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Effects of Long Run Rotary Tilling on Soil Structure and Maize (*Zea mays* L) Root Growth

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted to examine the influence of soil aggregate size on maize root growth and development. The loamy soil samples resulted from different number of passes of rotary tilling experimental runs under the controlled soil bin were selected. The soil texture chosen 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 moisture content of 10.28 % (w.b). Soil samples collected were kept for the pot experiment. The roots were analysed at 8DAE, 16DAE, and 24DAE for their early growth. Duncan's multiple range tests for the effect of soil aggregate size on root growth showed the decrease in root growth in soil aggregates finer than 1.5 mm. The decline in root length considerable after 30 passes of rotary tilling (40 passes:74.32cm, 50passes:63.77cm, 60passes:46.63cm).The declined root growth in soil aggregates finer than 1.5mm was attributed to continuous rotary tilling deteriorated the soil structure and hindered the root growth. The soil structure starts degrading with excessive application of rotavator and which in turn develops compacted soil layers in 20-30cm sub soil depth.

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

1. INTRODUCTION

Soil tillage is as old as agriculture itself. It is the basic operation in production agriculture which influences soil properties, environment and crop production. Through tillage operation, soil pulverization takes place which eases in hindered root growth and movement of air and

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water in soil [1]. The tillage undertaken imparts a bigger impact on the sustainable use of soil resources through its influence on soil physical properties [2]. Maintaining a high degree of soil aggregation enables healthier root growth, penetration, ensuring efficient water storage in root zones. The size soil aggregates could be an indicator of the effect of tillage method on soil structure and environment [3].

Well-aggregated soil delivers better moisture retention, adequate aeration and easy root penetration. Proper plant growth depends upon soil properties namely texture, structure, organic matter content and soil strength. 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 [4]. Rotary tillage is a superior to conventional tillage and viable options to attain good soil pulverization [5]. Rotavaor is the tillage tool that handles soil at a speed that is different from the tractor forward speed. In the recent past, rotavator has been in extensive use on Indian farm. At present, a total of 6720 rotavators are in operation exclusively in Punjab alone [6] 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 [7,8].

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 [5, 9-15]. They also reported their concern about the rotavator and its long-run effects on the destruction of soil aggregates. Also stated the long term repeated tillage effects on oxidizing the organic matter that is critical for soil aggregation and structure, in turn after decades soil becomes compact and dense. 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 [16-21]. The influence of soil aggregate size has considerable effect on shoots and root growth. Nandian *et al*. [22] studied the effects of soil aggregate size and mycorrhizal colonization on phosphorus (P) accumulation and root growth of Berseem clover (*Trifolium alexandrinum* L.) and reported that, root length with increased aggregate diameter. Donald *et al*. [23] reported that, total root length in the coarsest aggregate system was less than 60% of that in the finest system. There is few authenticated research results on soil aggregate's influence on root growth of maize crops. And also to know the effect of finer soil aggregates on root growth, the study was undertaken to investigate the long-run effects of rotary tilling on soil physical properties under simulated soil bin.

2. METHODOLOGY

2.1 Soil Bin Experiment

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. During and after each test run, the mean weight diameter was recorded. The soil samples were collected in the soil layers of 0–10 cm, 10–20 cm and 20–30 cm using a cylindrical soil core sampler immediately after each experimental run from the sub lengths of soil bin experimental track.

2.2 Determination of Soil Aggregate Size

For computing the soil aggregate size in terms of soil mean weight diameter, the soil samples were allowed to pass through sieve set (mechanically powered sieve shaker) of 16 mm, 12 mm, 10 mm, 4.75 mm, 2.36 mm, 1.18 mm, 1 mm, 0.707 mm, 0.088 mm and mass of the soil retained over the each sieve was noted. The mean weight diameter was calculated using the following equation;

$$MWD = \frac{\sum Xi.Wi}{W} \quad (1)$$

Where, MWD = Mean weight diameter, mm, X_i = sieve opening in ith sieve, mm, W_i =Weight of soil retained over i^{th} sieve, g, W = Total weight of soil sample sieve analysis, g.

2.3 Pot Experiment

The undisturbed soil samples obtained after various intervals of rotary tilling passes in soil bin condition were collected in blocks and placed in pots without alteration in order to simulate sub-soil condition in pots. The pot experiment was conducted in well-equipped poly house. Totally, 7 pots were laid out, including 1 pot under control with three replications. Poly fibre pots with size 30cm diameter and 30cm depth were used in the experiment. Approximately, 8kg soil block collected after different intervals of passes was filled in the pots and ten seeds of Hybrid 9005 cultivar of maize were sown equidistantly in pots at the depth of 20mm. Three plants were left in pot and rest were uprooted ten days after sowing. The roots were analysed at 8, 16, and 24 DAE (Days after emergence) for their early growth. At 60 DAS (Days after sowing), 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.

