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Consequences of various tillage management practices on soil physical properties and yield of soybean (*Glycine max*)

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Abstract
A field investigation entitled "Consequences of various tillage managment practices on soil physical properties and yield of soybean" was conducted at research farm of AICRP on Weed Management, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) during the year 2016-17 on medium deep black soil. The experiment was laid out in strip plot design with three replications. There were eighteen treatment combinations consisting six tillage and crop management practices. On the basis of results obtained in the present investigation, the soil physical properties i.e rate of infiltration, soil moisture content and hydraulic conductivity were significantly improved with deep tillage consisting of 2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + planking + Residue (CTR). The next best treatment that improved physical properties of soil was that of 2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + planking (CT). Zero tillage and minimum tillage treatments were found inferior in improving soil physical properties. On the basis of results the values of plant growth, yield attributes and yield of soybean were significantly increased with tillage treatment of 2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + planking + Residue (CTR) as compared to other tillage treatments.

Keywords: Tillage, soil bulk density, porosity and penetration resistance, soybean, yield

Introduction

Tillage is the oldest art associated with development of agriculture. Tillage operations are carried out to prepare a fine seed-bed for sowing crops. Tillage plays an important role in the crop growth and production. A soil tillage practice improves soil physical properties and enables the plant to show their full potential and growth. Soil tillage techniques are used to provide suitable environment to seed growth and development, control weeds, manage crop residues, reduce soil erosion and level the surface for planting, irrigation, drainage and incorporation of organic and inorganic fertilizers in the soil. Continuous use of soil tillage practices strongly influence the soil properties, it is important to apply appropriate tillage practices in the soil to avoid the degradation of soil structure, maintain crop yield as well as flora and fauna stability in the soil. The success of any tillage practices is directly related to the improvement of the soil physical properties which in turn may affect the growth and yield of crops due to the different soil conditions created. The choice of any tillage system is too critical for maintenance of the soil physical properties necessary for crop growth. Rotavator plows are rotational tillage implements that break and mix the soil by using either the tractor's power (rotary tiller, rotary power harrow) or an external power source (small motorized rotary tiller), and the operation typically needs only one pass to let the soil ready for planting.

Soybean (*Glycine max.* L.) is one of the important oilseed as well as a leguminous crop. Soybean as a miracle "Golden bean" of the 21st century. It is an excellent source of protein and oil besides it contains high level of amino acids such as lysine, lucien, lecithin and large amount of phosphorous. Soybean contains approximately 40-45% protein and 18-22% oil and is a rich source of vitamins and minerals. Soybean is a worlds first rank crop as a source of vegetable oil. The area covered under soybean in India was 116.285 lakh ha which produced 86.426 lakh MT with productivity of 781 kg ha^{-1} whereas, in Maharashtra the area under cultivation was 37.739 lakh ha which produced 27.835 lakh MT with productivity of 776 kg ha^{-1}. In Vidarbha, area under soybean was 18.726 lakh ha which produced 18.453 lakh MT with productivity of 973 kg ha^{-1} (SOPA, 2015) [1]. It is the cheapest and richest source of high quality protein. It supplies most of the nutritional constituents essential for human health.

