Journal of AgriSearch, 6(2):83-86
An Open Access International Peer Reviewed Quarterly
ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v6i02.15756

Effect of Microbial Seed Treatment on Root Growth of Wheat under Compacted Soil Condition

SURAJIT MONDAL[1], DEBASHIS CHAKRABORTY[2], AND SANGEETA PAUL[3]

ARTICLE INFO

Received on	:	08/01/2019
Accepted on	:	29/05/2019
Published online	:	05/06/2019

ABSTRACT

Soil compaction can seriously restrict root growth both in surface and subsurface soil layers, preventing the root system to uptake water and nutrients from deeper layers in wheat due to intensive puddling in rice. To understand the effect of compaction (BD_1 = bulk density 1.4 g cm^{-3} and BD_2 = 1.8 g cm^{-3}) on root growth of wheat, a pot experiment was conducted in ambient condition during wheat growing period (November-April) in 2017-18. This experiment was done with microbially treated wheat seeds (M_1 to M_6) to observe the effects of microbial cultures on root growth under compacted soil condition in comparison to control where no seed treatment was done. BD_1 registered a marginally 28% higher root length density than BD_2. Among seed treatment with microbial cultures (MC), MC_5 resulted in highest root length density (23% higher than the control). Unlike root length density, root volume density was influenced significantly ($p<0.05$) by microbial seed inoculation, although soil compaction had marginal impact. Average diameter of root varied significantly among treatments due to both soil compaction and microbial seed treatment ($p<0.01$). Average diameter was significantly higher (20%, $p<0.01$) in BD_2 than BD_1. MC_2 recorded higher (45-33%, $p<0.01$) root diameter than other treatments but was comparable with MC_3. It can be concluded that Seed treatment with suitable microbial culture can promote the crop growth in general and root growth in particular under compacted soil condition.

KEYWORDS

Soil compaction, root length density, root diameter, seed treatment, microbial culture.

INTRODUCTION

The rice-wheat cropping system, world's largest agricultural production system with an area of 15.8 M ha is predominant in the Indo-Gangetic Plains of India. Rice and wheat together account for 40% of global food production, and is fundamentally essential for ensuring the food security of entire South Asia. However, the yield growth rate has been considerably slowed down in recent years putting the sustainability issues of this system at stake. The sub-surface compaction due to intensive puddling in rice (the lowland crop) has been a major concern, but the effect on the succeeding wheat (the upland crop) has not been adequately addressed, except in a few reports (Kukal and Aggarwal, 2003; Mondal *et al.*, 2018).

Rice-wheat rotation is a unique system due to its completely contrasting edaphic environment. Two of major issues with soil physical environment under rice-wheat system are the degradation of soil structural condition and a reduction in soil organic carbon pool, and the development of a sub-surface compact layer due to repeated puddling in rice over the years. The structural degradation through puddle-transplanting of rice has serious consequence to the following crop of wheat (Kukal and Aggarwal, 2003). This accompanied with loss in soil carbon (Singh *et al.*, 2014; Mondal *et al.*, 2016) cause adverse impact on soil physical condition.

Moreover, sub-surface soil compaction has been a major concern in rice-wheat system in Indo-Gangetic Plains (Aggarwal *et al.*, 2006; Kumar *et al.*, 2014) and elsewhere. European Union has acknowledged the compaction as a serious form of soil degradation covering an area of 33 M ha in Europe (FAO, 2015). Similar problems have been reported in India, Australia, Russia, China, Japan and New Zeeland. Soil compaction impairs the function of subsoil by impeding root growth and hindering water and gaseous exchange (Mc Garry and Sharp, 2003). This may reduce root biomass by 50–68% in highly puddled soil (Kukal and Aggarwal, 2003), and the crop yield as much as 60% (Sidhu and Duiker, 2006).

