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Intrinsic Implication of Different Tillage Practices on Soil Penetration Resistance and Crop Growth

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ABSTRACT

The cone penetrometer is the most widely used instrument to measure soil penetration resistance. Soil strength is a parameter commonly used to evaluate the effectiveness of various tillage practices and to locate sub-soil layers impeding root growth. This study was conducted to evaluate the effect of conservation tillage (one pass of dyna drive followed by one pass of diskharrow and one pass of tine cultivator) and conventional tillage (one pass of mould board plough followed by two passes of diskharrow and two passes of tine cultivator) on penetration resistance and its impact on seed germination, plant population density and crop yield. Penetration resistance of soil was found to vary directly with density and inversely with soil moisture content. Mould board plough followed by two passes of tine cultivator was found to be more appropriate and profitable implement in improving soil surface conditions and crop yield.

Key Words: Conventional tillage; Conservation tillage; Soil penetration resistance; Crop growth

INTRODUCTION

Tillage practices modify soil structure by changing its physical properties such as soil moisture content, soil bulk density and soil penetration resistance, etc. Annual disturbance and pulverising caused by conventional tillage (mouldboard ploughing) produces a finer and loose soil structure as compared to conservation tillage, which leaves the soil intact. This difference results in a change of number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water, agricultural chemicals and crop growth. This in turn controls erosion, runoff and crop performance. Changes in soil penetration resistance affects the seedling emergence, plant population density, root distribution and crop yield.

Conservation tillage often results in decreased pore space (Hill, 1990), increased soil strength (Baurder *et al.,* 1981) and stable aggregates (Horne *et al.,* 1992). The pore network in conservationally tilled soil is usually more continuous because of earthworms, root channels and vertical cracks (Channel, 1985). Therefore, conservation tillage may reduce disruption of continuous pores. Whereas, conventional tillage decreases bulk density of soil (Khan *et al.,* 1999) and soil penetration resistance. This also improves porosity, conductivity and water holding capacity of the soil. Continuity of pore network is also interrupted by conventional tillage, which increases the tortuousity of soil. This all leads to a favourable environment for crop growth and nutrient use.

The specific objective of this study was to measure penetration resistance of soil and crop growth affected by conventional and conservation tillage under a sandy clay loam soil continuously for two years.

MATERIALS AND METHODS

To study the effect of conservation and conventional tillage on penetration resistance and its impact on seed emergence, plant population and crop yield, a study area measuring 24x96 m was selected at experimental farm of the University of New Castle Upon Tyne, U.K. The study area was divide into 16 plots, each plot size was 24x6 m. Mouldboard plough followed by two passes of disk harrow and followed by two passes of tine cultivator (treatment 1 and 2) was regarded as conventional tillage. Whereas, dyna drive followed by one pass of disk harrow and followed by one pass of tine cultivator (treatment 3 and 4) was regarded as conservation tillage. Each treatment was replicated four times in the field. Conventional and conservation tillage were compared and evaluated as they affected shear strength and crop growth during the crop growing season.

Pastoral, a variety of winter barley was sown at the rate of 169 and 172 Kg ha^{-1} during year 1 and year 2, respectively. The plots were sprayed to kill seeds and insects. All other necessary operations such as fertilisation and inter-culture were also carried out to facilitate the investigation and measurements of crop growth during study period. Seedling emergence was recorded for both the years from a line of 1 m length replicated five times in each plot at random positions. Seed germination was recorded on both sides of the line on different days till germination stopped. From the germination data plant population density was calculated and crop yield was measured at maturity for both the years (Khan *et al.,* 1999). Penetration resistance of soil was measured after cultivation and winter during year 1 and 2. Data were recorded in four replications form each plot up to a depth of 52.5 cm with an increment of 3.5 cm. In this study, a compact and automatic digital recording electronic cone penetrometer was used to measure penetration resistance directly in the field (Gregorich *et al.,* 1993), because of its accuracy and fast in use.

RESULTS AND DISCUSSION

Soil penetration resistance. During year 1, significantly greater soil penetration resistance of treatment 1 than 2 and treatment 4 than 3 (Table I) was observed after cultivation which showed soil loosening effect of primary and secondary tillage implements used. After winter, significantly lower soil penetration resistance for treatments 1 and 2 as compared to treatments 3 and 4 (Table I) may be associated with the effect of primary tillage implements.