Materials and methods

Field experiment was carried out during *Kharif* season of 2016-17 at the All India co-ordinated research project on weed management 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 experimental plot topography was fairly uniform and leveled. The result of the initial chemical analysis indicated that, the soils have pH 7.84 with electrical conductivity 0.25 dSm^{-1} and organic carbon content was 5.44 g kg^{-1}. The available nitrogen and phosphorus content of soil was low i.e. 234 and medium 24.42 kg ha^{-1}, respectively. However, soils were sufficiently higher in available potash content (478.52kg ha^{-1}). The experiment was laid out in strip plot design with three replications. The treatments were randomly allotted in each replication. There were eighteen treatment combinations consisting six tillage and crop management practices, viz., T_1-2 harrowing by tyne cultivator + 1 harrowing by blade harrow + planking; T_2 - 2 harrowing by tyne cultivator + 1 harrowing by blade harrow + planking + Residue; T_3 – 1 Rotavator tillage; T_4 -1 Rotavator tillage + Residue; T_5 – zero tillage;T_6 – zero tillage + Residue and three levels of weed management, i.e.H_1– Diclosulam 30g/ha (PE)*fb*Imazethapyr + Imazamox 100g/ha (POE) 20 DAS; H_2-1 hand weeding 20DAS *fb* Imazethapyr +imazamox 100g/ha (POE) 40 DAS ; H_3–weedy check (unweeded). The net plot size was 6.3 x 5.5 m. Sowing of soybean (var. JS-335) was done on 21st June, 2016. Double ring infiltrometer (Michael 1999) [13] was used for measurement of infiltration, moisture was estimated by 'Micro-Gopher moisture profiling System' made by Dataflow System Pty Ltd, New Zealand from the depth of 0-15 and 15-30 cm and hydraulic conductivity was determined by constant head method using permeameter.

Note : CT : 2 Harrowing by tyne cultivator+ 1 harrowing by Blade harrow+ planking, CTR : 2 Harrowing by tyne cultivator+ 1 harrowing by Blade harrow+ planking+Residue, ZT : Zero tillage, ZTR : Zero tillage+ Residue MT : Rotavator tillage and MTR : Rotavator tillage+ Residue, RH :Diclosulam 30g/ha (PE), *fb* Imazethapyer + Imazamox 100 g/ha (POE) 20 DAS, HHW : Hand weeding (20 DAS) fb Imazethapyer + Imazamox 100 g/ha (POE) 40DAS, UW : Unweeded.

Results and discussion

Rate of infiltration (cm hr^{-1})

Surface entry, transmission through soil and depletion up to storage capacity of soil are three main phases which governs the rate of infiltration in the soil. While computing the rate of infiltration (IR), initial rate of water movement is much higher, while it gradually reduces and stables at certain level. The relevant data obtained from study are presented in Table1

Effect of tillage management

As observed from the mean values, it is evident that the rate of infiltration decreased to a higher extent at harvest (1.42 cm hr^{-1}) when compared to its initial status (1.99 cm hr^{-1}). The data reveals crucial effect of various tillage practices over IR. At the time of sowing, across the various tillage treatments, maximum improvement in IR at sowing was observed with tillage treatment of CT (2.65 cm hr^{-1}) and tillage treatment CTR (2.61 cm hr^{-1}) both being statistically similar with each other and conversely, significant reduction in IR was noted with the treatment ZT (1.55 cm hr^{-1}) and ZTR (1.54 cm hr^{-1}), both being at par with each other. As far as IR at the time of harvest is concerned, though the IR values were lower than that of sowing, at all the treatments, the treatment differences were found to be differed to a level of significance. At this stage,again the maximum improvement in IR was noted with tillage treatment of CTR by registering the value of 1.91 cm hr^{-1}, which was closely followed by treatment CT (1.86 cm hr^{-1}), both being statistically non-significant with each other.

Effect of weed management

The IR data pertaining to weed management treatment did not show any significant effect on IR at the time of sowing and harvest.

Interaction effect

An interaction effect of various tillage treatments and weed management practices on IR was found to be non-significant during the course of investigation. Thus in general, it can be stated that the degree of soil manipulation plays a major role in deflecting the IR values. Potter *et al*. (1995) [14] also concluded that, water infiltration rates can be large soon after tillage. After rainfall and settling, however, infiltration was reduced in a tilled vertisol, probably because of reduced macropore continuity after tillage. Abdullah and Ghazal (2000) [2], Kargas *et al.* (2012) [8] and Ahuchaogu *et al.* (2015) [14] also reported greater rate of infiltration with greater tillage intensity and depth.