Soil compaction can seriously restrict root growth both in surface and subsurface soil layers, preventing the root system to uptake water and nutrients from deeper layers. Soil compaction restricts root penetration (Batey, 2009), hinders the root proliferation and curbs the root elongation in the soil profile (Guaman *et al.*, 2016). It is well accepted that root proliferates maximum in the surface soil layer due to greater availability of water and nutrients (Lynch, 2011). Presence of subsurface compact layer reduces the ability of plant to extract water and nutrient from deeper layers and increase the risk of nutrient leaching particularly NO_3 in ground water. Reduced yield potential and restricted root growth under compacted subsoil layer have been reported (e.g. Bengough *et al.*, 2011).

In the present study we hypothesized that effect of soil compaction can be reduced by seed treatment with microbial culture which may promote root growth and thereby diminishes the yield loss of wheat under compacted soil condition.

MATERIALS AND METHODS

Filling of Pot

To understand the effect of compaction on root growth of wheat, a pot experiment

[1]Division of Land & Water Management, ICAR Research Complex for Eastern Region, Patna, Bihar, India
[2]Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi, India
[3]Division of Microbiology, Indian Agricultural Research Institute, New Delhi, India
*Corresponding Author Email: surajit.iari@gmail.com

was conducted in ambient condition during wheat growing period (November-April) in 2017-18. Pot that used in the study was 6″ in size. Tow soil compaction levels viz. a) no compaction (BD_1 ~ 1.4 Mg m^{-3}), and b) high compaction (BD_2 ~ 1.8 Mg m^{-3}) were used in our study. To achieve the desired compaction or bulk density, soil amount was calculated based on the pot volume and thereafter, soil was compacted layer wise (1-2 cm layer). Upper 3 cm loose soil was kept for proper germination of seed. After filling with soil, all pots were saturated by capillary rise of water and left at room temperature for drying. 4 seeds were sown at each pot and after germination only two plants were kept per pot.

Microbial Seed Treatment

This experiment was done with microbially treated wheat seeds to observe the effects of microbial cultures on root growth under compacted soil condition in comparison to control where no seed treatment was done. All the microbial cultures have some beneficial effect under water stress condition. The list of microbial culture used in the experiment are given below (Table 1):

Table 1: Name of the microbial culture used for pot experiment

Treatment Name	Code No.	Microbial spp.
M1	NAD -7	*Bacillus cereus*
M2	MRD -17	*Bacillus sp.*
M3	NRSSS -1	*Bacillus aryabhattai*
M4	MKS -1	*Cronobacterdublinensis*
M5	MCL -1	*Shewanellaputrefaciens*
M6	MKS -6	*Bacillus casamancencis*
Control	-	No seed treatment

Root Analysis

a) Root washing

Each pot was inverted and emptied on a 0.5 mm sieve and then washed slowly with tap water. Thereafter, washed roots were soaked in water containing sodium hexameta-phosphate to remove any adhered soil materials if any.

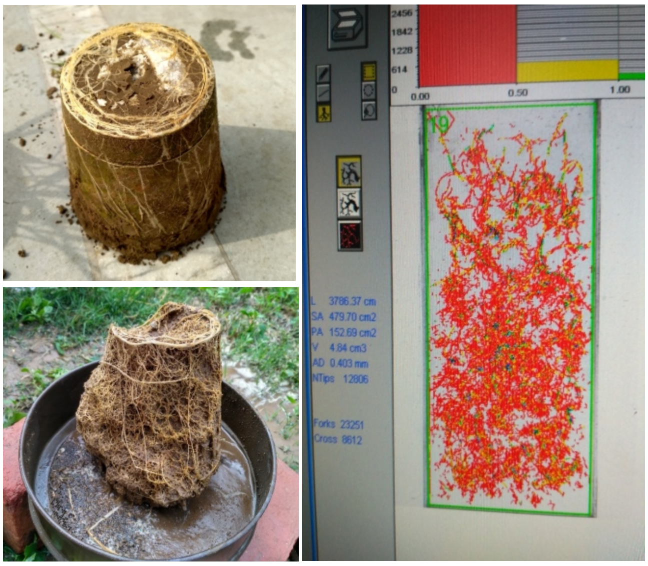

Fig.1: Washing and scanning of roots

Finally, washed roots were placed in butter paper bags and stored in refrigerator to prevent degeneration until it was scanned (Fig 1).

