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Response of penetration resistance of soil and soybean productivity to preparatory tillage systems on more than seven year uncultivated vertisol of central India

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Abstract

A field experiment was conducted at Agronomy Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during rainy season of 2016-17, to study the effect of preparatory tillage systems on soil physical properties and soybean productivity. The experiment was laid out in randomized block design, assigning eight different tillage treatments and replicated thrice. Experimental results revealed that deep tillage treatment of PTtB (ploughing + 2 tyne harrow + blade harrow) recorded minimum value of penetration resistance and higher seed yield of soybean but remain statistically at par with another deep tillage treatment PTR (1 Ploughing + 1 Tyne Harrow + 1 Rotavator). Conversely the highest values of penetration resistance were recorded with treatment BR (Blade Harrow + 1Rotavator) and minimum lowest soybean productivity was recorded with treatment ZT (zero tillage).

Keywords: harrow, penetration resistance, soybean, tillage

1. Introduction

Soil tillage is one of the most important components of soil management. It has been part of most agricultural systems throughout history because tillage can be used to achieve many agronomic objectives such as soil condition, weed and pest suppression, residue management, incorporation/mixing segregation, land forming, shaping. More specific tillage objectives include seed bed formation, stale seed bed formation, compaction alleviation, fracturing of soil crust, severing/desiccation of weeds, maceration of bio-fumigant cover crops, stimulation of soil biology and harvesting of root crops. Different tillage practices modify soil structure by affecting soil physical properties such as soil bulk density, soil moisture content, porosity, roughness and soil penetration resistance, etc. Bulk density and penetrometer resistance are used as critical indicators of soil compaction. Plant roots are adversely affected by soil layers with high mechanic resistance (Barut and celik, 2017) [1]. An increment in soil penetration or mechanical resistance decreases the rate of root elongation and penetration of the roots into the soil. Besides, higher penetrometer resistance values also reflect a higher compaction level, which can produce adverse effects like a decrease in crop growth (Hall and Raper, 2005) [5]. Annual disturbance and pulverizing caused by conventional tillage *i.e.* deep ploughing produces a finer and loose soil structure as compared to conservation tillage, which leaves the soil compact. This difference results in a change of number, size distribution, shape and continuity of the pores network, which controls the capability of soil to store and transmit air, water, agricultural chemicals and crop growth (Khan *et. al*., 2001) [6]. This in turn controls erosion, runoff and crop performance. Changes in soil compaction (penetration resistance) affect the seedling emergence, plant density, depth and distribution of root and finally yield of crop. Khurshid *et al.* (2006) [8] reported that among the crop production factors, tillage contributes up to 20%. However, there was a great variability of soil penetration resistance (kPa) for a given degree of compaction. This variability in penetration resistance in the field is linked to several controlling variables, i.e. soil water content, soil bulk density, porosity, particle size distribution and clay content in soil. As the soil compaction is the static state property, the composite result of changes in solid, gaseous and liquid phases in soil, is extremely difficult and time consuming to measure and study it directly. Therefore, the penetration resistance is used as the surrogate measurement for the degree of compaction; so studies on soil compaction were seem to be a reliable way to estimate the resistant that's offered by soil and affect the growth of plant roots.

Soybean is the most important rainy season oilseed crop grown on *Vertisols* of the *Vidarbha* region of Maharashtra (India). Annual rainfall and its monthly distribution are highly variable in this zone. Drought of unpredictable intensity and duration results in low and unstable crop productivity of soybean in this region and during summer season soil become more compact after drying resulted in higher soil compaction, that's why appropriate tillage system is desired which can increase water holding capacity or water availability for crops and decrease soil penetration resistance for deeper root system and proper aeration in root zone. In this type of soil by increasing infiltration and thereby facilitating root growth in zones of the soil profile from where water is lost by evaporation (Lopez and Arrue, 1997; Lampurlanes *et al*., 2001) and ultimately increase crop yield. Therefore, efficient soil management and profitable production systems are needed for this non irrigated region to improve the economic condition of the farmers. So the objective of this research was to determine the effects of different preparatory tillage systems on yield of soybean and soil physical property like penetrometer resistance in the *Vidarbha* province of Maharashtra (India).

2. Material and Methods

The field experiment was carried out during Kharif season of 2016-17 at the Research Farm of Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, situated at the latitude of 22°42' North and longitude of 77°02' East and 281.12 meter above the mean sea level. The soil was silty clay in texture with high amount of potassium (323.72 kg ha^{-1}), moderate in phosphorus (16.12 kg ha^{-1}) and low in available nitrogen (191.25 kg ha^{-1}), having pH (7.3) about to normal. The rainfall received during the crop growing season was 832.9 mm in 45 rainy days which was 14.31 per cent more than the normal.