The observations pertaining to root growth were subjected to Duncan's multiple range tests for means with 't' test in SPSS 4.0 statistical software.

3. 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=0.05) at 16 DAE and 24DAE, but no significant variations were observed at 8 days 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 and control at 16 and 24 DAE (Fig.2&3) which was significantly different than root length under pots with soil aggregate size finer than 0.96mm. The decrease in total root length with aggregates finer than 0.96mm compared to 8.95-0.96mm sized soil aggregates was 29.3 per cent and 29.6 per cent at 16 and 24 DAE, respectively. The decrease in root volume were found to be 40.5 per cent and 25.6 per cent with aggregates finer than 0.96mm compared to 8.95-0.96mm sized soil aggregates at 16 and 24 DAE, respectively. The surface area and root diameter of were maximum soil aggregates of 8.95-0.96mm and same was decreased significantly (p=0.05) for the aggregates finer than 0.96mm at 16 and 24 DAE (Fig 4&5). The decrease in root surface area under aggregates finer than 0.96mm compared to 8.95- 0.96mm was 47.5 and 23 per cent at 16 and 24 DAE, respectively. Duncan's multiple range test for means showed the greatest significant (p=0.05) decline in root diameter was with plants grown under soil aggregates <0.96mm for 16 and 24 days after emergence (Table.1).

3.1 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.6), however, both total root length and root volume declined significantly (p=0.05) 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 under soil aggregate size 8.95-0.96 mm, whereas values decreased for finer aggregates (Fig.7). 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 8.95-0.96mm sized aggregates.

Soil aggregate structure has significant role on early emergence and root development [24,25,26]. 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 decreased significantly (p=0.05) at 8, 16, 24 DAE and 60 DAS. The results are in agreement with Alexander and Miller [27].

