Assessment of soil compaction due to the motion of prime mover and tillage machinery in temperate region of Kashmir Valley

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Abstract: The study was undertaken to assess the impact of prime movers (40 hp and 50 hp) and agricultural machinery (cultivator, disc harrow and rotavator) on soil compaction. Initially, the prime movers were operated at three speeds (2 kmh^{-1}, 3 kmh^{-1} and 5 kmh^{-1}) for 1, 2 and 3 passes and responses were measured in terms of bulk density (g cm^{-3}), particle density (g cm^{-3}), porosity (%), cone index (kPa), infiltration rate (cm h^{-1}), hydraulic conductivity (cm h^{-1}) and particle size distribution (mm). The experiments were planned as per Randomized Block Design (RBD). It was observed that bulk density, particle density and cone index increased with an increase in the number of passes from 1 to 3. Maximum percentage increase of 5.82% bulk density, 2.78% particle density and 26.96% cone index from the initial values were observed in the operation of 50 hp tractor without implement. The infiltration rate showed a decrease of 1.08% and 1.5% after 1 pass for 40 and 50 hp tractor, respectively. Mass mean diameter (MMD) of soil decreased with the increase in the number of passes from 1 to 3 and the maximum decrease of 11.24% was recorded during operation of 50 hp tractor. In the next phase, three secondary tillage implements viz. cultivator, disc harrow and rotavator were attached with the 50 hp prime mover at three different inflation pressure (0.8 kg cm^{-2}, 1.2 kg cm^{-2}, 1.5 kg cm^{-2}) for 1, 2 and 3 passes, respectively. It was observed that the bulk density decreased by 27.57% for cultivator, 29.87% disc harrow and 30.20% rotavator. The cone index decreased with number of passes for all the implements and the maximum value of 36% was associated with rotavator. About 45% increase in infiltration rate, 25% hydraulic conductivity and 37.70% decrease in mean mass diameter (MMD) was recorded with the operation of rotavator after three passes.

Keywords: compaction, machinery, inflation pressure, rotavator, cone index

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1 Introduction

Soil compaction is a multifaceted intricate phenomenon between soil, crop, weather and machinery with its close association in the bolstering of bulk density and waning of porosity (Alakukku, 2012) resulting in degradation of soil structure (Pagliai et al., 2003). The induced stress, internal or external, results into the densification as air is displaced from the pores between the soil particles. The external pressure, inappropriate soil cultivation and management practices often culminates into compaction of subsoil, resulting in the formation of impermeable layers within the soil, that restrict water and nutrient cycle. Mechanically, soil compaction and degradation mainly occur due to the increased mass of prime mower powered agricultural machineries, overuse of machinery system (Vitlox and Loyen, 2002) intensification of the mechanized agriculture and improper crop rotation practices (Tenu et al., 2012). The interactive effect of physical and mechanical properties: soil structure, wheeling, number

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of passes and farming practices has direct impact on structure of tilled soil and soil water status (Hamza and Anderson, 2005). This process has the propensity to cause on-site effects such as reduced crop growth, plummeting yield, low quality as well as off-site effects such as increased surface run-off, escalating soil erosion, emission of greenhouse gases, eutrophication, abridgement in ground water recharge and a loss of biodiversity (Batey et al., 2009).

With the advancement in socio-economic status of the farmers and the thrust to utilize heavier machinery after consolidating the land, the vulnerability towards soil compaction has increased (Bhattacharyya et al., 2015). The unplanned and irregular traffic results in the generation of rutted soil surface and trampled spots at different field locations (Shen et al., 2000). The top layer of the soil is primarily affected by the vehicular traffic. When a tractor is driven on the soil surface, the induced stress is transmitted to the lower layers through particle to particle contact (Figure 1). The intensity of the compaction depends on the contact pressure between the wheels and the soil surface and the level of the interaction is governed by the soil moisture content (Berisso et al., 2012). The inflation pressure of tyre and number of passes of agricultural machinery over same area has substantial effect on increasing soil compaction (Jarosław et al., 2005; Chehaibi et al., 2012; Botta et al., 2009). Moreover, the compacted layer with soil strength more than 1 MPa imposes limitation to the root expansion and influences yield level (Tsegaye and Mullins, 1994).

In agricultural perspective, soil compaction modifies the surrounding environment of the crop and is considered as ‘costliest and most serious environmental problem caused by conventional agriculture’ adversely impacting physical, chemical and biological properties and inducing a limitation on the functional ability of the soil (FAO, 2003; Patel et al., 2011). This results in the reduction in water infiltration, water holding capacity, runoff, erosion, crop yield and profitability of farming system (Hamza et al., 2005). The reduction in water permeability provokes water stress that interferes with the metabolic activities of the plants. Soil compaction also induces preferential flow in macro pores, responsible for colloid transport of immobile pollutants such as phosphorus and pesticides to the water bodies (Jarvis et al., 2007). This reduces the saturated hydraulic conductivity, triggering surface runoff and water erosion (Alexander et al., 2010). The ultimate impact of the soil compaction is manifested through curbs on root growth and inhibition of plant development, directly or indirectly, contributing to the reduction in the agricultural production (Sivarajan et al., 2018). Highly compacted soil, particularly in the surface layers, generates inadequate soil physical conditions for the emergence of the seedling, thereby, impacting the crop yield (Botta et al., 2010).

