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Impact of different tillage practices on soil physical properties and yield of pearl millet (*Pennisetum glaucum* L.)

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Abstract

A field experiment was conducted to know the impact of different tillage practices on physical properties of soil and yield of pearl millet during the year 2015-2016 at Bajra Research Scheme, College of Agriculture, Dhule. The experiment was laid out in a randomized block design with five treatments replicated four times. The treatments comprise the tillage operation with the use of mould board plough, cultivator and rotavator. The experimental findings indicated that the physical properties of soil viz., particle density, bulk density, porosity were improved with degree of soil loosening by different tillage practices. Hydro physical properties of soil i.e. infiltration rate and hydraulic conductivity were also significantly enhanced by different tillage practices. The highest particle density (2.71 Mg m^{-3}) with reduced bulk density (1.25 Mg m^{-3}) and highest porosity (56.95%), hydraulic conductivity (0.76 cm hr^{-1}) and infiltration rate (1.97 cm hr^{-1}) were observed in treatment ploughing with tractor operated mould board plough followed by treatment harrowing with tractor operated cultivator. Growth of pearl millet in terms of growth attributes viz., plant height and number of leaves plant⁻¹ and root length were significantly influenced due to different tillage treatments. It was found higher in treatment ploughing with tractor operated mould board plough than treatment three rotavator operations. The significantly highest grain yield (34.62 q ha^{-1}) and fodder yield (60.23 q ha^{-1}) of pearl millet was recorded with treatment ploughing with tractor operated mould board plough followed by treatment harrowing with tractor operated cultivator. Besides these, lowest grain (28.46 q ha^{-1}) and fodder (49.52 q ha^{-1}) yield was recorded with treatment three rotavator operations.

Keywords: Tillage, soil physical properties, growth attributes, pearl millet, yield

Introduction

Pearl millet (*Pennisetum glaucum* L.) is major warm season coarse grain cereal which is cultivated on about 30 million ha in more than 30 countries of five continents viz., Asia, Africa, North America, south America and Australia as a staple food grain and source of feed for poultry and green fodder for cattle. At individual country level, India has the largest area (7 million ha) with 9.25 million tons of production with an average productivity of 1270 kg ha^{-1} (Yadav *et al.*, 2016) [16]. Pearl millet is the most widely grown type of millet. It is the most drought tolerant crop among cereals and millets. It is grown in the hottest, driest, semi-arid and arid regions where rainfed agriculture is practiced which receives annual rainfall of 150 to 750 mm. Because of its tolerance to difficult growing conditions such as drought, low soil fertility and high temperature, it can be grown in areas where other cereal crops, such as maize or wheat would not survive.

Soil Tillage is defined as physical, chemical or biological soil manipulation to optimize conditions for germination, seedling establishment and crop growth. Soil tillage can also be defined as any physical loosening of the soil carried out in a range of cultivation operations, either by hand or mechanized. Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20%. Many farmers perform tillage operations without being aware of the effect of these operations on soil physical properties and crop responses. Soil compaction of agricultural soils is a global well recognized problem. These problems are usually associated with tillage practices or with naturally formed restrictive layers found in many soils. One of the reasons for reduction in food production is poor land management.

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Soil compaction in agriculture affects the soil physical environment for crop production. Sufficient compaction establishes seed-soil contact and enhances germination. Excessive compaction on the other hand is detrimental for maintaining a good root environment. About 0.3-0.5 percent of tropical arable land is lost to soil degradation annually; mainly as a result of uncontrolled tillage systems. Soil conservation oriented tillage must be encouraged and properly implemented to preserve the remaining available land from further degradation and nutrient depletion. Soil compaction can cause unfavourable soil physical, chemical and microorganism conditions in subsoil which hinder root growth and crop yield. Tillage is one of the most effective ways to reduce soil compaction (Daniells, 2012) [7]. Conventional tillage usually involves mould board ploughing and additional secondary tillage to prepare the seedbed. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil intact.

Dhule region comes under scarcity zone, so there is wide scope for soil moisture conservation through mechanized tillage for crop production. A wide range of mechanized tillage methods e.g. Ploughing, harrowing, disking and rotavator is being used without evaluating their effects on soil physico-chemical properties and crop response. Hence, there is need to examine the potential of pearl millet crop using such mechanized tillage methods and their effects on soil properties and nutrient uptake. Therefore, the present investigation was planned to determine effect of different tillage practices on physical properties of soil and crop yield.