Soil moisture content (%)

The amount of moisture the soil retains under a given condition is closely related to porosity and size of voids as well as properties of the soil particles. The soil moisture is modified by tillage through particle to particle contact and porosity of the soil. The root growth and its proliferation are directly related to water availability in soil profile. Thus soil moisture can greatly impact nutrient transformation, its release from organic forms, its uptake by roots and subsequent translocation and utilization by plant. The data in respect of soil moisture content at the depth of 0-20 cm recorded periodically during the crop growth period are presented in Table.2.

Soil moisture content (%) at the depth of 0-20 cm

The overall crop growth and development is largely dependent on available soil moisture within the crop root zone. Moreover, activity of soil macro/microorganisms and their quantum in the soil are largely influenced by soil moisture status.

Effect of tillage management

Tillage practices significantly affected the mean moisture content (Table2). Remarkable improvement in conserving the rainfall was noted with deep tillage consisting of 2 harrowing by tyne cultivator + 1 harowing by blade harrow +planking + residue (CTR) and 2 harrowing by tyne cultivator + 1 harowing by blade harrow +planking (CT) throughout the investigational period. At the time of sowing, tillage treatment CTR (22.79) and tillage treatment CT (22.51) shows the significantly higher moisture percent than remaining treatments. Significantly highest (in the range of 34.09 per cent) moisture conservation was noted with tillage treatments CTR and CT, even though this was the period when there was no significant difference found in moisture per cent due to effect of various tillage practices.

Subsequently, at 40 DAS, moisture content at all the plots was improved to satisfactory level. At this stage, the tillage treatments did not differ significantly by recording the soil moisture to the tune of 34.04 and 34.31 per cent. At 60 DAS, treatments CTR and CT recorded significantly higher value of soil moisture than that of MT, MTR, ZT and ZTR. There was dry spell about 15 days, reflecting over the soil moisture content at 80 DAS. Though there was less receipt of rainfall at this stage, the deep tillage treatments i.e. CTR and CT significantly conserved the soil moisture to a higher extent of 18.95 and 18.75 per cent, respectively.

Effect of weed management

The soil moisture data pertaining to weed management treatment didn't show any significant effect on soil moisture content at the time of sowing to harvest but moisture per cent was recorded higher at treatment HHW at the time of sowing, 20,40,60, 80 DAS and at harvest.

Interaction effect

An interaction effect of various tillage treatment and weed management practices on soil moisture was found to be non-significant during the course of investigation. Thus, it can be inferred that deep tillage practice consistently improved the status of soil moisture not only under adequate rainfall condition but also under the condition of inadequate receipt of rainfall. Barua *et al.* (2014) [6] reported that soil moisture was reduced significantly with the reduction in depth of operation. Similar observations were recorded earlier by Karuma *et al*. (2014) [7] and Meidani (2014) [12].

Hydraulic conductivity (cm hr^{-1}) of soil

The rate of movement of saturated flow mainly depends upon the magnitude of the potential gradient and of the transmission coefficient of the soil. It depends mainly on the size, shape and distribution of the pores. During the course of present investigation the saturated hydraulic conductivity was measured over a disturbed soil samples, collected from the depth of 0-20 cm profile. The relevant observations are placed at Table 3 and represented graphically in Fig.1.

Effect of tillage management

It is revealed that the hydraulic conductivity of the soil didn't differ significantly due to various tillage treatments. It ranged from 2.03 to 2.16 cm hr^{-1} at the time of sowing. Maximum water conduction (2.16 cm hr^{-1}) under saturated condition was recorded with treatment CTR. It was followed by treatment CT with corresponding value of 2.13 cm hr^{-1}, being statistically similar with CTR. The hydraulic conductivity values did not differ statistically with treatments MT, MTR, ZT and ZTR. However, numerically lower hydraulic conductivity (2.03 cm hr^{-1}) was observed with treatment ZT, suggesting greater soil compaction status.