Soil compaction enhances harmful physical, chemical and biological processes, which in the context of inappropriate soil management leads to soil degradation. The movement of the agricultural machinery induces mechanical strength and stiffness to the soil, which is directly correlated with the energy consumption. The increase in energy consumption induces a limitation to the farmer’s budget in terms of number of passes of agricultural machinery. Therefore, it is imperative to understand the soil dynamics to determine the optimum number of passes required to prepare the soil for cultivation. Moreover, soil stiffness enhances the friction forces, fuel consumption and emissions from the engine, directly contributing to anthropogenic global climate change. Soil compaction also affects the amounts of fertilizer and energy used in crop production, which may have additional adverse environmental consequences (Holland et al., 2004). The parameters that define the ability of the soil compaction to influence crop growth are illustrated in terms of aeration, bulk density and cone index (Mansonia et al., 2019). The critical visual indicator of topsoil compaction is rut depth, usually affected by the movement of agricultural tractor (prime mover) and machinery traffic on the soil. The rut depth is related with initial soil condition, inflation pressure, tyre width and number of passes of agricultural machinery (Botta et al., 2010).

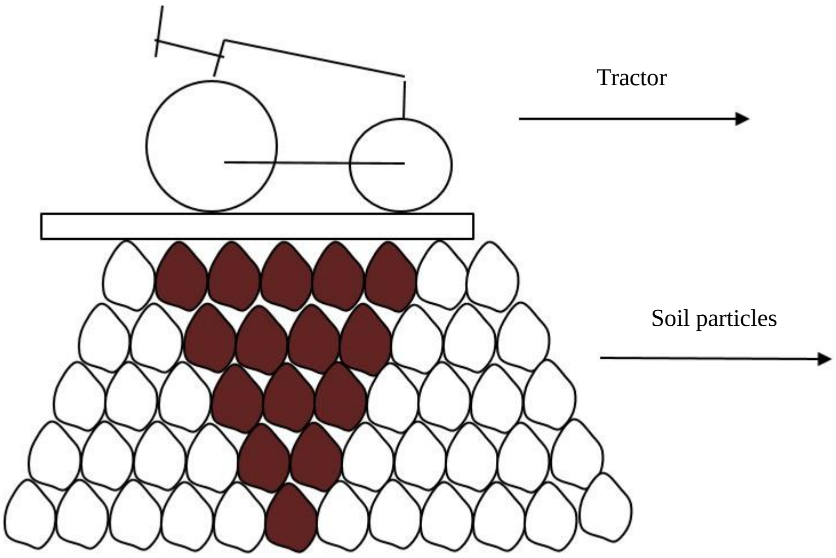


Figure 1 Stress transmission through granular material (soil)

2 Material and methods

2.1 Selection of prime movers

A trial of preliminary experiments was carried out to understand the dynamics and select the relevant parameters influencing the soil compaction. Most commonly used prime movers (40 hp and 50 hp) were identified and selected through a survey of different villages, Plate 1. The individual specifications of prime movers were measured and compared with the specification list provided by the manufacturer, Table 1.

Figure 1 Prime movers (40 hp and 50 hp) used for the investigation of soil compaction

2.2 Selection of the experimental plots

The experimental plots were selected on the basis of their usage throughout the year. The idea was to assess the soil compaction on the fields, which were used regularly to cultivate the crops. Two plots were selected from the main campus of Sher-e-Kashmir University of Agricultural Science and Technology (SKUAST-K), Shalimar. The initial properties in terms of bulk density, particle density, porosity, cone index, particle size, infiltration rate and hydraulic conductivity were measured, Table 2. The moisture content of experimental plots ranged from 12-15 percent.

2.3 Plan of experiment for the assessment of prime movers

The experiments were laid as per the plan of experiment with three variables: capacity of prime mover, speed of operation and number of passes and seven response parameters: bulk density (g cm^{-3}), particle density (g cm^{-3}), porosity (%), cone index (kPa), hydraulic conductivity (cm mm^{-1}), infiltration rate (cm h^{-1}) and particle size distribution (mm), Table 3.

Table 1 Specifications of the selected prime movers

Parameter	40 hp (PM_1)	50 hp (PM_2)
Brake Power, hp	40	50
Weight, kg	1810	2110
Wheel base, mm	1970	2050
Length, mm	3410	3535
Width, mm	1810	1850
Front tyre Size, mm	(150 x 410), 8PR	(170x 510), 8PR
Rear tyre Size, mm	(340 x 710), 12PR	(430 x710), 12PR
Ground clearance, mm	415	435
Fuel tank capacity, L	60	68
Turning radius with brakes, mm	2900	3150
Maximum lifting capacity, kgf	1600	2000
3 Point linkage	Automatic depth and draft control (ADDC)	Automatic depth and draft control (ADDC)
Steering type	Power	Fixed column-Power
RPM	2100	2400
Cylinders	3	3
Brakes	Oil immersed disc brakes	Hydraulically actuated, oil immersed disc brakes

