# EFFECTS OF LONG RUN ROTARY TILLING ON SOIL STRUCTURE AND MAIZE (ZEA MAYS *L.*) ROOT GROWTH


## ABSTRACT

A pot experiment was carried out to examine the influence of soil aggregate size on maize root growth. The experiment consisted of 7 ~~sandy~~ loamy soil samples resulted from ~~a~~ different number~~s~~ of passes of rotary tiller experimental runs under the soil bin. The soil texture considered in this study was sandy loam. The soil samples were obtained after the interval of 10 passes of rotary tilling (10, 20, 30, 40, 50, 60 passes) at a moisture content of 10.28 % (w.b). Soil samples collected were kept for the pot experiment. The roots were analyzed at 8DAE, 16DAE, and 24DAE for their early growth. Duncan's multiple range tests for means of the effect of soil aggregate sizes on root growth showed that root growth declined in soil aggregates finer than 1.5 mm. The declined root growth in soil aggregates finer than1.5mm suggested that continuous use of rotary tiller after 30 passes deteriorated the soil structure and hindered the root growth.


**Comment [A1]:** Give the root length values in parenthesis after every treatment


***Keywords:*** Rotary tiller, sub-soil, root growth, soil aggregate size.


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## INTRODUCTION

Soil tillage is as old as agriculture itself. It is one of the basic operations in production agriculture because of its influence on soil properties, environment, and crop production. Through tillage operation, soil pulverization takes place which eases in unhindered root growth and movement of air and water in soil (Tapela and Colvin, 2012). The method of tillage undertaken imparts a bigger impact on the sustainable use of soil resources through its influence on soil physical properties (Hammel, 1989). One of the most important goals in the tillage is to maintain a high degree of soil aggregation enabling healthier root growth, penetration, ensuring efficient water storage in root zones. The size and stability of soil aggregates can be indicators of the effect of different tillage on soil structure (ref?).

Well-aggregated soils provide better moisture retention, adequate aeration and easy penetration of roots. Proper plant growth depends upon soil physical properties namely texture, structure, organic matter content and soil strength. Foremost soil properties which affect the uptake of moisture, as well as nutrient contents, are bulk density, hydraulic conductivity and soil strength (ref?). The desired soil bulk density for optimum growth of different crops ranges between 1.4 to 1.80 Mg/m$^3$ for different soil types (Pravin *et al.*, 2013).

Rotary tillage is a superior to conventional tillage methods and viable options to achieve maximum soil pulverization during seedbed preparation (Destan and Houmy, 1990). Rotavaor is an energetic tillage tool that processes the soil at a speed that is different from the tractor forward speed. In the recent past, rotavator has been in extensive use on Indian farms. At present, a total of 6720 rotavators are in operation exclusively in Punjab alone (Anon, 2011) with an increasing trend. The recent increasing trends of the requirement of rotavators specify their scope in crop production. It has an ample opportunity and gaining huge scope under horticulture production, particularly, the use of offset rotavators in orchard cultivation and trend has been increased in recent years (Ramesh *et al*., 2015; Krutz, 2006).