b) Root scanning and image analysis

Scanning of root was carried out in a root scanner (LA-1600) and the root morphology and architecture parameter measurement (viz. total root length, root surface area, root volume, average root diameter etc.) were done by Win-RHIZO programme (Reagent Instruments Inc., Canada). The washed roots were spread with thin film of water on transparent plate for scanning purposes. After image acquisition, the root portion was selected for analysis and for getting different root parameters. Scanned root samples were again collected by passing the water through sieves and oven dried at 65° for 48 h and weighed. The measured root length, surface area and root dry weight were divided by the volume of the pot to get respective densities.

Measurements of root morphological characteristics were based on Regent's non-statistical method with overlap compensation. The advantage of Regent's non-statistical method over Tennant's statistical method was that in addition to root length density, root surface area and volume measurements, it further gave information of their distribution in various size classes based on their diameter.

Statistical Analysis

The statistical analysis was performed using Statistical Analysis System (SAS, 2006) through the Indian NARS Statistical Computing Portal (Indian NARS Statistical Computing Portal (http://stat.iasri.res.in/sscnarsportal). MS Excel was also used for a few basic statistical analysis, and preparation of figures.

RESULTS AND DISCUSSION

Effects of compaction and microbial seed treatments on root growth of wheat were statistically significant for some parameters (Table 2). Root length and surface area density were always higher in normal condition as compared to compacted soil while average root diameter was always higher under soil compaction. Effect of microbial seed treatment was significant for root volume density and average diameter while for other parameters it was statistically non-significant. Average diameter of root was the most sensitive parameter under soil compaction and was statistically significant results were obtained between compacted and non-compacted soils.

Table 2. Statistical significance of root parameters

Factors	df	Root length density	Surface area density	Root volume density	Average diameter	Root weight density
Compaction	1	ns	ns	ns	**	ns
Microbial treatment	6	ns	ns	*	**	ns
Compaction *microbial treatment	6	ns	ns	ns	ns	ns

*P<0.05, significant level; **P<0.01, significant level

Soil compaction did not produce any difference in root length density. BD_1 registered a marginally 28% higher root length density than BD_2 (Fig 2). Among seed treatment with microbial cultures (MC), MC_5 resulted in highest root length density (23% higher than the control). Unlike root length density, root volume density was influenced significantly ($p<0.05$) by microbial seed inoculation, although soil compaction had marginal impact. In case of microbial cultures, MC_2 had a higher value of root volume density (88-91%, $p<0.05$) than MC_6 and control, and it was comparable with all other MCs.

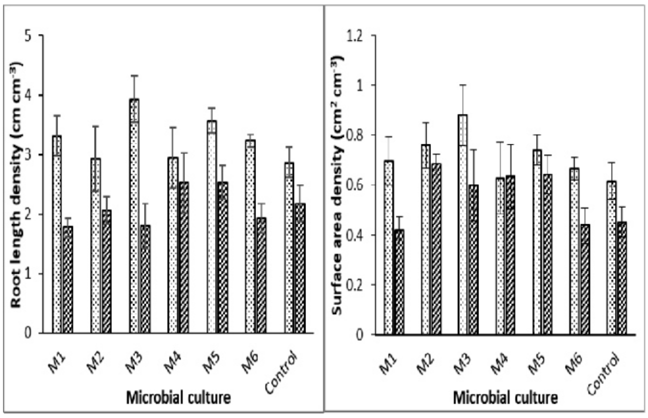

Fig. 2: Effect of microbial treatment to seeds on root length density and surface area density in wheat grown in a compacted (bulk density at 1.8 Mg m^{-3}, BD~1.8) and a normal (bulk density at 1.4 Mg m^{-3}, BD~1.4) soil (M1 to M6 are different microbial cultures details of which are given in Materials and Methods section; control refers to no seed treatment; vertical bars indicate ±SEM).