Table 2 Initial soil properties of different plots

Soil Properties	Plot 1 (SKUAST-K)	Plot 2 (SKUAST-K)
Bulk density, g cm^{-3}	1.46	1.40
Particle density, g cm^{-3}	2.66	2.51
Porosity,%	45.01	45.54
Cone index, kPa	1390	1215
Particle size, mm	14.75	16.90
Infiltration Rate, cm h^{-1}	1.87	1.93
Hydraulic Conductivity, cm min^{-1}	0.0284	0.0296
Area, ha	0.156	0.143

Table 3 Experimental variables in the study

Variables	Levels	Responses
Prime mover	2 (40 hp, 50 hp)	Bulk density (g cm^{-3}) Particle density (g cm^{-3})
Speed of operation/ forward speed of tractor	3 (2 kmh^{-1}, 3 kmh^{-1}, 5 kmh^{-1})	Porosity (%) Cone index (kPa)
Number of passes	3 (1 pass, 2 passes, 3 passes)	Infiltration rate (cm h^{-1}) Hydraulic conductivity(cm min^{-1}) Particle size distribution (mm)

2.4 Measurement of response parameters

The selection of the response parameters plays a crucial role in providing a clear picture of the problem. The response parameters were selected on the basis of the magnitude, relevance and feasibility. The parameter of bulk density, particle density, porosity, infiltration rate and hydraulic conductivity are essential to quantify the soil compaction (Chaney et al., 1985).

2.4.1 Bulk density (g cm^{-3})

Soil bulk density represents the mass of the entity per unit volume and serves as an indicator of soil structure and void space. It was determined by core sampling method with length 13.5 cm and diameter 8 cm (Ruehlmann and Korschens, 2009).

2.4.2 Particle density (g cm^{-3})

Soil particle density is defined as the ratio of mass (oven-dry weight) to the particle volume with no pore space, expressed in gram per cubic centimetre. The particle density was measured with pycnometer method (Blake and Hartge, 1986). This method relies on the fact that the volume of soil can be determined by measuring the volume of the water displaced by the particles.

$$\rho_s = W(pw) + 10 - W(pws) \quad (1)$$

W(pw) = weight of Pycnometer with water

W(pws) = weight of Pycnometer with water and solids

2.4.3 Porosity (%)

Soil porosity refers to the amount of pores or open space, between soil particles. Pore spaces may be formed due to the movement of roots, worms, and insects; expanding gases trapped within these spaces by groundwater or the dissolution of the soil parent material. Soil texture, the relative proportion of sand, silt and clay, can also affect soil porosity. The porosity (ϕ) of soil was calculated on the basis of bulk density (ρ_b) and particle density (ρ_s) (Leeds et al., 1999).

$$\emptyset = (1 - \frac{\rho_b}{\rho_s}) \times 100 \quad (2)$$

2.4.4 Cone index (kPa)

Cone index is the measure of soil penetration resistance, essential to determine the soil compaction. The cone index of soil was measured with help of a digital cone penetrometer. The penetrometer consists of a digital display, handle, push rod and a conical tip with apex angle of 30°.

2.4.5 Infiltration rate (cm h^{-1})

The infiltration rate is the velocity or speed at which water enters into the soil. Soil infiltration refers to the soil's ability to allow water movement into and through the soil profile. It represents the depth (cm) of the water layer that can enter the soil. The infiltration rate of soil was measured with the help of mini-disc Infiltrometer.

2.4.6 Saturated hydraulic conductivity (cm min^{-1})

Saturated hydraulic conductivity is one of the most significant elements overseeing fluid transmission in unsaturated soils (Rawls et al., 1982). Hydraulic conductivity is the proportion of the capacity of a soil to direct water under a unit water hydraulic potential gradient.

2.4.7 Particle size / Mean mass diameter (mm)

A sieve analysis (or gradation test) procedure was used to assess the particle size distribution (mean mass diameter) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is retained on each sieve as a fraction of the whole mass (Table 4).

$$MMD = \frac{1}{W}(A + 2.4B + 3.4C + 4.8D + 6.8E + XF) \quad (3)$$

Table 4 Mean mass diameter (MMD) through sieve analysis

Size of aperture (mm)	Diameter of soil passing the upper sieve and retained on the next small aperture sieve (mm)	Representative dia. of soil (mm)	Weight of soil (Kg)
2	Less than 2	1	A
2.8	2 - 2.8	2.4	B
4.0	2.8 – 4.0	3.4	C
5.6	4.0 – 5.6	4.8	D
8.0	5.6 – 8.0	6.8	E
11.2	8.0 – 11.2	-	F

2.5 Statistical analysis

The analysis of the data was carried out with the help of R-software to assess the significant differences of treatment combinations between bulk density, particle density, porosity, cone index, infiltration rate, hydraulic conductivity and mean mass diameter of soil particles. It was also used to understand the role of tillage implements, inflation pressure, number of passes and their interactive effect on soil compaction. The results were analysed through RBD design at 5% level of significance. The critical difference (CD) value of the experiments was used to compare different treatment combinations.

