

Tillage Effects on Bulk Density, Hydraulic Conductivity and Strength of Vertisol in Central India

Avinash Kumar Gautam, Atul K. Shrivastava,
Nokelal Mehra, Abhay Sinha

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Abstract This study was to conduct an enquiry into the effects of different tillage operations on bulk density, hydraulic conductivity and strength properties of a vertisol (clay loam) soil of central India. A replicated randomized complete block design with treatments consisting of (i) T_1 (m. b. plough x1 + cultivator x1 + disc harrow x1) (ii) T_2 (m. b. plough x1 + cultivator x2 + disc harrow x1) (iii) T_3 (cultivator x2 + disc harrow x1 and (iv) T_4 (no-tillage) operations established was used for the study. The soil bulk density, cone index of penetrometer resistance, hydraulic conductivity and moisture content retention characteristics were determined for each of the treatments. The cone penetration resistance was determined at the depths of 5, 10 and 15 cm while the soil moisture content (0–15 cm) soil. The soil parameters were determined monthly over a period of 0, 30, 60 and 90 days after tillage operations. All the tillage operation were noteworthy

different in their effects on soil bulk density and was in the pass down order of $T_4 > T_3 > T_2 > T_1$. The soil bulk density decreased with the degree of soil manipulation during tillage practices, with no-tillage (T_4) having the highest (1.66 g/cc) and T_1 having the least (1.39 g/cc). The soil bulk density also increased with increase in time after cultivation. The soil bearing strength of soil was consistent with bulk density data, with no-tillage also having the highest bearing strength of 745 kPa at 90 days after tillage. Soil hydraulic conductivity at 0, 30, 60 and 90 days after tillage decreased with increased intensity of soil manipulation by tillage. The highest conductivity was recorded under T_1 (3.8×10^{-4} m/s) and the least under no-tillage (1.0×10^{-4} m/s) at 0 days of after tillage operations.

Keywords Tillage, Bulk density, Moisture content, Bearing strength, Hydraulic conductivity invertisol.

Introduction

Reduction of labor requirements has been the principal motivating force in agricultural mechanization. The application of machines to agricultural production has been one of the out standing developments in the developed countries. The expanding population of these countries has required and will continue to demand an ever-increasing agricultural

A. K. Gautam*, A. K. Shrivastava, N. Mehra, A. Sinha
Department of Farm Machinery and Power Engineering,
College of Agricultural Engineering, JNKVV, Jabalpur, MP,
India
e-mail: avipavan75@gmail.com
*Correspondence

production of feeds and fibers. The application of machines to agricultural production did not only reduce burden and drudgery of farm work, but also increased the output per worker. Tillage operation is the mechanical manipulation of soil to develop a desirable soil structure for a seedbed and to establish specific surface configuration for planting, irrigation, drainage, harvesting operations [1]. Tillage operation is also concerned in many ways with the adjustment of the soil moisture content to meet the needs of the crop [2]. The cumulative effect of tillage operations on soils leads to soil loosening. The degree of loosening may depend upon the soil type, soil moisture content and the type of tillage operation. Some physical properties of soil that may be affected by loosening include bulk density, soil strength, infiltration capacity, water redistribution within the soil and the moisture retention. Soil parameters that are adversely affected by compaction or loosening of soil particles are those that control the content and transmission of water, air, heat and nutrients. Soil dry bulk density and penetration resistance increased with increase in the number of traffic passes while air permeability has been found to decrease with increase traffic intensity. Conservation tillage practices have gained considerable support by merit of their erosion control capabilities. Yield potential of different conservation tillage practices is site specific [3]. They found that conservation tillage has a lower yield relative to conventional tillage practice on poorly drained, cool soils. On well-drained sites, where moisture is in short supply, conservation tillage treatments produced higher yields. When three conservation tillage systems: chisel ploughing, till-plant and no-tillage were compared to conventional mouldboard ploughing, soil moisture advantages with conservation tillage vary. Soil moisture was higher and less water was removed from the 0.5-1.0 m zone in the no-tillage treatment. In a study, full chisel ploughing was found to double the infiltration rate over fall mouldboard ploughing. Variety of conservation tillage systems and found them all to increase water intake [4]. Disturbed soils, as in sieved and repacked samples have higher water retention capacities at a given water potentials than undisturbed soils. The objective of this study therefore, is to investigate the effect of different tillage methods on some physical properties of a loamy sand soil and its implication to agricultural production.

Materials and Methods

Teaching and Research Farm, Jawahar Lal Nehru Krishi Viswavidalaya, India was used for the study. Total annual rainfall of the study area is range 1000 to 1500 mm. The average daily minimum temperature ranged between 20°C and 22°C and the average maximum temperature between 27°C and 35°C. The texture of the plough layer (0–15 cm) clay (54.75%), silt (20.15%) and other (25.10%).