Table I. Penetration resistance (Kpa) with respect different tillage treatments and study period averaged over all depths during experiment 1 and 2

Treatments	Experiment 1		Experiment 2	
	AC	AW	AC	AW
T1	2050	1365	1052	1653
T2	1964	1369	0964	1552
T3	1969	1658	1719	1903
T4	2017	1647	1659	1492

Kpa = Kilo pascal; Trts. = Treatments; AC = After cultivation; AW = After winter

Increase in soil penetration resistance after cultivation and with depth (Table II) can be associated with soil moisture, which decreased with depth or compactive effect of soil under natural consolidation (Khan *et al.,* 1999). Decrease in cone index at a depth of 7 cm after winter (Table II) may be due to greater soil moisture content. This is in line with Ghuman *et al.* (1984) that penetration resistance decreased with increase in soil moisture content.

During year 2, after cultivation significantly greater soil penetration resistance for treatments 3 and 4 than 1 and 2 (Table I) is partly associated with soil moisture content and partly with set of primary and secondary tillage implements used. This is in line with Ghuman *et al.* (1984) that penetration resistance decreased with increase in soil moisture content. In another study, Malhi *et al.* (1990) pointed out that penetration resistance was higher in conservation tillage than conventional tillage. After winter, significantly lower cone index under treatments 1 and 2 as compared to treatment 3 (Table I) may be associated with effect of primary tillage. The reason of significantly lower cone index of treatment 4 (Table I) is not known. The increase in cone index with depth (Table II) may be because of decreasing soil moisture content. Therefore, it verified the recommendations of Braunack *et al.* (1991) that initial water content was the only factor to effect cone index significantly.

Seed germination. Penetration resistance adversely affects the seed emergence. Significantly greater plant population density and seed germination for treatment 4 than 1, 2 and 3 during experiment 1 (Table III) may be associated with per cent seed germinated that was 69, 65, 62 and 85% for treatments 1, 2, 3 and 4, respectively. The increased number of seed germinated under treatment 4 on each date can be attributed to greater seed moisture uptake when compared to all other treatments (Table III). The plant population density was increasing at each date; whereas, seed germination was decreasing (Table III). The plant population density in case of treatment 4 was maximum after seed germination was over. However, seed germination was maximum after 25 days of sowing (Table III). The variation in seed germination at each date under different tillage treatments (Table III) may be associated with seed-soil contact characteristics.

Table II. Effect of different tillage treatments on penetration resistance (Kpa) with respect to depth averaged on study period during experiment 1 and 2

Depth (cm)	Experiment 1				Experiment 2			
	Treat. 1	Treat. 2	Treat. 3	Treat. 4	Treat. 1	Treat. 2	Treat. 3	Treat. 4
3.50	400.50	419.10	625.50	690.60	133.35	119.06	138.11	138.11
7.00	328.60	328.60	466.70	528.60	557.21	481.01	585.79	685.80
10.50	400.50	419.10	657.20	719.10	638.17	661.99	971.55	957.26
14.00	581.00	619.10	1190.60	1104.90	814.38	804.86	190.60	1038.20
17.50	638.20	714.40	1095.40	1062.00	852.49	847.72	1395.40	1033.50
21.00	581.00	619.10	1190.60	1104.90	933.45	947.74	1333.50	1052.50
24.50	638.20	714.40	1095.40	1062.00	1071.60	966.79	1566.90	1357.30
28.00	1976.40	1900.20	2224.10	2243.10	1404.90	1214.40	2071.60	1676.40
31.50	2138.40	1986.00	2286.00	2238.40	2195.50	2100.00	2595.60	1895.50
35.00	1976.40	1900.20	2224.10	2243.10	2433.60	2376.50	2695.60	2005.00
38.50	2138.40	1986.00	2286.00	2238.40	2647.90	2533.60	2705.10	1938.30
42.00	2147.90	2243.10	2338.40	2347.90	2714.60	2543.20	2571.70	2090.70
45.50	2190.70	2214.60	2409.80	2386.00	2657.50	2509.80	2738.40	2095.50
49.00	2147.90	2247.90	2328.90	2347.90	2838.40	2528.90	2895.60	2128.80
52.5	2190.70	2228.80	2419.30	2386.00	2909.90	2643.20	3086.10	2286.00

cm= centimetre; Treat. 1 = Treatment 1; Treat. 2 = Treatment 2; Treat. 3 = Treatment 3; Treat. 4 = Treatment 4