3 Result and discussion

3.1 Effect of forward speed and number of passes on bulk density (g cm^{-3}) of soil

The bulk density decreased with the increase in forward speed and number of passes, Figure 2. The initial mean bulk density of plot 1 with an area of 0.156 ha was recorded as 1.46 g cm^{-3}. In plot 1, when the forward speed of 40 hp tractor was kept at 2 kmh^{-1}, the bulk density increased from 1.493 to 1.538 g cm^{-3} as the number of passes increased from 1 to 3. However, the bulk density decreased from 1.493 g cm^{-3} to 1.48 g cm^{-3} with increase in speed from 2 kmh^{-1} to 5 kmh^{-1}. When the speed was further increased to 3 kmh^{-1}, there was an increase of 1.54% in bulk density from 1 to 3 passes. When the speed was further increased to 5 kmh^{-1}, the bulk density increased from 1.48 to 1.508 g cm^{-3} in the same manner.

In plot 2, the movement of 50 hp 2.11 tonne tractor at 2 kmh^{-1} increased the bulk density from 1.44 to 1.48 g cm^{-3}, 2.77 percentage change from the initial value. When the speed was further increased to 3 kmh^{-1}, the bulk density increased proportionally to 1.472 g cm^{-3} as the passes were increased from 1 to 3. At 5 kmh^{-1}, the interaction of the tyre and soil caused an increase in bulk density from 1.424 to 1.455 g cm^{-3} with increase in passes from 1 to 3. It was also observed that the maximum change of 5.7% in the bulk density occurred in plot 2. This may be attributed to the passage of 2.11 tonne 50 hp tractor that resulted in the compaction of the soil layers. Therefore, it was observed that the bulk density increased with an increase in tractor horse power (weight) and number of tractor passes. The effect of all the variables viz., weight of prime mover, forward speed and number of passes were significant ($P \leq 0.05$), as the difference between two treatment levels was higher than CD value, Table 5.

3.2 Effect of forward speed and number of passes on particle density of soil (g cm^{-3})

The particle density represents the density of the soil mass without void space. It was observed that the particle density decreased with the increase in forward speed and number of passes, Figure 3. In Plot 1, the initial particle density of 2.66 g cm^{-3} increased to 2.734 g cm^{-3} as the number of passes of 40 hp tractor operated at 2 kmh^{-1} was increased from 1 to 3. It is pertinent to mention that the particle density decreased from 2.691 to 2.675 g cm^{-3} with increase in speed from 2 kmh^{-1} to 5 kmh^{-1}. The increase in the particle density at lower speed was mainly due to more time of contact between the traction device (tyre) and soil. At higher speed of 5 kmh^{-1}, the particle density increased from 2.675 g cm^{-3} to 2.714 g cm^{-3} for 1 to 3 passes. In plot 2, the initial particle density was measured as 2.51 g cm^{-3}. When the 50 hp 2.11 tonne tractor was operated at 2 kmh^{-1}, the particle density increased from 2.554 g cm^{-3} to 2.573 g cm^{-3} as the passes were increased from 1 to 3. The results showed a clear relation between the particle density, forward speed and number of passes. It was observed that the effect of number of passes and weight of prime mover were found to be significant ($P \leq 0.05$), as the difference between two treatment levels was greater than CD value, Table 5.

3.3 Variation in porosity (%) due to the treatment combinations

The porosity of the soil represents the gap between the bulk density and particle density. The porosity of the sol increased with an increase in forward speed of prime mover and decreased with the increase in number of passes, Figure 4. The initial porosity of soil in plot 1was recorded as 45.01%. The porosity increased from 44.51% to 44.66%, when the speed of the 40 hp tractor capacity increased from 2 kmh^{-1} to 5 kmh^{-1} within a single pass. But, the porosity decreased from 44.51% to 43.68% as number of passes was increased from 1 to 3. This may be due to higher pressure induced at repeated intervals, resulting in displacement of void space and compaction of soil particles. In plot 2, the movement of 50 hp tractor at 2 kmh$_{-1}$ resulted in an increase in porosity from 43.6% to 43.83% within a single pass. A similar trend was also observed in plot 1 at 2 kmh^{-1}. When the speed was increased from 2 kmh^{-1} to 5 kmh^{-1}, the porosity reduced from 43.83% to 42.58% with the increase in passes from 1 to 3. It was observed that the effect of all the variables viz., number of passes, forward speed of prime movers and weight of prime mover were significant ($P \leq 0.05$), as the difference between two treatment levels was greater than CD value, Table 5.

3.4 Effect of forward speed and number of passes on cone index (kPa)

The cone index is an essential parameter to determine the strength of the soil. It was measured with the help of cone penetrometer. The cone index showed indirect relation with the forward speed and direct relation with number of passes of prime mover, Figure 5. The cone index decreased from the initial value of 1467 kPa to 1420 kPa as the speed increased from 2 kmh^{-1} to 5 kmh^{-1} in single pass. When the passes were increased, a similar trend was observed. At 5 kmh^{-1}, the porosity increased from 1420 kPa to 1598 kPa as passes were increased from 1 to 3. In Plot 2, it was observed that the cone index increased from 1325 kPa to 1532 kPa at 2 kmh^{-1} as the number of passes was increased from 1 to 3. It was analyzed that more contact surface for long duration at lower speed induced higher load at lower layers. It was observed that the effect of all the variables viz., number of passes, forward speed of prime movers and weight of prime mover were significant. It was observed that the effect of all the variables viz., number of passes, forward speed of prime movers and weight of prime mover were significant (P≤0.05), as the difference between two treatment levels was greater than CD value, Table 5.