At the time of harvest, due to greater degree of subsequent soil compaction; the values of hydraulic conductivity were found to be decreased moderately among all the tillage treatments. At this time, the hydraulic conductivity (2.08 and 2.11 cm hr^{-1}) was found to be improved with treatments CT and CTR both being similar statistically. The remaining tillage treatments i.e. MT, MTR, ZT and ZTR with lower values of hydraulic conductivity, were found to be statistically similar with each other. However, numerically the lowest hydraulic conductivity of 2.01and 2.04cm hr^{-1} was recorded with treatments ZT and ZTR, respectively. Higher saturated water conductivity with treatments CTR and CT could be ascribed to improvement in the physical status of the soil, especially higher porosity, reduced soil strength.

Effect of weed management

The hydraulic conductivity data of soil pertaining to weed management treatment didn't show any significant effect on hydraulic conductivity of soil at the time of sowing to harvest but somewhat improvement in HC was noted in treatment HHW, (2.12 cm hr^{-1}) followed by treatments RH (2.10 cm hr^{-1}) and UW(2.06 cm hr^{-1}) during sowing and the similar phenomena was noticed at harvest stage.

Interaction effect

An interaction effect of various tillage treatment and weed management practices on hydraulic conductivity of soil was found to be non-significant during the course of investigation.

Schwen *et al.* (2011) conducted an experiment on arable field of Vienna and observed that the near saturated hydraulic conductivity was greater in conventional, moderate in reduced and lowest in no-tillage treatments. Celik (2011) [7] also observed that the HC was higher in conventional tillage than that of reduced tillage systems. Kargas and Londra (2014) [9] and Reichert *et al.* (2015) reported similar phenomena of increased hydraulic conductivity with higher tillage intensity.

Seed yield and straw yield (kg ha^{-1}) of soybean

During the period of present investigation, the net plot yield values were converted to per hector yield by using the hector factor. The relevant data in respect of seed and straw yield as obtained during the given year 20015-16 are presented in Table7 and graphically represented in Fig.1.

Effect of tillage management

Marked effect of tillage practices of varying depth and intensity was observed over seed and straw yield of soybean during given period of study. It is apparent that treatment consisting of CTR posed a great impact along with treatment CT in respect of seed yield. Treatment CTR recorded seed yield to an extent of 2305 kg ha^{-1}, while treatment CT; being non-significant with treatment CTR recorded the corresponding value of 2298kg ha^{-1}. These two treatments in together recorded a yield advantage of about 11.15 % over the zero tillage treatments of ZT and ZTR, where, the soybean seed yield was 2068 and 2071 kg ha^{-1}, respectively. It is noteworthy to mention that medium deep tillage treatments i.e. MT and MTR; being statistically similar with each other, also found superior over no-tillage treatments of ZT and ZTR and recorded the seed yield of soybean in the range of 2171 to 2192 kg ha^{-1}.The similar trend of treatment differences were noticed when the straw yield of soybean was measured after harvest of the crop. Alizadeh and Allameh (2015) [5] reported the highest seed yield in tillage treatment of mouldboard plough plus rotavator. Similar kind of research results were reported earlier by Varshney *et al.* (1990) [17], Ahmad *et al*. (2010) [3] and Meena *et al*. (2011) [11].

Effect of weed management

The seed yield and straw yield (kg ha^{-1}) pertaining to weed management treatment had shown significant effect on seed yield and straw yield at harvest. The treatment HHW (2396 kg ha^{-1}) was found to be significantly superior, followed by the treatment RH (2268 kg ha^{-1}). However treatment UW (1888 kg ha^{-1}) recorded the minimum seed yield compeered with other remaining treatment. The treatment HHW (2400 kg ha^{-1}) was found to be superior, being statistically similar with treatment RH (2388 kg ha^{-1}) with respect to straw yield. However treatment NH (2366 kg ha^{-1}) recorded the minimum straw yield compeered with other remaining treatment. The effect of various weed management practices on biological yield was found to be significant. The treatment HHW (4796 kg ha^{-1}) recorded the significantly superior biological yield, followed by the treatment RH (4656 kg ha^{-1}) and UW (4214 kg ha^{-1}).