Material and Methods

A field experiment was conducted to study the effect of different tillage practices on physical properties of soil and yield of *kharif* pearl millet during the year 2015-2016 at Bajra Research Scheme, College of Agriculture, Dhule. The field experiment with five treatment combinations were laid out in randomized block design in four replications. Treatments consisted of T₁.Ploughing with tractor operated mould board plough, T₂.Harrowing with tractor operated cultivator, T₃.One rotavator operation, T₄.Two rotavator operations and T₅.Three rotavator operations. Pearl millet variety Aadishakti (DHBH-9071) was sown at 45 x 15 cm. At the time of sowing of pearl millet, basal doses of primary nutrients viz., N, P and K were applied through fertilizers like urea, SSP and MOP respectively as per RDF (50:25:25 kg NPK ha⁻¹) to the crop and top dressing dose of N applied at 30 days after sowing. During the field experiment, the soil samples were collected and analyzed by using standard analytical methods. Soil texture was determined by International Pipette method described by Piper (1966) [12], while, particle density, bulk density, porosity, infiltration rate and hydraulic conductivity were estimated by the standard methods suggested by Black and Hartge (1986) [4]. The soil pH and EC (Jackson 1973) [9], organic C (Nelson and Sommer, 1982) [11], available N (Subbiah and Asija, 1956) [15], P (Jackson, 1973) [9] and K (Chapman and Pratt, 1961) [6] were estimated by adopting standard analytical methods. The soil of the experimental field was clay in texture, low in available N, medium in available P and high in available K. The soil was neutral to slightly alkaline in reaction (Table 1).

Results and Discussion

Soil physical properties

The data pertaining to physical properties of soil as influenced by different tillage practices presented in Table 2. The effects of different tillage practices on soil particle density were not significant range. This shows that the particle density was not altered easily by normal physical manipulation of soil. However, the maximum particle density was observed in the treatment (T₁) ploughing with tractor operated mould board plough *i.e.* 2.71 Mg m⁻³ followed by treatment (T₂) harrowing with tractor operated cultivator *i.e.* 2.70 Mg m⁻³ while, minimum particle density was observed in the treatment (T₅) three rotavator operations *i.e.* 2.67 Mg m⁻³ (0 to 20 cm soil depth). The treatment T₂ was found at par with treatment T₁ and rest of the treatment were found on par with Treatment T₁. The finding was in full agreement with those of Alam *et al.*, (2013) [3] they showed that tillage did not alter the soil particle density.

The data revealed that bulk density of soil under different treatments of tillage practices was in the range between 1.25 to 1.59 Mg m⁻³. The maximum bulk density exists in treatment (T₅) three rotavator operations *i.e.* 1.59 Mg m⁻³ while the minimum bulk density exists in treatment (T₁) ploughing with tractor operated mould board plough *i.e.* 1.25 Mg m⁻³ (0 to 20 cm soil depth). Treatment T₁ was found significantly superior over rest of the treatments. However, the treatment T₂ was found at par with treatment T₁. Working depth of implement would be a reason for this issue. It was attributed to high production of large aggregates and break down of hard pan as well as up turning of surface and subsurface soil layer which leads to decreased bulk density, enhanced soil porosity and increased particle density under treatment T₁. It was observed that bulk density decreased with the increase in tillage depth, which was helpful to the downward growth of crop roots. Result discussed above are in close conformity with result reported by Adekiya *et al.*, (2009) [1] who has reported that deep ploughing results into more stirring (loosening and mixing) of soil decreasing the large size aggregates, but improved the granulation of similar aggregates and thereby increased the total pore spacing, and consequently decreased the bulk density in both the surface and subsurface soil layers, as consequence of enhanced proliferated root growth. The data recorded showed that soil porosity under different treatments of tillage practices was in the range between 31.80 to 56.96 percent. Soil porosity was significantly influenced by the different tillage practices. The maximum porosity (56.95%) was observed in treatment (T₁) ploughing with tractor operated mould board plough followed by treatment (T₂) harrowing with tractor operated cultivator (53.54%) and the minimum (31.80%) was in treatment (T₅) three rotavator operations. The treatment T₁ and T₂ was found at par with each other while, all other treatment were on par with treatment T₁. Higher soil total porosity in the treatment T₁ might be due to more pore spaces in the soil due to deep and intensive cultivation. Higher porosity in ploughing results from increased particle density and decreased bulk density. These results are in consonance with those of Adekiya *et al.*, (2009) [1], who documented that higher soil porosity was recorded in the ploughing + harrowing (P + H) tillage treatment over ploughing + two harrowing (P + 2H) treatment.