An experimental plot consisting of four treatments and three replicates was laid out in randomized complete block design. The treatments consisted of 4 tillage methods as given below: T_1 = M.B. plough x1+cultivator x1+disc harrow x1 (Conventional tillage), T_2 = M. B. plough x1 + cultivator x2+ disc harrow x1, T_3 = Cultivator x2 + disc harrow x1, T_4 = No-tillage.

The maximum depth of tillage was maintained at 15 cm five undisturbed soil samples per replicate treatment were collected randomly from the upper (0–15 cm) layer of the soil for laboratory using 50 mm × 54 mm cylindrical cores. The samples were collected a day after the treatments were applied and at monthly intervals there after until the 0, 30, 60 and 90 days. Penetration resistance of the plots was taken immediately after tillage operations with the use of a hand-held cone penetrometer to depths of 5, 10 and 15 cm and at weekly intervals thereafter 0, 30, 60 and 90 days (3 months). The hydraulic conductivity was measured by using a falling head method at the depth of 15 cm.

Results and Discussion

Table 1 shows the MMD and bulk density of after each tillage operation. The MMD, bulk density and cone index was decreased after each operation of implement.

Bulk density

The Figure 1 shows the bulk density of soil for different treatments. It is evident from the Figure 1 that the maximum bulk density (1.66 g/cc) was found for T_1 and lowest was 1.39 g/cc for T_1 treatment. There was virtually no change in bulk density after tillage as

Table 1. Soil pulverization for different treatments.

| Sl. No. | Treatments | Soil pulverization (mm) | | | |
|---------|----------------|-------------------------|----------------------------|----------------------------|-------------------|
| | | After M. B. plough | After 1 st pass | After 2 nd pass | After disc harrow |
| 1. | T ₁ | 12.59 | 11.75 | 0 | 9.73 |
| 2. | T ₂ | 12.89 | 11.97 | 10.56 | 8.19 |
| 3. | T ₃ | 0 | 13.76 | 12.95 | 11.23 |
| 4. | T ₄ | 0 | 0 | 0 | 0 |

using this machine only a slit is formed in the field and there is no disturbance of soil. The bulk density

increased with time after tillage for all tillage treatments as the soil gradually get compacted under the

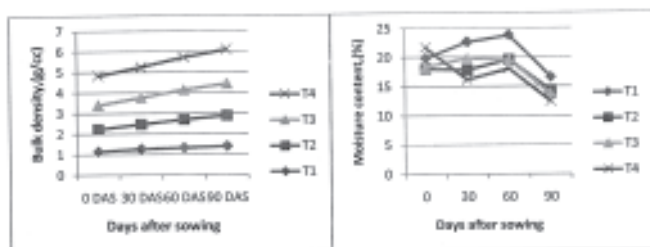


Fig.1 Bulk density at 0-150 mm for different treatments Fig.2 Moisture content of soil for different treatments

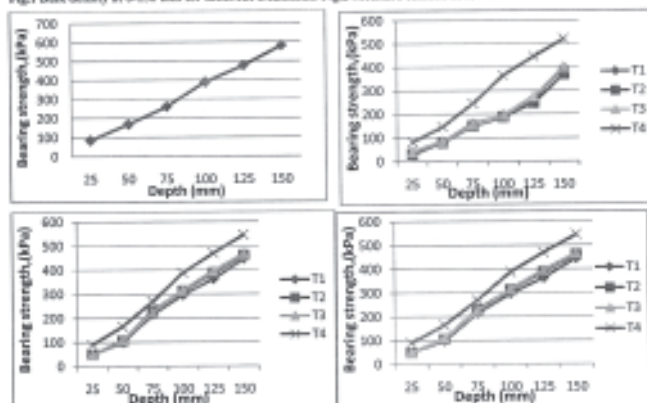


Fig. 3. Bearing strength of soil at depths of (a) Before tillage (b) 30 days (c) 60 days (d) 90 Days in response to different tillage methods

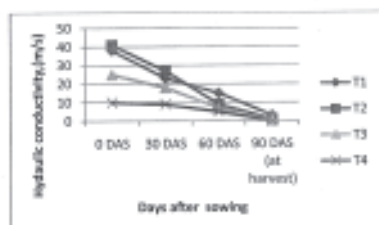


Fig. 4. Hydraulic conductivity (x 10⁻⁵ m/s) of soil for different treatments

Fig. 1. Bulk density at 0-150 mm for different treatments. **Fig. 2.** Moisture content of soil for different treatments. **Fig. 3.** Bearing strength of soil at depths of (a) Before tillage (b) 30 days (c) 60 days (d) 90 Days in response to different tillage methods. **Fig. 4.** Hydraulic conductivity (x 10⁻⁵ m/s) of soil for different treatments.