Interaction effect

An interaction between tillage and weed management practices was found to be significant at harvest. It is obvious that treatment combination of CT x HHW and CTR x HHW, recorded significantly maximum seed yield (kg ha^{-1}) than rest of the treatment combinations. An interaction between tillage and weed management practices of CTRx RH and CTR x HHW was found to be significantly superior over rest of the treatment combinations by recording highest values of straw yield of soybean (2725 and 2690 kg ha^{-1}, respectively). An interaction CTR X HHW and CT x RHrecorded significantly maximum biological yield (5235 and 5133 kg ha^{-1}) and proved to be the best treatment combinations.

Table 1: Rate of infiltration (cm hr^{-1}) as affected by various tillage and weed management practices

Treatment	Initial and final rate of infiltration (cm hr^{-1})	
	At sowing	At harvest
A) Tillage management		
CT	2.65	1.86
CTR	2.61	1.91
MT	1.82	1.42
MTR	1.86	1.46
ZT	1.55	1.27
ZTR	1.54	1.28
SE (m)±	0.05	0.04
CD at 5%	0.14	0.13
B) Weed management		
RH	2.06	1.45
HHW	1.96	1.40
Uw	1.96	1.40
SE (m)±	0.04	0.03
CD at 5%	NS	NS
Interaction (AxB)		
SE (m)±	0.09	0.08
CD at 5%	NS	NS
GM	1.99	1.42

Table 2: Soil moisture content (%) at the depth of 0-20 cm as affected by various tillage and weed management practices.

Treatment	At sowing	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
A) Tillage management						
CT	22.51	33.81	34.92	28.47	18.75	32.93
CTR	22.79	34.09	35.01	29.06	18.95	33.14
MT	20.49	33.52	34.57	27.12	17.41	32.61
MTR	20.67	33.70	34.74	27.25	17.62	32.77
ZT	19.92	32.00	34.04	26.45	16.58	32.19
ZTR	20.12	32.30	34.31	26.94	16.89	32.41
SE (m)±	0.57	0.66	0.70	0.60	0.31	0.66
CD at 5%	1.65	NS	NS	1.72	0.90	NS
B) Weed management						
RH	20.97	33.27	34.55	27.39	17.93	32.68
HHW	21.41	33.60	34.87	27.42	17.58	33.03
UW	20.87	32.84	34.37	27.85	17.60	32.32
SE (m)±	0.41	0.47	0.49	0.42	0.22	0.47
CD at 5%	NS	NS	NS	NS	NS	NS
Interaction(AxB)						
SE (m)±	0.99	1.14	1.21	1.04	0.54	1.14
CD at 5%	NS	NS	NS	NS	NS	NS
GM	21.08	33.24	34.60	27.55	17.70	32.68

Table 3: Hydraulic conductivity (cm hr^{-1}) of soil as affected by various tillage and weed management practices

Treatment	Initial and final hydraulic conductivity (cm hr^{-1})	
	At sowing	At harvest
A) Tillage management		
CT	2.13	2.08
CTR	2.16	2.11
MT	2.08	2.05
MTR	2.10	2.07
ZT	2.03	2.01
ZTR	2.06	2.04
SE (m)±	0.04	0.03

CD at 5%	NS	NS
B) Weed management		
RH	2.10	2.07
HHW	2.12	2.09
UW	2.06	2.03
SE (m)±	0.03	0.02
CD at 5%	NS	NS
Interaction (AxB)		
SE (m)±	0.07	0.04
CD at 5%	NS	NS
GM	2.09	2.06