The experiment was laid out in Randomized Block design (RBD) with eight treatments; replicated three times. The tillage treatments constituted of T_1 - Zero tillage + PE & PoE application of Herbicides (ZT), T_2 – 1 Rotavator + 1 PE Herbicide Application + 1 PoE Herbicide Application (HR), T_3 - 1 Blade Harrow + 1Rotavator (BR), T_4 - 1 Tyne Harrow + 1 Rotavator (TR), T_5 - 1 Tyne Harrow + 1 Blade Harrow + 1 Rotavator (TBR), T_6 - 2 Tyne Harrow + 1 Blade Harrow + 1 Rotavator (TtBR), T_7 - 1 Ploughing + 1 Tyne Harrow + 1 Rotavator (PTR), T_8 - 1 Ploughing + 2 Tyne Harrow + 1 Blade Harrow (PTtB). Sowing of soybean variety JS 335 was done on 30th June 2016 and harvested on 18th October, 2016. Periodically observations were recorded on growth and yield contributing character of soybean to evaluate treatment effect.

2.1 Penetration resistance (cone index) of soil (kPa): The penetration resistance of soil was taken by using single- tube and dial pressure gauge proven ring type cone penetrometer (Recommended by ASAE 1995). The cone was hold vertically above the measuring point and pushed it slowly and evenly at the rate of 30 mm/s (72 in/min). The surface reading was measured at the instance when the base of cone (1 cm^2 diameter) gets flushed with the soil surface. The dial gauge and depth readings were recorded from the depth of 0-10 cm, 10-20 cm and 20-30 cm. The readings were repeated at every 20 days interval as per the prevailing moisture status in the soil during growing period of crop.

$$\text{Penetration resistance of soil (kg cm}^{-2}\text{)} = \frac{\text{Force applied (kg)}}{\text{Base area (cm2)}}$$

Penetration resistance = kg cm^{-2} × 98.066 = kPa.

3. Results and Discussion

3.1 Penetration resistance (kPa): After the tillage treatments it was significantly decrease due to tillage effect and sufficiency in moisture content during crop period. In order to measure the extent of change in penetration resistance (PR) due to various tillage practices, the periodical observations at the depth of 0-10, 10-20, and 20-30 cm were taken and presented in Tables 1, 2 and 3.

3.1.1 Penetration resistance (kPa) of soil at the depth of 0-10 cm: Tillage treatments had significant effect on penetration resistance however, up to the depth of 0-10 cm penetration resistance did not differ much because all tillage treatments had tillage depth of more than 8 cm except ZT. It is obvious from the Table 1 that the mean of PR increased gradually from sowing to 60 DAS but after 60 DAS there was somewhat reduction in kPa values because of rainfall at 80 DAS and at harvest stage, there was more water availability as compared to 60 DAS.

The initial average value of penetration resistance at 0-10 cm was 113.33 kPa that was recorded in the month of May in dry condition before the tillage operation and rainfall. After the rainfall and tillage operation, penetration resistance drastically decreased in most of the tillage treatments and maximum penetration resistance at 0-10 cm depth was registered with ZT as there was no tillage operation carried out. Although, all the tillage treated plots were tilled by using rotavator up to the depth of 10 cm, except ZT, so it was expected that the PR values may not vary at this depth. However, it seems that, increase in the PR values with treatments HR and BR might be due to decrease in soil moisture content as compared to deep tillage treated plots. The second reason behind increase in PR values with treatments HR and BR may be due to the increase in bulk density and decrease in mean weight diameter of the soil particles. Qamar *et al*. (2015) [15] also concluded that, the practice of deep tillage significantly decreased penetration resistance when compared with conventional tillage, zero tillage with zone disc tiller, and happy seeder.

3.1.2 Penetration resistance (kPa) of soil at the depth of 10-20 cm: The corresponding values of PR as obtained from the depth of 10-20 cm are presented in Table 2. It is obvious that the values of PR increased markedly at this depth when compared with its upper soil profile. At the depth of 10-20 cm, the initial average value of PR was 167.14 kPa (before tillage operation) and after tillage operation i.e. at the time of sowing, treatment differences were quite significant with maximum PR value of 48.11 kPa in treatment ZT and minimum PR value of 35.61 kPa in the treatment of PTtB; thus, according to the depth of soil tillage, the values of PR differed orderly. At 20 DAS and 40 DAS, the same trend was recorded but at 40 DAS treatment BR (56.33 kPa) came statistically similar with treatment of ZT (58.00 kPa). At 40 DAS, the treatment with deep tillage i.e. PTtB, recorded significantly lowest value of cone index 38.52 kPa. It was followed by treatments PTR and TtBR, with respective PR values of 40.23 and 51.66 kPa. Highest value of PR also registered with tillage treatment of ZT and BR with respective values of PR 58.00 and 56.33 kPa. At 60 DAS, the highest soil resistance (79.14 kPa) was registered with treatment BR which in turn was statistically similar with treatment ZT having 77.66 kPa value. The lowest value of kPa was noticed in treatment PTtB (61.00 kPa) while treatment PTR (61.92 kPa) was statistically similar with it. Similar trend of various treatment differences was also noticed at 80 DAS and at harvest but values of kPa were somewhat lesser due to increase in soil water content at this stages.