Table 2. Bulk density for different tillage treatments.

| Sl. No. | Treatments | Before tillage | Bulk density (g/cc) | | | After disc harrow x1 |
|---------|----------------|----------------|----------------------|---------------------------------------|----------------------------|----------------------|
| | | | After M.B. plough x1 | Cultivator After 1 st pass | After 2 nd pass | |
| 1. | T ₁ | 1.53 | 1.31 | 1.28 | - | 1.15 |
| 2. | T ₂ | 1.53 | 1.37 | 1.31 | 1.18 | 1.09 |
| 3. | T ₃ | 1.53 | - | 1.45 | 1.25 | 1.16 |
| 4. | T ₄ | 1.53 | - | - | - | - |

influence of rainfall and particle resettlement.

Bearing strength of soil

Bearing strength at different depths in response to tillage, over a period of 3 month after tillage is shown in Figure 3. The bearing strength of the soil varied significantly with the method of tillage operations. The highest bearing strength of 745 kPa at 90 days was recorded under the more compacted no-tillage soil, while the least value of 600 kPa at 90 days was recorded on the more intensely manipulated for T₁ plot. However, while the bearing strength increased with time after tillage under other treatments, it decreased slightly under NT at the three depths sampled. There was almost a convergence of CI values between the no-tillage and the tilled plots at the end of 3 months where there was no significant difference amongst the soil bearing strength on all the treatments at 0-5 cm depth. This was however not the case at 5-10 cm and 10-15 cm depths as the bearing strength was significantly and consistently higher under no-tillage through out the 3 month duration of the study. The soil's bearing strength generally increased with increase in depth for all treatments. While the time after tillage operations had no significant effect on bearing strength of the plots. On the average, the highest bearing strength was recorded at 3 month after tillage operations, while the least bearing strength was recorded on the third week. The soil's bearing strength decreased with the intensity of soil manipulation during tillage. There was also no significant difference in resistance between the T₂ (m.b. plough x1 + cultivator x2 + disc harrow x1) and the conventionally tilled soil T₁ (m. b. plough x1+ cultivator x1 + disc harrow x1). Bearing strength is an indirect measure of soil shear strength. Significant increase in soil penetration resistance and increase in

shear stress with little increase in bulk density [4]. They attributed this to lower saturation of the soil with high bulk density compared with the low density soil at the same potential and this tend to increase its adhesion over the soil with lower bulk density soil. Soils with high bulk density will generally have higher proportion of small diameter pores and therefore higher suction and greater shear strength compared to soils with lower density when they both have the same moisture content.

Moisture content of soil

Figure 2 shows the moisture content of soil at 150 mm depth after 0,30,60 and 90 days. The Figure 3 also shows that there was minimum loss of moisture in case of no-tillage (T₄) compared to other treatments. Because, of the reason that no tilling of soil in this treatment but 90 days after tillage the maximum loss of moisture content in this treatment and minimum moisture content of soil was 16.56% available for T₁ treatment at 90 days after tillage.

Hydraulic conductivity of soil

The soils' hydraulic conductivity (Fig. 4) was found to be highest under T₁ (a mean of 4.1×10^{-4} m/s) and lowest under no-tillage (1.0×10^{-5} m/s) at 0 days but hydraulic conductivity of soil was highest under T₁ (3.0×10^{-6} m/s) and lowest under T₄ (5.5×10^{-7} m/s). Macropores volume is generally a small fraction of the soil volume, but its contribution to soil hydraulic conductivity is very high [6-8].

Though the T₁ treatments had a higher macroporosity compared to the T₄ no-tillage treatments. The hydraulic conductivity of the plots generally decreased with weeks after cultivation apparently due to soil resettlement and compacting effects

of rainfall and runoff over the soil. This agrees with the earlier findings [5] who similarly observed a decrease in soil conductivity with time after cultivation in an Algerian soil. The no-tillage treatments consistently had the highest conductivity while the hydraulic conductivity of the T₂ treatment did not differ significantly from that of the T₃ treatments. However, as a result of similarities in pore size distribution within each tillage treatment the soil hydraulic conductivity tended to increase with increase in total porosity within each tillage treatment.

Conclusion

The bulk density, bearing strength and hydraulic conductivity of soil was better for T₁ (m. b. plough x1 + cultivator x1 + disc harrow x1) compared to T₂ (m.b. plough x1 + cultivator x2 + disc harrow x1), T₃ (cultivator x2+ disc harrow x1) and T₄ (no- tillage).

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