**Comment [A2]:** Also include any latest reference

Beside its positive impact on crop production, serious speculation has been made by Agronomists, Soil scientists and Agricultural Engineers that, use of a rotavator in long run may destruct soil structure and creates a compacted layer immediately below the tilling depth, which can have a negative impact on sustained crop yield (ref?). Camacho and Rodriguez (2007) reported that the excessive application of rotary cultivators, rotary discs and rotary tillers at the same depth is destructing the soil by increasing soil resistance and reduced porosity in subsoil leading to a reduction in crop yield. Biswas (2009**)** stated that recurrent soil tilling at same depth results in degradation of soil structure leading to compacted soil composed of fine particles with low levels of organic matter. Schillinger (2001) specified that tillage breaks down the soil aggregates, decomposes the soil organic matter, breaks the pore space continuity and creates hardpans which limit water and air movement and root growth. The powdered soil on the surface is more prone to sealing, crusting and erosion. Grubinger (2007) reported his concern about the intensive tillage tool rotavator and its long-run effects on the destruction of soil aggregates. Also stated that, long term repeated tillage oxidizes the organic matter that is critical for soil aggregation and structure, in turn after decades soil becomes compact and dense. The churning effect of tillage tools in the plough layer destroy the structure by exposing the soil organic matter to air making it dense and compact (Neal *et al.*, 2015). It was reported that, frequent tilling and harrowing and tillage with heavy equipment tend to break down the stable soil aggregates lead to the destruction in soil structure and created of hard pan immediately below the soil tilling depth (Sharma, 2008). Nigel and James (2004**)** reported that, too many passes of rotavator operation destruct the soil structure and affects the seedling emergence and root growth. Appropriate tillage can improve soil-related constrains, whereas redundant tillage methods can cause an undesirable process such as destruction of soil structure, reduction of organic matter, organic carbon and plant nutrients (Iqbal *et al*., 2005; Hill, 1990; Horne *et al*., 1992; Lal, 1993; Khan *et al*., 1999; Khan *et al*., 2001). Therefore, the study was undertaken to investigate the long-run effects of rotary tilling on soil physical properties under simulated soil bin. In this paper, the effect of soil aggregate sizes on maize root growth at different days of harvests is discussed.

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## METHODOLOGY

**Comment [A4]:** How a pot experiment be simulated to compaction created by rotavator in field? Because only compaction and hard pan creation has been reviewd as an ill effect

**Comment [A5]:** A table should be included to show treatment, soil particle size in respective treatment

**Comment [A6]:** All the instruments used has to be given with their make and model in methods

**Comment [A7]:** How soil particle size was measured

**Comment [A8]:** Detailed methodology should be provided, how each parameter was measured, when and how many times irrigated, how much and when nutrients were supplied etc. Even statistical analysis should be mentioned in methods

**Comment [A9]:** How many replications

An experiment was carried out in soil bin by simulating the conditions of long term usage of rotary tiller to examine its effects on soil physical properties and maize crop response in tilled soils. The experiment consisted of 7 sandy loam soil samples resulted from different number of passes of rotary tiller experimental runs under soil bin. The soil samples were obtained after the interval of 10 passes of rotary tilling (10, 20, 30, 40, 50, 60 passes). The moisture content of 10.28 % (wb) was maintained throughout the soil bin. Soil samples collected were kept for pot experiment to examine the effects of soil aggregate size on maize root growth. The pot experiment was conducted in ~~well equipped~~well-equipped poly house. Totally, 7 pots were laid out, including 1 pot under control). Poly fibre pots with size 30cm diameter and 30cm depth were used in the experiment. Approximately, 8kg soil was filled in all the pots and ten seeds were sown equidistantly in pots at the depth of 20mm. ~~three~~ Three plants were left in pot and rest were uprooted ten days after sowing. The roots were analysed at 8 DAE, 16 DAE, and 24 DAE for their early growth. At 60DAS, the plants were uprooted and kept in polythene bag for analysing rizhosperic parameters. The total root length, root volume, projected area, surface area and root diameter were recorded using Rhizo root scanner facility available in Water Science and Technology Division, Indian Agricultural Research Institute, New Delhi.

