was significantly higher (23.70) than permanent raised bed system (22.50) and conventional tillage system contents (19.70).

Passioura, 2002 showed that soil structure affects crop yield through a complex of root based mechanisms which might affect the biomass production. The better root growth found under CA compared to CT might be attributed to lesser compaction (Blanco-Canqui *et al*., 2006).

Root CEC

The results pertaining to the root CEC content as influenced by the different cropping systems and tillage practices have been presented in Table 4. A critical insight into the data revealed that root CEC was found to vary from 9.42 to 16.50 meq/100g. Under different cropping systems the root CEC was found to be significantly higher under maize-chickpea system (15.01) as compared to maize-wheat (13.83) and maize-maize (11.91) system. Highest root CEC was recorded in case of maize-chickpea cropping system (T1C3) under zero tillage (16.50) and minimum in case of maize-maize cropping system (T3C1) under conventional tillage (9.42). The root CEC content in zero tillage system (T1) was significantly higher (15.00) than permanent raised bed system (14.55) and conventional tillage system contents (11.19).

Among different tillage systems, zero-tillage (ZT) may have potential advantages over other tillage systems in terms of nutrient and water uptake by plants. The other advantages include increased carbon sequestration and climate mitigation potential over conventional tillage systems. Other soil physical properties benefited by ZT systems are increased soil water availability and increased number of biopores that where the roots of the subsequent crop can grow. The initial step of nutrients uptake by plant roots is the physico-chemical process of the exchange

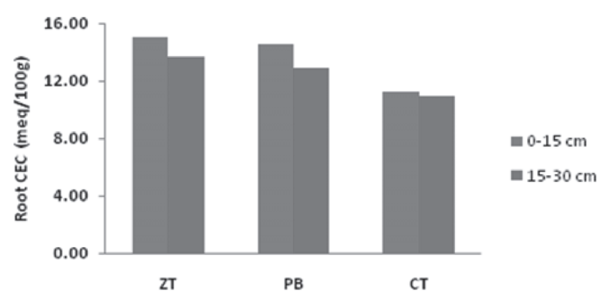

Fig. 1. Root CEC of soil as affected by different (a) cropping system (b) tillage practices at 0-15 cm and 15-30 cm depth

Table 4. Effect of cropping systems and tillage practices on root CEC of soil after seven years under maize based cropping system

Treatment	Root CEC (meq/100g)			
	0-15 cm			
	T1 : Zero Tillage	T2: Permanent Raised Bed	T3: Conventional Tillage	Mean
C1 : Maize – Maize	15.00	12.50	9.20	10.23
C2 : Maize – Wheat	13.50	10.50	8.50	10.83
C3 : Maize – Chickpea	16.50	13.50	10.10	10.70
Mean	13.33	12.17	9.27	
CD (P=0.05)	T : 0.229; C : 0.232; T × C : 0.402			

and adsorption of nutrients to root surface. Tillage also affects root density as well as distribution. In general, conservation tillage results in the stratification of soil nutrients, especially of immobile nutrients like P and produces greater soil fertility near the soil surface, causing an increase in root length density near the soil surface. Subsequent wetting through rain/ irrigation reduced the rate of root penetration down the profile and also negated deep tillage effects on rooting depth. The exchange properties of roots appear to be attributable mainly to carboxyl groups present in pectic substances. Such sites are considered about 70-90% of the exchange properties of roots. Legumes and other dicotyledons generally have values at least double the CEC of monocotyledons, including grasses. Legumes and other plant with high CEC values tend to absorb divalent cations such as calcium (Ca^{2+}) preferentially over monovalent cations, whereas the reverse occurs with grasses where more absorption of monovalent cations like potassium (K^{+}) takes place.

Conclusion

Root distribution of maize under conservation tillage (ZT and PB) and root CEC was significantly higher in ZT. Conservation tillage system are increased soil water availability and increased number of biopores that where the roots of the subsequent crop can grow. Thus tillage method increases WUE where as Root CEC increases nutrient ion uptake and ultimately increases yield.

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