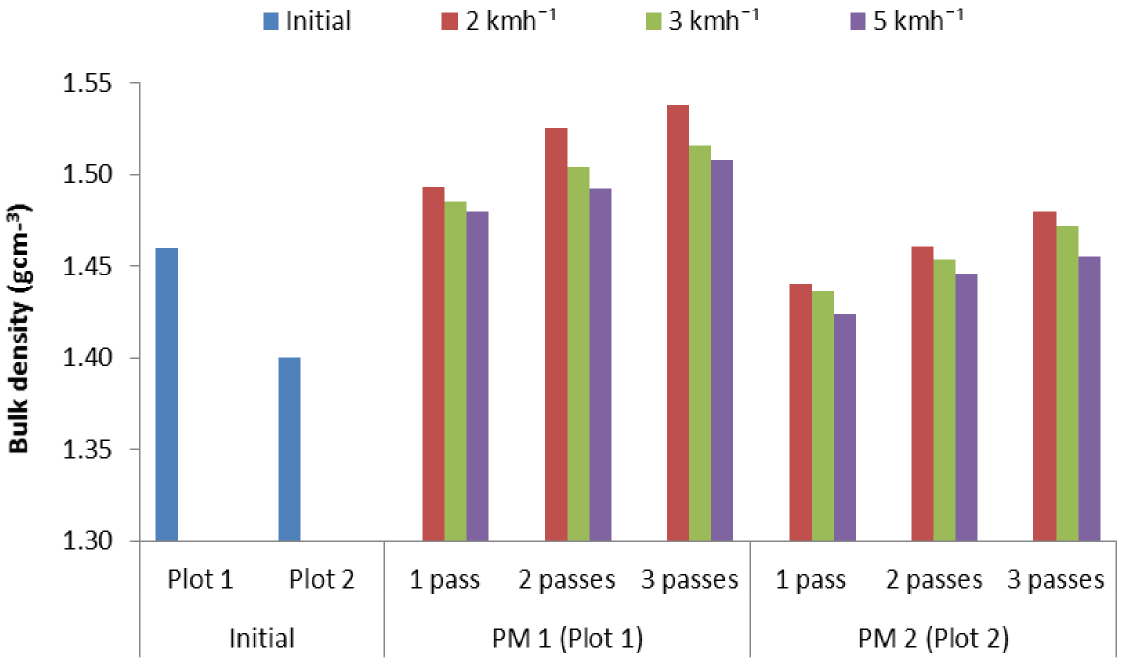
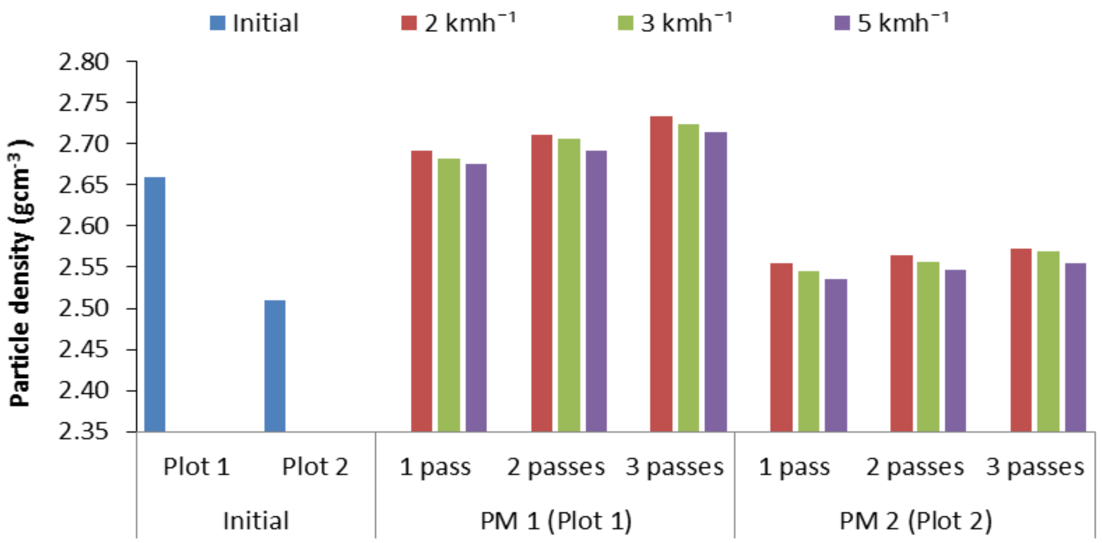


Figure 2 Effect of number of passes and forward speed of prime movers on bulk density



Where,

PM 1 = Prime mower 1 (Tractor 40 hp), PM 2 = Prime mower 2 (Tractor 50 hp)

Figure 3 Effect of number of passes and forward speed of prime movers on particle density

4.5 Change in infiltration rate with the forward speed and number of passes of prime movers

The movement of the agricultural prime movers and transport vehicles increases the soil strength and induces limitations in the flow of water through different layers. The impact of compaction on water flow was assessed with the measurement of infiltration rate. At the beginning of the experiment, the infiltration rate measured with disc infiltrometer was recorded as 1.87 cm h^{-1} for plot 1 and 1.93 cm h^{-1} for plot 2. The infiltration rate increased with an increase in forward speed and decreased with the increase in the number of passes, (Figure 6). The infiltration rate increased from 1.85 to 1.86, when forward speed was increased from 2 to 5 kmh^{-1} within a single pass. It was observed that number of passes presented a similar picture as that of a single pass. However, when a single forward speed was analyzed at different passes, it can be noticed that Infiltration rate decreased continuously. At 2 kmh^{-1}, the Infiltration rate decreased from 1.87 to 1.81 as the number of passes was increased from 1 to 3. The individual parameters as well as their interactive effects were significantly influencing the infiltration rate at 5% level of significance, as the different between two treatments was greater than CD values, Table 5.