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## RESULTS AND DISCUSSION

The root growth parameters viz. total length, volume, surface area, and root diameter were recorded at 8, 16, 24 DAE and 60 DAS. The data was analysed and subjected to Duncan's multiple range test to note the variations in root growth pattern under different proportions of soil aggregate sizes. The root length, root volume, surface area and average root diameter of plants grown in the pots with aggregate size of 0.96-0.48mm and finer than 0.48mm decreased significantly (p=?) at 16 DAE and 24DAE, but no significant variations were observed at 8 days

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after emergence (Table.1). The maximum root length and volume were recorded for plants grown under the pots with 8.95-0.96mm range of soil aggregate size at 8, 16 and 24 DAE (Fig.1&2) which was significantly different than control need to be mentioned. Per cent decrease in total root length with aggregates finer than 0.96mm compared to > 0.96mm soil aggregates was 29.3 and 29.6 at 16 and 24 DAE, respectively. The decrease in root volume were found to be 40.5 and 25.6 per cent with aggregates finer than 0.96mm compared to > 0.96mm soil aggregates at 16 and 24 DAE, respectively. The surface area and average root diameter of roots were maximum soil aggregates of 8.95-0.96mm range, and thereafter values decreased for the aggregates finer than 0.96mm at 16 and 24 DAE (Fig 3&4). There were 47.5, and 23 per cent decrease in surface area with aggregates finer than 0.96mm compared to > 0.96mm soil aggregates at 16 and 24 DAE, respectively. Duncan's multiple range test for means showed the greatest significant decline in root diameter was with plants grown under soil aggregates <0.96mm for 16 and 24 days after emergence (Table.1).

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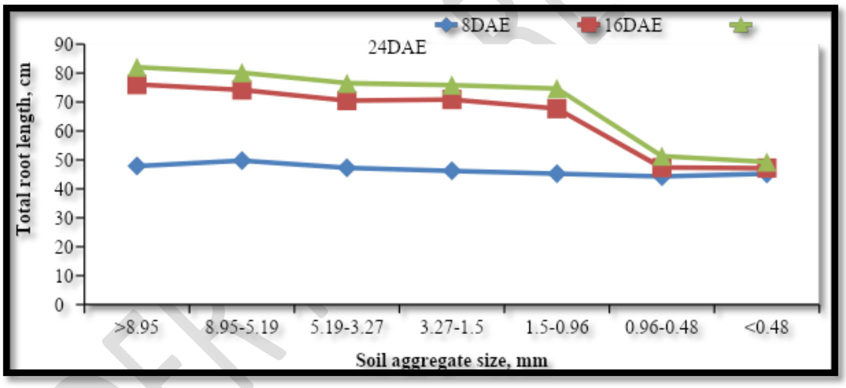