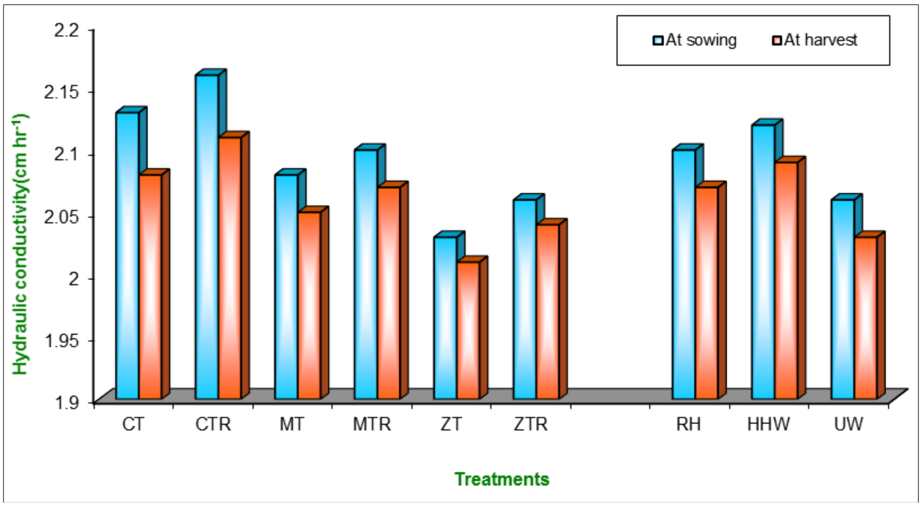

Fig 1: Hydraulic conductivity (cm hr-1) of soil as affected by various tillage practices

Table 6: Seed and straw yield (kg ha^{-1}) of soybean as affected by various tillage and weed management practices

Treatment	Yield of soybean (kg ha^{-1})		
	Seed	**Straw**	**Biological**
A) Tillage management			
CT	2298	2568	4866
CTR	2305	2696	5001
MT	2171	2298	4469
MTR	2192	2420	4611
ZT	2068	2085	4154
ZTR	2071	2162	4233
SE (m)+-	20.617	19.967	30.314
CD at 5%	59.246	57.378	87.110
B) Weed management			
RH	2268	2388	4657
HHW	2396	2400	4796
UW	1888	2326	4214
SE (m)+-	14.579	14.119	21.435
CD at 5%	41.893	40.572	61.596
Interaction (AxB)			
SE (m)+-	36	35	52.51
CD at 5%	102.62	99.38	150.88
GM	2184	2372	4556

Table 7: Seed yield (kg ha^{-1}) of soybean as affected by interaction of various tillage and weed management practices after harvest

Treatment	CT	CTR	MT	MTR	ZT	ZTR
RH	2331	2307	2280	2282	2212	2200
HHW	2503	2510	2397	2410	2263	2292
UW	2060	2098	1835	1883	1730	1720
SE (m)+-			35.710			
CD at 5%			102.617			

Table 8: Straw yield (kg ha^{-1}) of soybean as affected by interaction of various tillage and weed management practices after harvest

Treatment	CT	CTR	MT	MTR	ZT	ZTR
RH	2630	2725	2358	2350	2118	2219
HHW	2598	2690	2321	2448	2086	2186
UW	2477	2573	2215	2461	2051	2081
SE (m)+			34.584			
CDat 5%			99.381			

Table 9: Biological yield (kg ha^{-1}) of soybean as affected by interaction of various tillage and weed management practices after harvest.

Treatment	CT	CTR	MT	MTR	ZT	ZTR
RH	5133	4947	4754	4760	4382	4512
HHW	4929	5235	4601	4730	4298	4386
UW	4537	4772	4050	4344	3781	3801
SE (m)±			52.505			
CD at 5%			150.879			

Conclusions

1. Significant improvement in terms of soil physical properties, i.e. rate of infiltration, soil moisture content and hydraulic conductivity were observed with tillage treatment of 2 harrowings by tyne cultivator + 1 harrowing by blade harrow + planking with or without residue addition.
2. Significantly highest soybean productivity gross and net monetary returns were observed with combination of 2 harrowings by tyne cultivator + 1 harrowing by blade harrow + planking with or without residue addition and recommended herbicide application treatments.

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