The overall increase in the values of PR may be ascribed to the pressure of the soil mass over-laden above this surface. The specific increase in the PR values with treatments ZT and BR could be attributed to higher bulk density, lower porosity, lower soil moisture content and decreased mean weight diameter values, while lower values of PR with treatments PTR and PTtB might be due to decreased soil bulk density and increased soil moisture content (Khedkar and Deshmukh, 2019) [11]. Ozpinar (2010) [13] and Celik (2011) [2] also reported greater PR values under zero or minimum tillage treatments. Mohammadi *et al*. (2013) [12] conducted a research in and results showed that, the greatest cone index was found in the minimum tillage and no tillage systems, as compared to deep tillage practices.

3.1.3 Penetration resistance (kPa) of soil at the depth of 20-30 cm: It is observed from the data presented in the Table 2, that, there was significant increase in the values of PR when measured at the depth of 20-30 cm than that of 10-20 cm depth. The average initial value of PR before applying the tillage treatments was very high (230.95 kPa) and subsequently, after the tillage operation there was significant decrease mostly with deep tillage treatments. At the time of sowing, the soil compaction values were in the range of 51.61 kPa to 75.66 kPa. This difference indicates that, the soil compaction was influenced to a greater extent by various tillage treatments, even at the time of sowing. As per statistical analysis of experimental data, it can be revealed that the treatments PTtB significantly reduced the PR value and it was closely followed by treatment PTR. Both the deep tillage treatments PTtB and TBR superseded all the other tillage treatments by recorded the lowest values of 51.61 and 54.13 kPa at the time of sowing, 52.66 and 55.66 kPa at 20 DAS, 57.67 and 57.33 kPa at 40 DAS, 78.12 and 78.23 kPa at 60 DAS, 77.24 and 77.54 kPa at 80 DAS and finally 63.66 and 69.00 kPa at the time of harvesting respectively. While, the highest soil compaction (75.66 to 110.15 kPa) was noticed with treatment BR, which was closely followed by ZT treatment (74.81 to 105.12 kPa) and being statistically most inferior treatment at all growth stages.

It is worthwhile to note the remarkable differences in soil compaction status as depicted from the values of PR at the depth of 20-30 cm. Further it can be observed that, amount of water content at different depth of soil significantly influenced the PR values. Swelling and shrinkage in response to changes in water content vary horizontally and vertically; because not all the parts of soil profile were wetted or dried uniformly. As there were significant changes in the hydraulic conductivity due to various tillage treatments, the resultant changes in the status of soil compaction might have been occur in a linear way. It has already been observed earlier that, there were remarkable reduction in soil porosity and hydraulic conductivity with treatments BR and HR. Hence, it can be stated that, shallow tillage either alone with rotavator or with rotavator + blade harrow did not help to alleviate the soil compaction that takes place even at the greater soil depth.

3.2 Seed Yield: Data presented in Fig.-1 revealed that use of deep tillage treatment (PTtB) recorded significantly highest seed yield of 2.38 ton ha^{-1}, being non-significant with treatment PTR, which recorded the corresponding value of 2.27 ton ha^{-1}. Whereas, the lowest seed yield (1.07 ton ha^{-1}) was noted in ZT treatment. Medium depth tillage treatments; TR, TBR and TtBR; recorded seed yield to the tune of 1.95, 1.99 and 2.06 ton ha^{-1}, respectively and remain statistically similar with each other, also found superior over shallow tillage treatments of BR and HR. Higher seed yield in deep tillage treatments PTtB and PTR may due to profuse root development, thereby higher absorption of nutrients to flourish aerial plant part, and subsequently higher production of photosynthates and metabolites, its efficient diversion towards the reproductive system, resulting in higher grain yield. The lower seed yield with ZT treatment, where the soil was undisturbed, may be attributed to the inferior values of plant growth and yield contributing characters. The seed yield with shallow tillage treatment of HR and BR also obtained lower values which indicate that crop didn't respond good to shallow tillage treatments. Meshram *et al.* (2019) [11], Gholami *et al*. (2014) [3], Gurumurthy *et al*. (2008) [4], reported the highest seed yield in deep tillage treatment of mouldboard plough plus rotavator. Contrarily, Parvin *et al*. (2014) [14] also revealed that the number of seedlings and yield was better in shallow tillage than in mouldboard ploughing.