**Fig. 1 Effect of soil aggregate size on length**

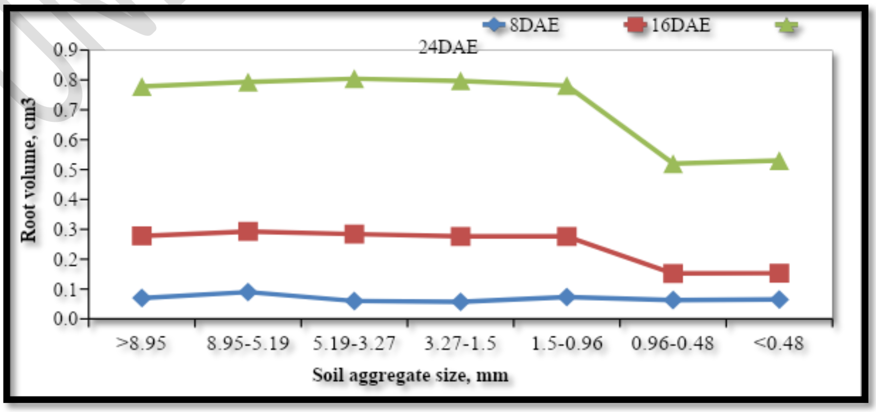

**Fig. 2 Effect of soil aggregate size on root volume**

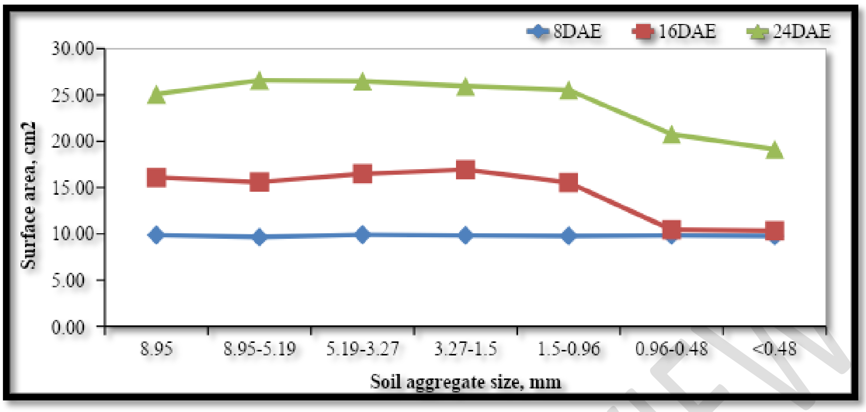


**Fig. 3 Effect of soil aggregate size on root surface area**

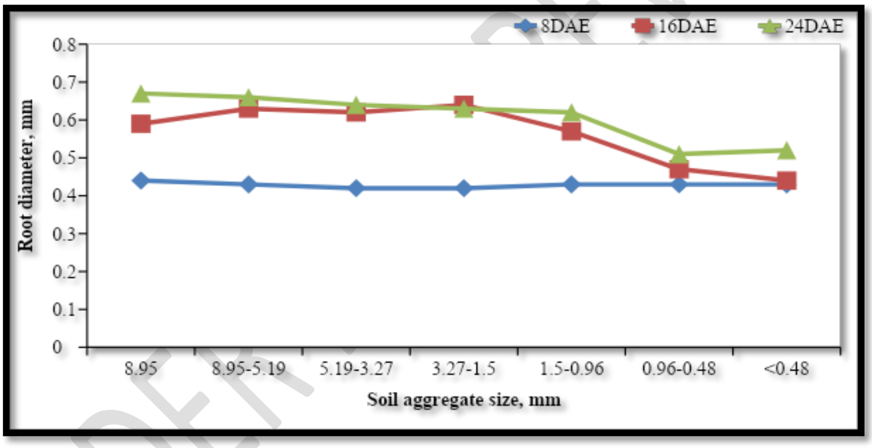


**Fig. 4 Effect of soil aggregate size on root diameter**

**Table1. Mean values of root growth parameters under different treatment**

| Treatments | Corresponding soil bulk density M gm$^{-3}$ | Soil aggregate size, mm | Total root length, cm | | | Root volume, cm$^{3}$ | | | Root surface area, cm$^{2}$ | | | Root diameter, mm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 8 DAE | 16 DAE | 24 DAE | 8 DAE | 16 DAE | 24 DAE | 8 DAE | 16 DAE | 24 DAE | 8 DAE | 16 DAE | 24 DAE |
| Control | 1.32 | >8.95 | 47.89$^{a}$ | 76.03$^{a}$ | 82.16$^{a}$ | 0.15$^{a}$ | 0.28$^{c}$ | 0.81$^{a}$ | 12.27$^{a}$ | 16.09$^{b}$ | 25.09$^{a}$ | 0.44$^{a}$ | 0.59$^{b}$ | 0.67$^{a}$ |
| 10 Pass | 1.37 | 8.95-5.19 | 47.77$^{a}$ | 74.16$^{b}$ | 80.23$^{b}$ | 0.14$^{a}$ | 0.29$^{a}$ | 0.76$^{a}$ | 11.08$^{a}$ | 15.59$^{b}$ | 26.59$^{b}$ | 0.48$^{a}$ | 0.63$^{a}$ | 0.66$^{a}$ |
| 20 Pass | 1.41 | 5.19-3.27 | 47.2$^{a}$ | 70.50$^{c}$ | 76.35$^{c}$ | 0.15$^{a}$ | 0.28$^{b}$ | 0.80$^{a}$ | 12.08$^{a}$ | 16.48$^{ab}$ | 26.48$^{cd}$ | 0.42$^{a}$ | 0.62$^{a}$ | 0.64$^{b}$ |
| 30 Pass | 1.44 | 3.27-1.5 | 46.17$^{a}$ | 69.8$^{dc}$ | 75.54$^{c}$ | 0.14$^{a}$ | 0.28$^{c}$ | 0.80$^{a}$ | 12.06$^{a}$ | 16.95$^{a}$ | 25.95$^{c}$ | 0.39$^{a}$ | 0.64$^{c}$ | 0.63$^{c}$ |