Table III. Effect of different tillage treatments on seed germination rate (seeds m-2) and plant population density (plants m-2) averaged over study period during experiment 1

Treatments	Days after sowing								
	8	9	12	15	19	23	33	47	Avg. Ppd m-2
T1	87	42	6	5	3	2	1	0	242
T2	79	44	6	4	3	2	1	0	228
T3	76	39	7	3	2	2	1	0	219
T4	113	46	8	5	4	2	1	0	307

Trts. = Treatments; Seeds m-2 = Seeds per square meter; Plants m-2 = Plants per square meter; Avg. Ppd m-2 = Average Plant population per square meter.

Table IV. Effect of different tillage treatments on seed germination rate (seeds m-2) and plant population density (plants m-2) averaged over study period during experiment 2

Treatments	Days after sowing								
	8	9	12	15	19	23	33	47	Avg. Ppd m-2
T1	115	23	18	5	3	2	1	0	333
T2	117	15	16	5	3	2	1	0	315
T3	115	15	15	5	4	2	1	0	318
T4	116	14	15	6	4	2	1	0	309

Trts. = Treatments; Seeds m-2 = Seeds per square meter; Plants m-2 = Plants per square meter; Avg. Ppd m-2 = Average Plant population per square meter.

During experiment 2 greater plant population density for treatment 1 than all other treatments is associated with per cent seed emergence of the total seed sown which was 92, 86, 88 and 86% for treatments 1, 2, 3 and 4, respectively (Table IV). The greater seed emergence at each date for treatments 2 and 4 than treatments 1 and 3 (Table IV) can be attributed to greater seed moisture uptake inspite of the fact that plant population density was greater for treatment 1. During experiment 2, one week early sowing delayed seedling emergence by one week but germination was maximum after 25 days (Table IV). This partly confirms the results forwarded by Edwards (1958) who found that sowing time did not have much effect on time of emergence and percentage of emergence. But it partly contradicts the results presented by Braunack and Dexter (1988) that early sowing date resulted in less time to emerge and higher percentage of emergence.

Crop yield. Although crop yield was greater under treatment 2 than under treatments 1, 3 and 4 but this difference was not significant (Table V). This is in line with the results reported by Chaney *et al.* (1985) on sandy clay loam that mean grain yields of spring barley were marginally low after direct drilling than after shallow conventional ploughing. In another study, Carter and Rannie (1985) pointed out that the areas in which soil moisture is a constraint for plant zero tillage has produced crop yield similar to conventional tillage. Greater crop yield for treatment 2 than 1 and similarly for treatment 4 than 3 can be associated with the tine cultivator used as a secondary tillage implement, which might have increased continuity of pore spaces, which can be affected by compaction caused by bearing area of the disk harrow. Therefore, greater yield for treatments in which tine cultivator is used as secondary tillage implement can be associated with appropriate seedbed/rootbed formation and improved soil structure.

During experiment 2 significantly greater crop yield under treatments 1 and 2 than under treatments 3 and 4 (Table V) may be associated with greater soil moisture content after winter through out crop growth period before harvesting (Khan *et al.,* 1999). Greater crop yield for treatment 2 as compared to treatments 1 and 4 as compared to treatment 3 can be associated to the effect of tine cultivator used as a secondary tillage implement that might have affected soil pores continuity and soil penetrability. The greater crop yield of treatments in which tine cultivator is used as secondary tillage implement can be associated with appropriate seedbed/rootbed and improved soil structure.

Table V. Crop yield (grains + Straw) ton ha^{-1} during experiment 1 and 2

Treatments	Experiment 1 Crop yield (ton ha^{-1})		Experiment 2 Crop yield (ton ha^{-1})	
	Grains	Straw	Grains	Straw
T1	7.83	11.37	7.16	9.20
T2	8.04	12.42	7.49	9.51
T3	7.83	12.79	6.46	7.29
T4	7.95	12.90	6.67	8.22

ha = hectare

CONCLUSION

1. Penetration resistance of soil varies directly with bulk density and inversely with soil moisture content.
2. Penetration resistance adversely affect the seed emergence and crop growth.
3. Mouldboard plough followed by two passes of tine cultivator have found to be more appropriate and profitable tillage treatment in improving soil surface conditions.

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