Surface area density was not affected by either compaction level or microbial culture (Fig 3). A little higher surface area density was noticed in BD_1 in comparison to BD_2. Among the microbial cultures, highest and lowest surface area density was recorded by MC_3 and control, respectively. The root weight density was similar under both compaction and also with culture. A marginally higher (12%, p=0.13) root weight density was although recorded in BD_3 than BD_1 (data not presented). The Highest and the lowest root weight densitywas recorded in MC_2 and in control, respectively. Average diameter of root varied significantly among treatments due to both soil compaction and microbial seed treatment ($p<0.01$). Average diameter was significantly higher (20%, $p<0.01$) in BD_2 than BD_1. MC_2 recorded higher (45-33%, $p<0.01$) root diameter than other treatments but was comparable with MC_3.

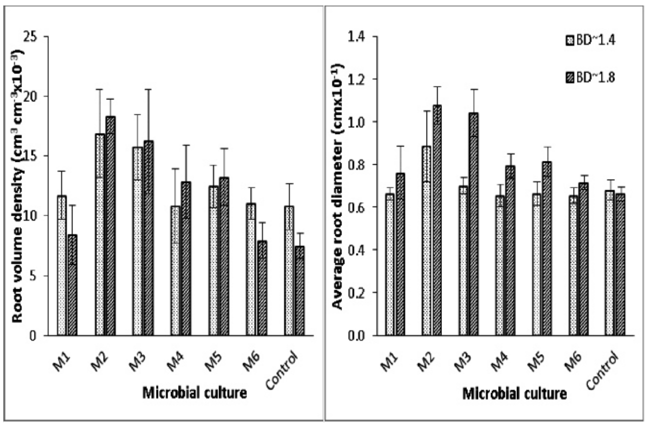

Fig. 3: Effect of microbial treatment to seeds on root volume density and average root diameter in wheat grown in a compacted (bulk density at 1.8 Mg m^{-3}, BD~1.8) and a normal (bulk density at 1.4 Mg m^{-3}, BD~1.4) soil (M1 to M6 are different microbial cultures details of which are given in Materials and Methods section; control refers to no seed treatment; vertical bars indicate ±SEM).

In all the cases, root growth was severely restricted in the compacted soil. Most of the root morphological parameters in wheat were modified under the compaction level often recorded in the field with similar soil texture under the rice-wheat rotation. This highlights the need to study the rooting behaviour under different tillage practices including conservation agriculture in rice-wheat cropping system in the Indo-Gangetic plain. A continuous network of suitably sized soil pores is required for proper root growth. The minimum pore size through which root can grow is estimated to be 10 µm (Gregory, 2006), and that few species have roots of smaller diameter. If a continuous pore structure of appropriate size is not present, the root tip must exert sufficient force to displace soil particles and create a channel.

Compacted layer also produced thinner roots. However, higher surface area, volume and diameter of roots were associated with similar root length in the surface layer with a compacted layer below. This was attributed to thickening of root as the root experienced higher impedance below. Similar results have been reported by Bengough *et al.* (2006, 2011). When plant roots encounter a compact subsurface layer, they become shorter in length and thicker in diameter due to an increased radial expansion (Bengough *et al.*, 2006). Penetration resistance increases with increasing bulk density, thereby increasing the diameter of pea roots (Kirby and Bengough, 2006). Croser *et al.* (2002) reported that the cortical cells of roots grown in compacted soil were shorter and wider than in roots grown in loose soil, whilst Materechera *et al.* (1991) concluded that the root diameter of seedlings grown in compacted soil increased by a factor of two due to the increased size of cortical cells and, occasionally, the presence of additional cell layers. It was also noticed that the development of larger pores (macro size) due to decayed root channel or soil cracking or water flow channel) favoured the root to escape the compacted layer, and proliferate in deeper layers. Results also demonstrated possibility of bringing better root growth through microbial inoculation to seeds of wheat to enable the roots to reduce the adversity of hard soil below.

CONCLUSIONS

The present study reveals that soil compaction arising out of uncontrolled traffic of machinery and soil puddling could affect the root growth of crops severely and might be a contributing factor of yield stagnation of rice-wheat system in Indo-Gangetic plain. Seed treatment with microbial culture can promote the crop growth in general and root growth in particular under compacted soil condition. To get a more insight into the mechanism, detailed studies on root and shoot growth is needed under soil compaction.