| 40 Pass | 1.46 | 1.5-0.96 | 46.26$^{a}$ | 67.71$^{d}$ | 74.32$^{d}$ | 0.15$^{a}$ | 0.15$^{e}$ | 0.78$^{a}$ | 11.44$^{a}$ | 15.53$^{c}$ | 25.53$^{d}$ | 0.43$^{a}$ | 0.57$^{c}$ | 0.62$^{d}$ |
| 50 Pass | 1.49 | 0.96-0.48 | 47.73$^{a}$ | 58.33$^{e}$ | 63.77$^{e}$ | 0.15$^{a}$ | 0.15$^{d}$ | 0.62$^{b}$ | 11.28$^{a}$ | 9.77$^{d}$ | 20.77$^{d}$ | 0.44$^{a}$ | 0.47$^{d}$ | 0.5$^{e}$ |
| 60 Pass | 1.53 | <0.48 | 46.45$^{a}$ | 42.89$^{f}$ | 46.63$^{f}$ | 0.16$^{a}$ | 0.15$^{d}$ | 0.57$^{b}$ | 12.70$^{a}$ | 7.14$^{e}$ | 19.14$^{e}$ | 0.45$^{a}$ | 0.44$^{e}$ | 0.52$^{f}$ |

*Means with different letters are significantly different at 5 per cent level

**Root growth at 60 DAS**

The maximum root length and root volume were recorded for the soil aggregate size of 8.95-1.5 mm range (Fig.5), however, both total root length and root volume declined significantly with aggregate size of 1.5-0.96 mm and finer than 0.96 mm (Table.2). There was 34.9 per cent and 27.8 per cent decrease in total root length and root volume, respectively, for aggregates finer than 1.5 mm compared to > 1.5 mm sized soil aggregates. The root surface area and average root diameter were found to be maximum for the sandy loam soil aggregate size 8.95-0.96 mm, whereas values decreased for finer aggregates, Fig.6. There were 42.7, and 41.5 per cent decrease in root surface area and root diameter, respectively, with aggregates finer than 0.96 mm compared to > 0.96 mm aggregates.