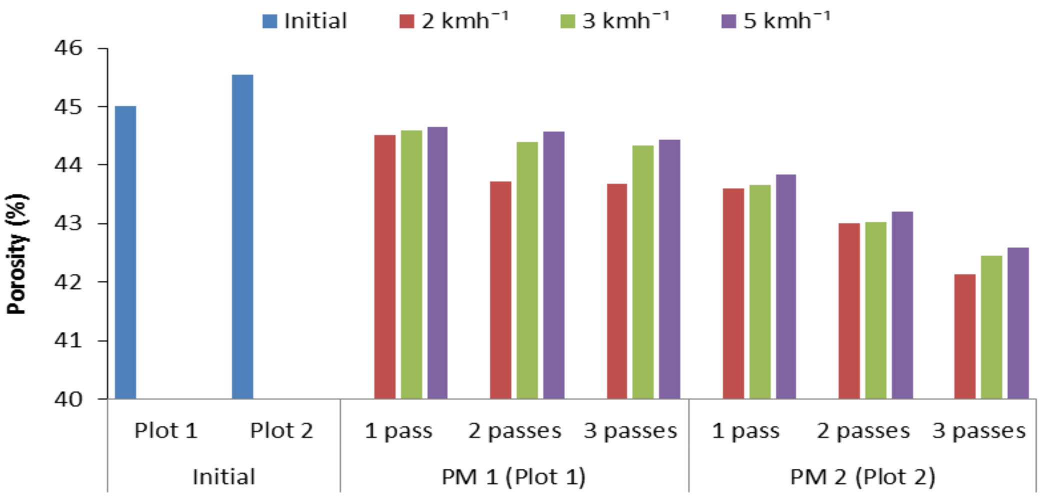
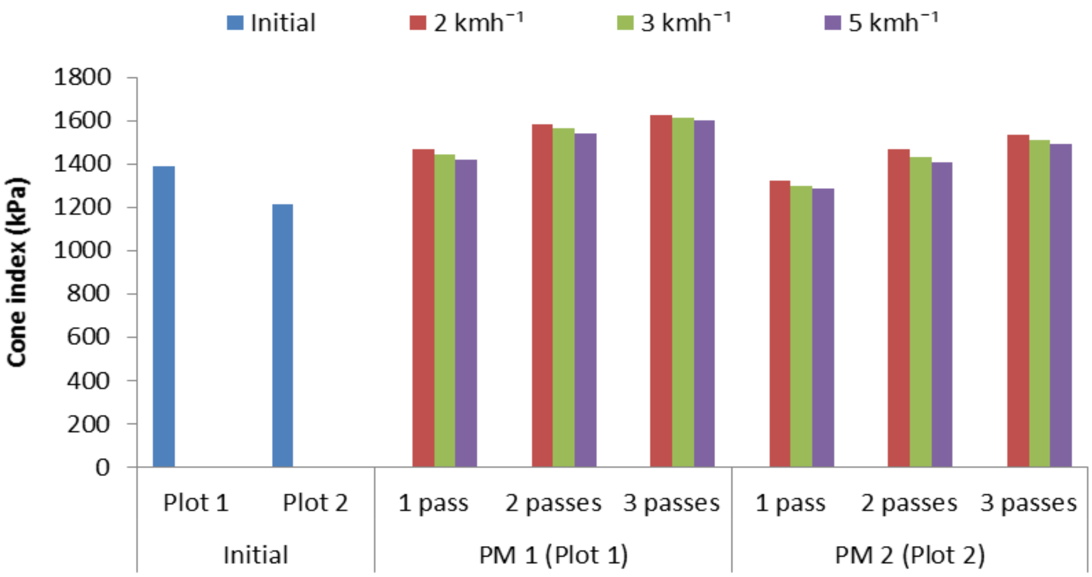


Figure 4 Effect of number of passes and forward speed of prime movers on porosity



Where,

PM 1 = Prime mower 1 (Tractor 40 hp), PM 2 = Prime mower 2 (Tractor 50 hp)

Figure 5 Effect of number of passes and forward speed of prime movers on cone index

4.6 Change in hydraulic conductivity (cm min^{-1}) due to forward speed and number of passes of prime movers

Hydraulic conductivity of soil is the indicator of free supply of water and air to the roots and influences the crop yield. The initial hydraulic conductivity of soil, as determined using mini disc infiltrometer was recorded as 0.02466 cm min^{-1} for plot 1 and 0.02567 cm-min^{-1} for plot 2. The hydraulic conductivity gradually decreased with increase in tractor horse power and number of tractor passes. However, for the similar pass it was observed that hydraulic conductivity increased with increase in forward speed of tractor (Figure 7). At forward speed of 2 kmh^{-1}, the hydraulic conductivity decreased from 0.0284 cm min^{-1} to 0.0228 cm h^{-1} as the number of passes increased from 1 to 3. A similar trend was observed with a forward speed of 3 kmh^{-1} and 5 kmh^{-1}. The parameters and the interactive effect were significantly influencing the hydraulic conductivity. It was observed that the effect of all the variables viz., number of passes, forward speed of prime movers and weight of prime mover were significant (P≤0.05), as the difference between two treatment levels was greater than CD value, Table 5.