The highest water infiltration rate exists in treatment (T₁) ploughing with tractor operated mould board plough (1.97

cm hr⁻¹). Whereas, the lowest once exist in treatment (T₅) three rotavator operations (0.60 cm hr⁻¹). In case of infiltration treatment T₁ was found significantly superior over the all the treatments. Rest of the treatments found on par with treatment T₁. Infiltration is the function of pore size distribution and it increased with increased in macro porosity in soil, possibly enhanced soil aeration. In other words, decreased bulk density and soil strength induced by tillage associated with higher water infiltration rates. Results discussed above are in close conformity with result reported by Ishaq *et al.*, (2002) [8]. Highest water infiltration rates in deep tillage than in no tillage are due to greater soil porosity and the breaking-up of hard pan to improve water movement within soil. Moreover, the deep tillage disperses soil aggregates, consequently, increased water infiltration rates.

The data revealed that hydraulic conductivity under different treatments of tillage practices was in the range between 0.38 to 0.76 cm hr⁻¹. Soil hydraulic conductivity was significantly affected by the different tillage practices and no treatment was found at par with Treatment T₅. It was greater in treatment (T₁) ploughing with tractor operated mould board plough than treatment (T₅) three rotavator operations. Mean soil hydraulic conductivity values were 0.76 and 0.38 cm hr⁻¹ for T₁ and T₅ respectively. It was observed that hydraulic conductivity was increased with increasing the intensity and depth of the tillage operation. The increase in hydraulic conductivity with treatment T₁ is related to soil loosening, greater porosity, and better pore continuity in T₁ than T₅. These results are in consonance with Celik (2011) [5] reported the soil compaction causes to decrease saturated hydraulic conductivity in soil. High bulk density values obtained under no tillage and reduced tillage systems are the indications of soil compaction and might be the cause of low hydraulic conductivity obtained in no tillage and reduced tillage system.

Plant count, plant height, number of leaves and root length of pearl millet

It is seen from data in Table 3 that plant count per hectare of pearl millet did not differ significantly due to different tillage practices. However, the highest plant count of pearl millet was (139667 ha⁻¹) recorded for the treatment T₁ and lowest was (139586 ha⁻¹) observed in treatment T₅. Rashidi and Keshavarzpour (2008) [13] observed non-significant effect of different tillage treatments on number of plants per hectare in melon.

The plant height of pearl millet was progressively increased with advancement of crop age. At the time of harvesting of pearl millet maximum plant height was recorded under treatment (T₁) ploughing with tractor operated mould board plough (172.25 cm) followed by treatment (T₂) harrowing with tractor operated cultivator (166.25 cm), while, the mean minimum plant height was recorded at harvest in treatment (T₅) three rotavator operations (144.25 cm). There was significant effect of tillage practices on number of leaves plant⁻¹. At time of harvest, the highest number of leaves plant⁻¹ were observed in treatment (T₁) ploughing with tractor operated mould board plough *i.e.* 26.40 followed by treatment (T₂) harrowing with tractor operated cultivator *i.e.* 24.55 whereas, the mean minimum plant height was recorded at harvest in treatment (T₅) three rotavator operations *i.e.* 17.80. Higher plant height and highest number of leaves of pearl millet under treatment T₁ and treatment T₂ may be attributed to reduced compaction, higher porosity, and more uniform distribution of nutrients in the soil which

facilitates a favourable seedbed preparation to support for crop growth and nutrient use which reflected on taller plants. This result is similar to that of Aikins *et al.*, (2012) [12] for maize. Plant height and number of leaves of maize increased under plough + harrow tillage and under plough and decreased under no tillage.

The root length of pearl millet under different treatments of tillage practices was in the range between 15.25 to 26.25 cm (Table 3). At time of harvesting of pearl millet, the longest roots of pearl millet were produced in treatment (T₁) ploughing with tractor operated mould board plough (26.25 cm) followed by treatment (T₂) harrowing with tractor operated cultivator (22.75 cm) while, shortest roots of pearl millet were produced at harvest in treatment (T₅) three rotavator operations (15.25 cm). Treatment T₁ resulted in longest roots, while shortest ones were produced under treatment T₅. It is due to the improved soil physical conditions resulting in a good stand for elongation and proliferation processes when roots system was developing and root penetration to the deeper layers with full utilization of moisture and nutrition in the soil. This improvement was reflected on healthy and longer roots. This result fully agreed with those of Mohamed Ali (2013) [10] showed that deep tillage produced significantly higher root dry weight followed by conventional and minimum tillage. Roots under deep tillage were bigger, and were not subjected to deformation as compared to those of under conventional and minimum tillage.