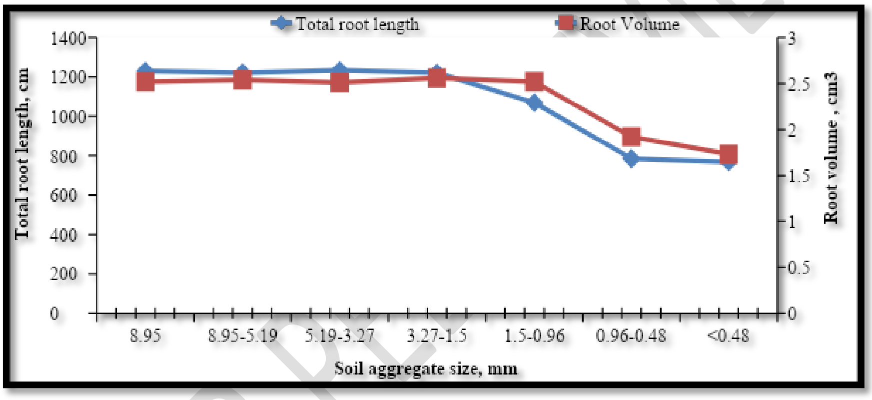


**Fig 5 Effect of soil aggregate size on root growth in sandy loam**

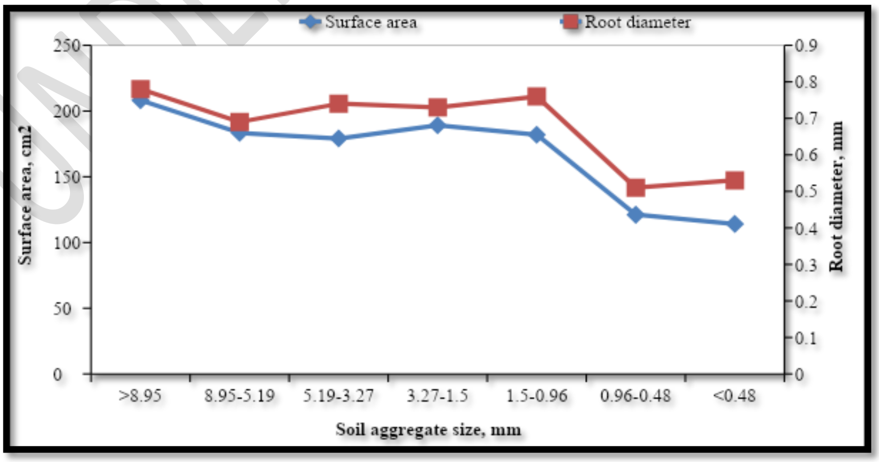


**Fig 6 Effect of soil aggregate size on root growth in sandy loam**

**Table 2 Mean values of root growth parameters on 60 DAS in sandy loam soil**

| Treatments | Aggregate size, mm | Total root length, cm | Root volume, $cm^3$ | Root surface area, $cm^2$ | Root diameter, mm |
|---|---|---|---|---|---|
| Control | >8.95 | 1229.6 [a] | 2.52 [a] | 208.21 [a] | 0.78 [a] |
| 10 Pass | 8.95-5.19 | 1221.0 [b] | 2.54 [a] | 183.42 [b] | 0.69 [c] |
| 20 Pass | 5.19-3.27 | 1233.5 [a] | 2.51 [a] | 179.12 [c] | 0.74 [b] |
| 30 Pass | 3.27-1.5 | 1220.7 [b] | 2.56 [a] | 189.14 [b] | 0.73 [b] |
| 40 Pass | 1.5-0.96 | 1069.5 [c] | 2.52 [a] | 182 [b] | 0.76 [a] |
| 50 Pass | 0.96-0.48 | 784.7 [d] | 1.92 [b] | 121.12 [d] | 0.51 [d] |
| 60 Pass | <0.48 | 769.1 [d] | 1.73 [c] | 114.14 [e] | 0.53 [d] |

*Means with different letters are significantly different at 5 per cent level

Soil aggregate structure has significant role on early emergence and root development (Donald *et al*., 2007; Taylor, 1994). Results of pot experiments to assess the effects of different aggregate proportions of soil on maize root growth revealed that, root growth started declining with decrease in soil aggregate size. Maximum root dimensions were observed for plants grown under the pots with 8.95-0.96 mm range of soil aggregate size, whereas root dimensions of plants with aggregate size of 0.96-0.48 mm and finer than 0.48 mm decreased significantly at 8, 16, 24 DAE and 60 DAS. The results are in agreement with Alexander and Miller (1991).

## CONCLUSION

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The results obtained from the pot experiment to assess influence of soil aggregate size on root growth lead to following key conclusions.

1. Duncan's multiple range tests for means of effect of soil aggregate sizes on root growth showed that root growth declined in soil aggregates finer than 1.5 mm in sandy loam and 2.51mm in clay loam soil.
2. The declined root growth in soil aggregates finer than1.5mm for sandy loam and 2.51mm for clay loam suggested that continuous use of rotary tiller after 30 passes in sandy loam and 40 passes in clay loam deteriorated the soil structure and hindered the root growth.

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