4.7 Variation in soil structure through mean mass diameter

Mean mass diameter of soil particles was used to determine the average size of soil after compaction. The initial mean mass diameter of soil particles, as determined by the method of sieve analysis was recorded as 14.74 mm for plot 1 and 16.90 mm for plot 2. The mean mass diameter of soil particles decreased with increase in tractor horse power and number of tractor passes, while as it was observed that mean mass diameter of soil particles increased with increase in forward speed of tractor (Figure 8). At forward speed of 2 kmh^{-1}, the mean mass diameter decreased from 13.59 mm to 13.22 mm as the number of passes increased from 1 to 3. A similar trend was observed at a forward speed of 3 kmh^{-1}, where an increase in number of passes from 1 to 3 decreased the mean mass diameter values from 13.85mm to 13.22 mm and 4 kmh^{-1}. A similar trend was also observed for 4 kmh^{-1}. It was observed that the effect of all the variables viz., number of passes, forward speed of prime movers and weight of prime mover were significant (P≤0.05), as the difference between two treatment levels was greater than CD value, Table 5.

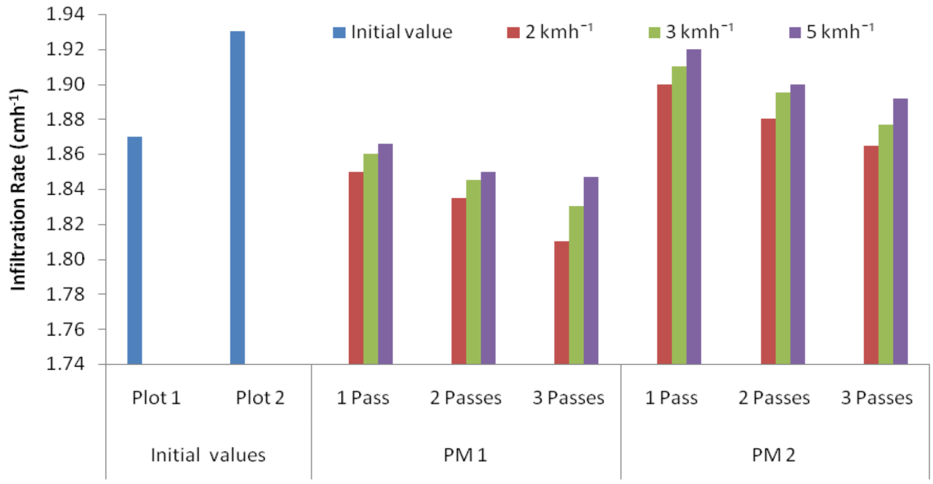
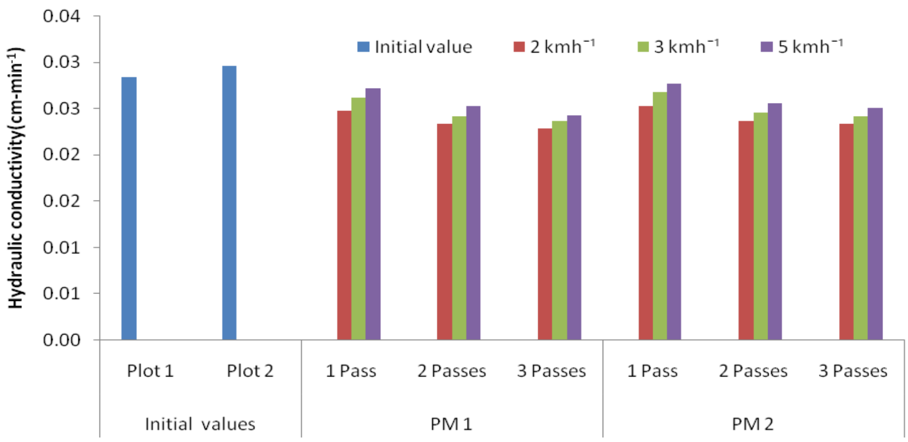