Crop yield

The data presented in Table 4 revealed that the grain and fodder yield of pearl millet under different tillage practices was in the range between 28.46 to 34.62 and 49.52 to 60.23 q ha⁻¹, respectively. The highest amount of grain and fodder yield were obtained in treatment (T₁) *i.e.* ploughing with tractor operated mould board plough (34.62 and 60.23 q ha⁻¹, respectively) followed by treatment (T₂) harrowing with tractor operated cultivator (33.57 and 58.13 q ha⁻¹, respectively) whereas, under three rotavator operations obtained lowest amount of grain and fodder yield (28.46 and 49.52 q ha⁻¹, respectively). The different tillage practices employed for pearl millet exhibited its effects on soil physical and chemical health and thereby increased the crop production. These results were in close agreement with the findings of Sinha (2015) [14].

Table 1: Physical and chemical properties of experimental site

Sr. No.	Particulars	Value
Physical Properties		
1	Soil texture	Clay
	Sand (%)	35.52
	Silt (%)	19.76
	Clay (%)	44.72
2	Particle Density (Mg m ⁻³)	2.73
3	Bulk Density (Mg m ⁻³)	1.34
4	Porosity%	51
5	Infiltration (cm hr ⁻¹)	1.81
6	Hydraulic conductivity (cm hr ⁻¹)	0.57
Chemical Properties		
1	pH	7.10
2	EC (dSm ⁻¹)	0.47
3	Organic Carbon (g kg ⁻¹)	6.9
4	Available N (kg ha ⁻¹)	238.93
5	Available P (kg ha ⁻¹)	17.60
6	Available K (kg ha ⁻¹)	357.65

Table 2: Soil physical properties as influenced by different tillage practices

Treatment details	Particle density (Mg m ⁻³)	Bulk density (Mg m ⁻³)	Porosity (%)	Infiltration (cm hr ⁻¹)	Hydraulic conductivity (cm hr ⁻¹)
T ₁ -Ploughing with tractor operated mould board plough	2.71	1.25	56.95	1.97	0.76
T ₂ -Harrowing with tractor operated cultivator	2.70	1.29	53.54	1.66	0.68
T ₃ -One rotavator operation	2.69	1.46	44.52	1.43	0.57
T ₄ -Two rotavator operations	2.68	1.50	36.05	0.89	0.47
T ₅ -Three rotavator operations	2.67	1.59	31.80	0.60	0.38
SE (m)±	0.01	0.01	2.12	0.037	0.01
CD at 5%	NS	0.03	6.52	0.114	0.03

Table 3: Plant count, plant height, number of leaves and root length of pearl millet as influenced by different tillage practices

Treatment details	Plant count (ha ⁻¹)	Plant height (cm)	No. of leaves (plant ⁻¹)	Root length (cm)
T ₁ -Ploughing with tractor operated mould board plough	139667	172.25	26.40	26.25
T ₂ -Harrowing with tractor operated cultivator	139633	166.25	24.55	22.75
T ₃ -One rotavator operation	139623	156.50	21.75	19.00
T ₄ -Two rotavator operations	139605	153.50	19.50	17.50
T ₅ -Three rotavator operations	139586	144.25	17.80	15.25
SE (m)±	14.810	1.07	0.41	0.45
CD at 5%	NS	3.31	1.27	1.10

Table 4: Grain and fodder yield of pearl millet influenced by different tillage practices

Treatment details	Yield (q ha ⁻¹)	
	Grain	Fodder
T ₁ -Ploughing with tractor operated mould board plough	34.62	60.23
T ₂ -Harrowing with tractor operated cultivator	33.57	58.13
T ₃ -One rotavator operation	32.40	56.04
T ₄ -Two rotavator operations	30.70	53.31
T ₅ -Three rotavator operations	28.46	49.52
SE ±	0.31	0.43
CD at 5%	0.95	1.31

Conclusion

Ploughing with tractor operated mould board plough was superior to rotavator operation (one, two and three) in improving of physical conditions of soil along with chemical strength which turn resulted in efficient use of water and nutrients for growth and development of pearl millet crop, which ultimately led to higher crop production.

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