Fig. 1. Scanning of maize root in Win RHIZO root scanner

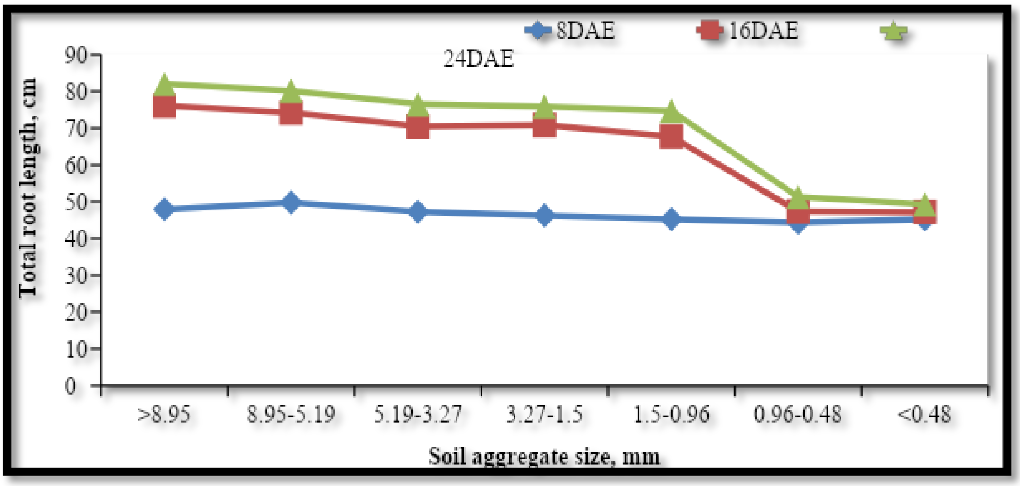

Fig. 2. Effect of soil aggregate size on length

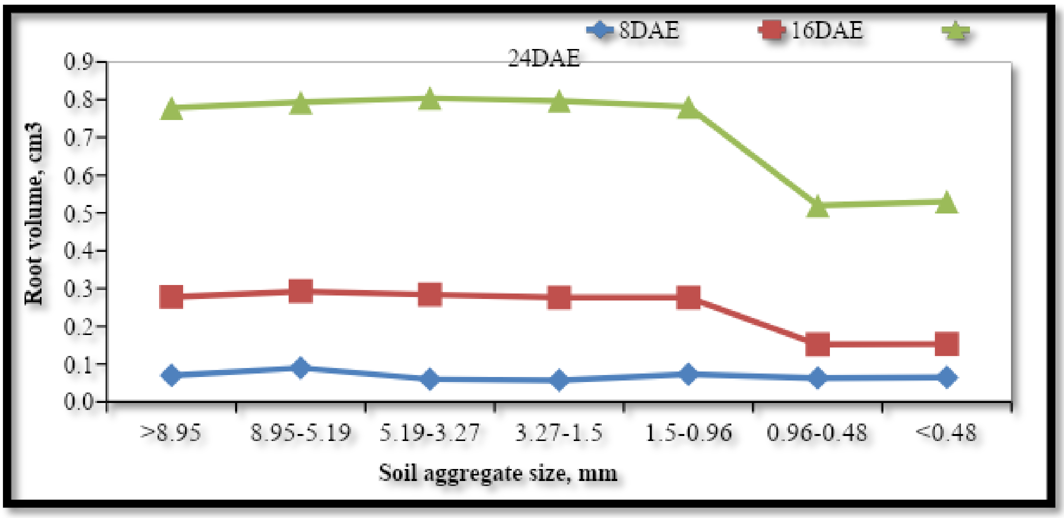

Fig. 3. Effect of soil aggregate size on root volume

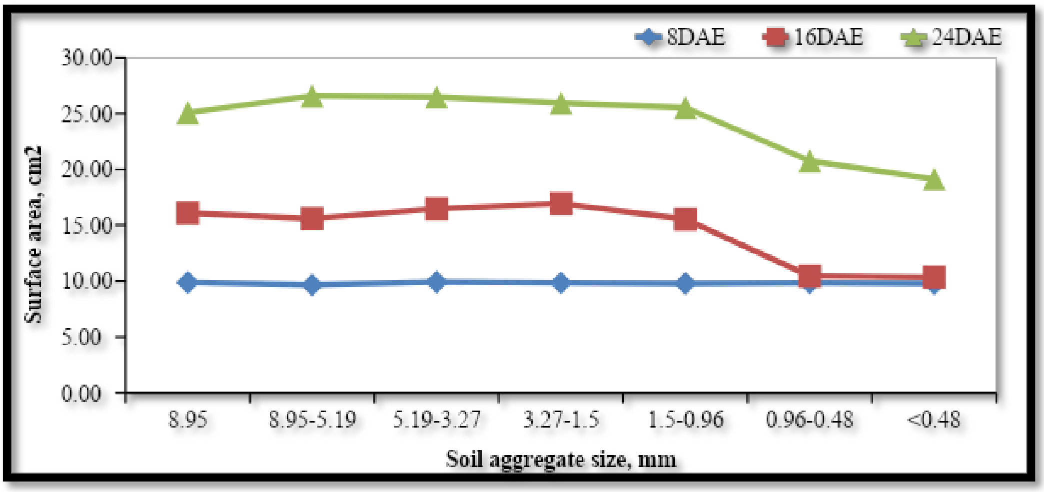

Fig. 4. Effect of soil aggregate size on root surface area

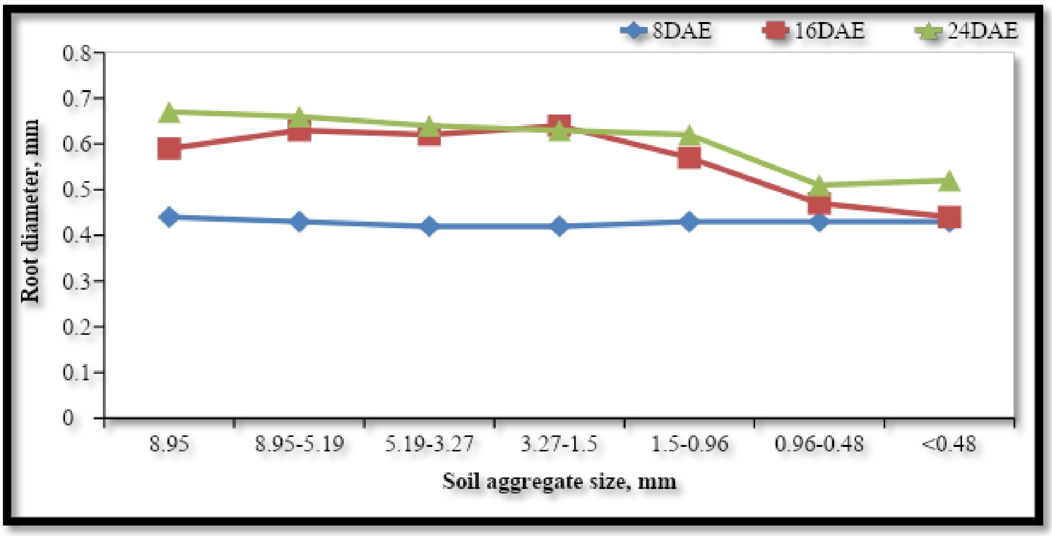

Fig. 5. Effect of soil aggregate size on root diameter

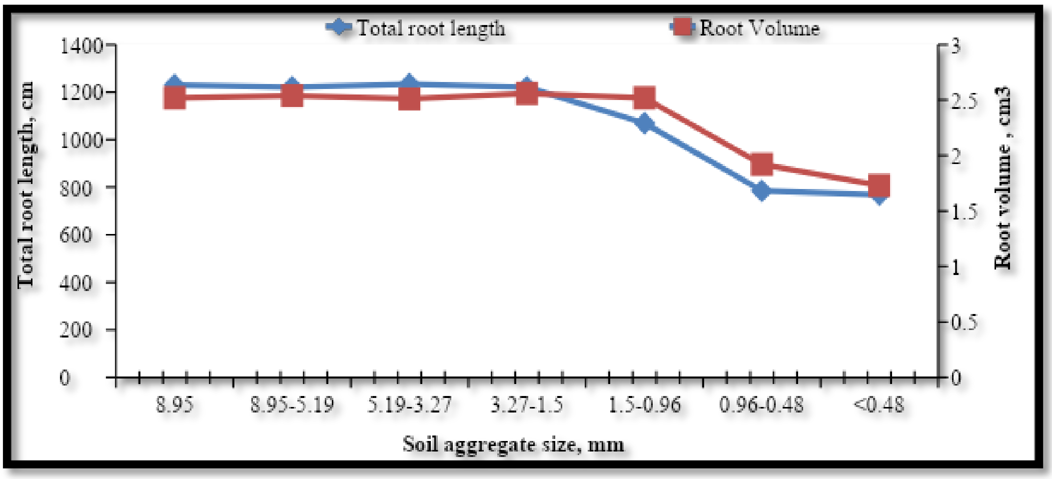

Fig. 6. Effect of soil aggregate size on root growth

Table 1. 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	47.20^{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*

Table 2. Mean values of root growth parameters on 60 DAS

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*

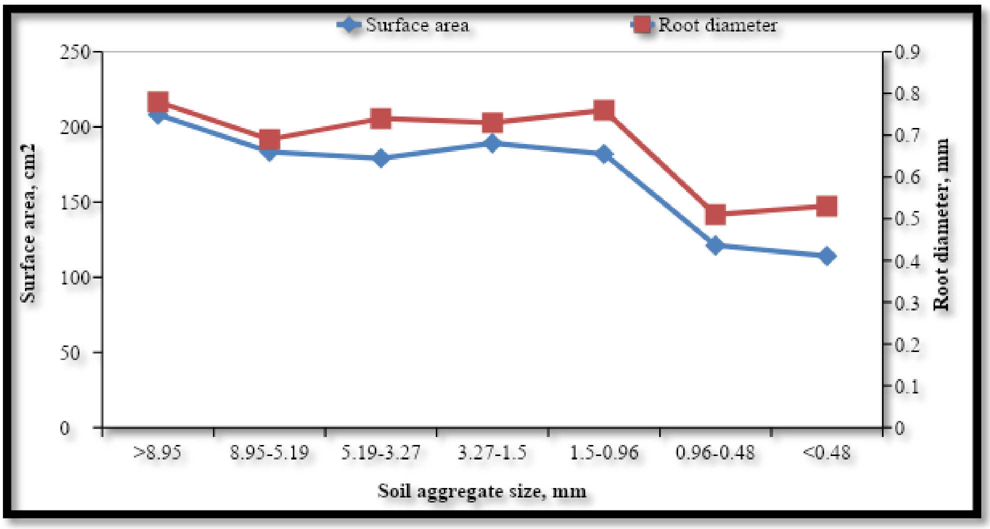

Fig. 7. Effect of soil aggregate size on root growth

4. CONCLUSION

The soil aggregate size plays a huge impact on early shoot and root growth of maize crop. As it is evident from this study and considerable supportive data of past research works, it could be concluded that, soil structure gets deteriorated with recurrent tillage at same depth of operation of rotary soil working tools. The rotary tilling after 40 passes resulted in finer soil aggregates (<0.96mm), which is not favourable for root growth and development. Duncan's multiple range tests for means suggested the decline in root growth for soil aggregates finer than 1.5 mm (after 30passes of rotary tilling) deteriorated the soil structure and hindered the root growth at 16 DAE, 24DAE and 60 days after sowing significantly (p=0.05). Hence, rotary tillage with horizontal axis rotavator or rotary tiller could be highly useful in respect of generating good soil pulverization with its use up to 30 times (passes) on particular land. The soil structure starts degrading once frequency of application of rotavator exceeds 30 passes as it leads to finer aggregates and which in turn develops compacted soil layers in sub soil in 20-30cm sub-soil depth.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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