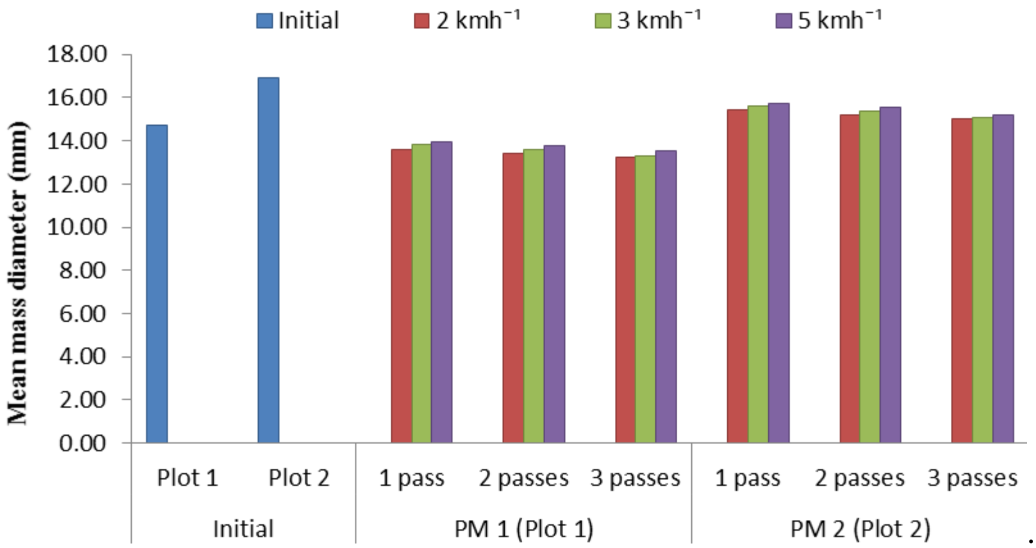
Figure 6 Effect of number of passes and forward speed of prime movers on infiltration rate



Where,

PM 1 = Prime mower 1 (Tractor 40 hp), PM 2 = Prime mower 2 (Tractor 50 hp)

Figure 7 Effect of number of passes and forward speed of prime movers on hydraulic conductivity



Where,

PM 1 = Prime mower 1 (Tractor 40 hp), PM 2 = Prime mower 2 (Tractor 50 hp)

Figure 8 Effect of number of passes and forward speed of prime movers on mean mass diameter of soil particles

Table 5 CD values of response parameters

CD value ($p \le 0.05$)	Bulk Density	Particle density	Porosity	Cone index	Infiltration rate	Hydraulic conductivity	Soil pulverization
Number of passes	0.0036	0.0021	0.013	1.227	0.004	0.0003	0.0187
Forward Speed	0.0036	0.0021	0.013	1.227	0.004	0.0003	0.0187
Prime Mover	0.0029	0.0017	0.011	1.002	0.003	0.0003	0.0152
Number of passes x Prime mover	0.0051	0.0030	0.019	1.735	0.006	0.0005	0.0264
Number of passes x Forward speed	0.0063	0.0037	0.024	2.125	0.008	0.0006	0.0324
Forward sped x Prime mover	0.0051	0.0030	0.019	1.735	0.006	0.0005	0.0264
Number of passes x Forward speed x Prime mover	0.0089	0.0053	0.033	3.006	0.001	0.0008	0.0458

5 Conclusion

The bulk density of soil increased with the increase in the number of passes, highest increase of 5.34% (1.46 g cm^{-3} – 1.53 g cm^{-3}) and 5.81% (1.40 g cm^{-3} – 1.48 g cm^{-3}) was found after 3rd pass for 40 and 50 hp tractor respectively. The particle density of soil increased with the increase in the number of passes with highest change of 2.50% at 2 kmph and 2.78% at 2 kmh^{-1} for 40 and 50 hp tractors respectively. The cone index of soil increased with the increase in the number of passes of Prime Mover with highest increase of 16.83% (1390 kPa – 1624 kPa) at 2 km h^{-1} and 26.69% (1215 kPa-1532 kPa) at 2 kmh^{-1} for 40 and 50 hp tractor respectively. Mean mass diameter (MMD) of soil decreased with number of passes from 1 to 3. The maximum decrease of 10.37% (14.75 mm – 13.22 mm) and 11.24% (16.90 mm – 15.00 mm) was found after 3 passes at 2 kmh^{-1} for 40 hp and 50 hp tractor, respectively. With the increase in the number of passes, infiltration rate witnessed a decreasing trend. The infiltration rate showed a decrease of 1.08% and 1.5% after 1 pass for 40 and 50 hp tractors respectively. Hydraulic conductivity decreased with the increase in number of passes. The hydraulic conductivity decreased by 1.2% at 2 km h^{-1} for 40 hp tractor and 1.9% at 2 km h^{-1} for 50 hp tractor for single pass. The bulk density at an inflation pressure of 0.8 kg cm^{-2} decreased by 27.57%, 29.87% and 30.20% with increase in number of passes from 1 to 3 for cultivator, disc harrow and rotavator, respectively. The particle density of soil decreased with increase in number of passes. The highest decrease occurred after three passes for rotavator (15.32%) followed by disc harrow (14.65%) and cultivator (13.46%). The mean mass diameter of soil was influenced by an increase in number of passes and inflation pressure. It decreased by 22%, 28.8% and 37.7% after three passes for cultivator, disc harrow and rotavator, respectively. Cone Index of soil decreased with the use of implements with highest reduction for rotavator (36%) followed by disc harrow (31%) and cultivator (29%) after three passes and 0.8 kg cm^{-2} inflation pressure respectively. Infiltration rate was found to be increasing by (45%) with use of rotavator followed by disc harrow (25%) and cultivator (21%) after 3 passes. Hydraulic conductivity increased with the increase in the number of passes with maximum change in rotavator (25%) followed by disc harrow (20%) and cultivator (15.54%), respectively.

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Conflict of interest

The author’s express that no conflict of interest exists.

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