REFERENCES

Aggarwal P, Choudhary KK, Singh AK and Chakraborty D. 2006. Variation in soil strength and rooting characteristics of wheat in relation to soil management.*Geoderma***136:**353-363.

Batey T. 2009. Soil compaction and soil management–a review.*Soil Use and Management* **25***:*335-345.

Bengough AG, Bransby MF, Hans J, McKenna SJ, Roberts TJ and Valentine TA. 2006. Root responses to soil physical conditions; growth dynamics from field to cell. *Journal of Experimental Botany* **57**:437–447.

Bengough AG, McKenzie BM, Hallett PD and Valentine TA. 2011. Root elongation, water stress, and mechanical impedance: a review of limiting stresses and beneficial root tip traits. *Journal of Experimental Botany* **62***:*59-68.

Croser C, Bengough AG and Pritchard J. 2000. The effect of mechanical impedance on root growth in pea (*Pisumsativum*). II. Cell expansion and wall rheology during recovery. *Physiol Plant* **109**:150-159.

FAO. (2015). Status of the world's soil resources (swsr)–main report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy, 650.

Gregory PJ. 2006. Plant Roots: Growth, Activity and Interaction with Soils. Blackwell, Oxford.

Guaman V, Båth B, Hagman J, Gunnarsson A and Persson P. 2016. Short time effects of biological and inter-row subsoiling on yield of potatoes grown on a loamy sand, and on soil penetration resistance, root growth and nitrogen uptake. *European Journal of Agronomy* **80***:*55-65.

Kirby JM and Bengough AG. 2002. Influence of soil strength on root growth: experiments and analysis using a critical-state model. *European Journal of Soil Science* **53**:119–127.

Kukal S and Aggarwal G. 2003. Puddling depth and intensity effects in rice–wheat system on a sandy loam soil: I. Development of subsurface compaction. *Soil & Tillage Research* **72** (1):1-8.

Kumar R., Aggarwal P, Singh R, Chakraborty D, Bhattacharya R, Garg RN, Kamble KH and Yadav B. 2014. Assessment of soil physical health and productivity of Kharkhoda and Gohana blocks of Sonipat district (Haryana), India. *Journal of Applied and Natural Science* **6**:6-11.

Lynch JP. 2011. Root phenes for enhanced soil exploration and phosphorus acquisition: tools for future crops. *Plant Physiology* **156**:1041-1049.

Materechera SA, Dexter AR and Alston AM. 1991. Penetration of very strong soils by seedling roots of different plant species. *Plant Soil* 135:31-41

Mc Garry D and Sharp G. 2003. A rapid, immediate, farmer-usable method of assessing soil structure condition to support conservation agriculture. In *Conservation Agriculture* (pp. 375-380). Springer, Dordrecht.

Mondal S, Das TK, Thomas P, Mishra AK, Bandyopadhyay KK, Aggarwal P and Chakraborty D. 2019. Effect of conservation agriculture on soil hydro-physical properties, total and particulate organic carbon and root morphology in wheat (*Triticum aestivum*) under rice (*Oryza sativa*)-wheat system. *Indian Journal of Agricultural Sciences* **89**(1):46-55.

Mondal S, Kumar S, Haris AA, Dwivedi SK, Bhatt BP and Mishra JS. 2016. Effect of different rice establishment methods on soil physical properties in drought-prone, rainfed lowlands of Bihar, India. *Soil Research* ***54***:997-1006.

Sidhu D and Duiker SW. 2006.Soil compaction in conservation tillage. *Agronomy Journal* **98**:1257-1264.

Singh A, Phogat VK, Dahiya R and Batra SD. 2014. Impact of long-term zero till wheat on soil physical properties and wheat productivity under rice–wheat cropping system. *Soil & Tillage Research* ***140***:98-105.

Citation:

Mondal S, Chakraborty D and Paul S.2019 .Effect of microbial seed treatment on root growth of wheat under compacted soil condition. *Journal of AgriSearch* **6**(2): 83-86