Table 1: Penetration resistance (kPa) of soil at the depth of 0-10 cm as affected by various tillage practices

Treatment	Periodical penetration resistance (kPa) at the depth of 0-10 cm					
	At sowing	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
ZT	31.01	33.66	36.66	58.40	41.33	27.00
HR	28.66	29.70	34.66	47.11	36.66	32.00
BR	25.41	30.00	36.33	56.66	38.00	36.66
TR	20.45	22.78	21.37	45.66	34.66	31.66
TBR	23.09	24.59	21.75	45.66	34.00	29.00
TtBR	21.34	23.17	21.43	39.70	32.33	28.33
PTR	21.86	23.07	20.33	39.33	32.00	27.66
PTtB	20.97	22.97	20.76	38.98	30.66	26.00
SE (m)±	0.727	0.742	0.777	1.505	1.112	0.991
CD at 5%	2.186	2.234	2.341	4.532	3.348	2.986
GM	24.10	26.24	26.66	46.44	34.96	29.79
Initial	113.33					

Table 2: Penetration resistance (kPa) of soil at the depth of 10-20 cm as affected by various tillage practices

Treatment	Periodical penetration resistance (kPa) at the depth of 10-20 cm					
	At sowing	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
ZT	48.11	49.33	58.00	77.66	62.66	54.00
HR	41.26	44.66	55.33	75.66	58.66	47.00
BR	46.49	47.33	56.33	79.14	59.66	55.00
TR	40.85	42.66	53.00	66.66	57.33	44.66
TBR	42.12	44.33	55.00	74.66	58.00	45.00
TtBR	40.57	41.66	51.66	66.00	56.00	44.66
PTR	36.91	38.33	40.23	61.92	50.66	43.66
PTtB	35.61	36.75	38.52	61.00	49.33	44.00
SE (m)±	0.65	0.619	0.668	1.142	1.446	0.792
CD at 5%	2.054	1.987	2.146	3.667	4.645	2.543
GM	41.49	43.13	51.01	70.34	56.54	47.25
Initial	167.14					

Table 3: Penetration resistance (kPa) of soil at the depth of 20-30 cm as affected by various tillage practices

Treatment	Periodical penetration resistance (kPa) at the depth of 20-30 cm					
	At Sowing	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
ZT	74.81	75.66	76.33	105.12	96.66	94.33
HR	71.54	74.66	79.00	101.07	93.33	92.33
BR	75.66	77.66	83.66	110.15	102.00	96.00
TR	64.17	66.66	69.00	89.66	87.33	83.33
TBR	68.20	72.70	69.33	100.33	89.00	86.33
TtBR	61.12	63.33	68.00	88.00	87.00	82.66
PTR	54.13	55.66	57.33	78.23	76.54	69.00
PTtB	51.61	52.66	57.67	78.12	77.24	63.66
SE (m)±	1.14	1.213	1.875	2.398	2.445	2.871
CD at 5%	3.440	3.654	5.647	7.225	7.364	8.647
GM	65.16	67.37	70.04	93.84	88.64	83.46
Initial	230.95					

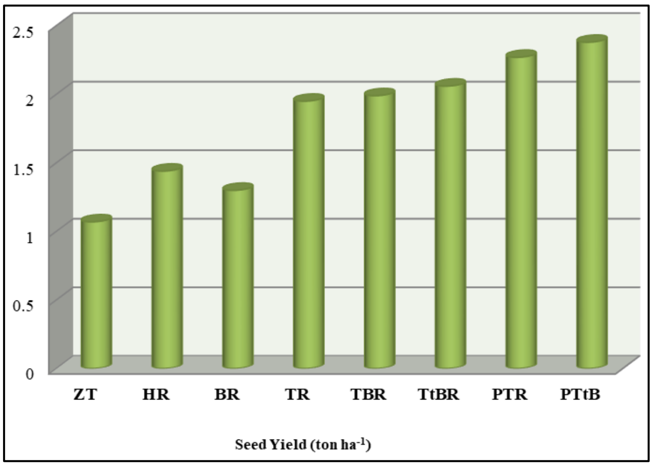

Fig 1: Seed yield (kg ha^{-1}) of soybean as affected by different preparatory tillage system

4. Conclusion

Data revealed that different preparatory tillage system significantly influenced the soil penetration resistance and productivity of soybean. Seed production and soil penetration resistance (compaction) were found to be opposite to each other, where penetration resistance was high, there were production was low and deep tillage treatment where penetration resistance was lower yielded more seed production. Deep tillage treatments (PTtB and PTR) recorded minimum value of penetration resistance and higher seed yield. Conversely the highest values of penetration resistance and lowest seed production were recorded with not tillage treatment ZT and shallow tillage treatment HR and BR.

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