International Journal of Applied Research 2019; 5(10): 89-95

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2019; 5(10): 89-95
www.allresearchjournal.com
Received: 07-08-2019
Accepted: 10-09-2019

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Soil physico-chemical properties and yield as influenced by tillage practices and soybean based crop sequences in inceptisol

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Abstract
The effect of tillage practices and different soybean based crop sequences on soil physico – chemical properties and yield was studied under the field experiment conducted at Research Farm of Dr. Panjaabrao Deshmukh Krishi Vidyapeeth, Akola at the end of third cropping cycle. The experimental soil was vertic haplustepts and the treatments of field experiments comprised of four main plots of soybean based crop sequence *viz*., Soybean – Safflower, Soybean – Chickpea, Soybean – Mustard, And Soybean – Rabi Sorghum while the sub plots of tillage practices comprised of No Tillage, Minimum Tillage, Conventional Tillage And Broad Bed Furrow Sowing having sixteen treatment combinations with three replications in the split design. The physical properties like bulk density and hydraulic conductivity were found to be improved under conventional tillage while under no tillage the bulk density showed significant increase and hydraulic conductivity showed significant decrease. However, the MWD was improved under minimum tillage. The minimum tillage practice recorded highest soil organic carbon and available NPK status of soil as compared to other tillage practices. Among the various cropping sequences soybean – chickpea recorded highest soil available nutrient status. The crop yield of *rabi* crops was significantly influenced under different cropping sequence.

Keywords: No tillage, inceptisol, soil biological properties, soybean, crop sequence

Introduction
The stagnation in the production and productivity of food grains for the past few years has become a matter of concern and is posing a serious threat to our national food security. Soil health degradation has emerged as a major factor responsible for the stagnation in agricultural production. In India, about 188 million ha of area is subjected to various forms of soil degradation. The degradation of soil health in many intensively cultivated areas is manifested in terms of loss of soil organic matter, depletion of native soil fertility due to imbalanced and unscientific use of fertilizers which is now one of the major constraints in improving crop productivity.
Tillage is the manipulation of soil with the help of implements to obtain a desired seed bed. Tillage is one of the most important component of conservation agriculture. It is labor-intensive activity in low resource agriculture of small land holders, and a capital and energy intensive activity in large scale mechanized farming. Judiciously used tillage can be useful asset in alleviating some of the soil related constraints such as compaction, crusting, reduced infiltration, accelerated run off and erosion, and degradation of soil and environment.
The effect of tillage practices on soil properties is being increasingly studied by the researchers and there are various thoughts on this aspect depending upon the type of soil and other management measures. In view of some indications of soil quality improvement in respect of properties especially like structure, organic carbon and some soil biological attributes due to reduced tillage practices reported by many workers it becomes necessary to ascertain the influence of different tillage practices on properties of black clayey soils predominant in semi-arid areas of Deccan plateau of Maharashtra.
In view of significant role of soil organic carbon in determining soil quality, adoption of judicious management practices to restore and upgrade soil organic carbon pool is essential. Increasing carbon sequestration in agricultural soils and making them a net sink for atmospheric carbon can be achieved by adoption of the best management practices.

This involves use of different crops and cropping systems, balanced fertilization, crop rotation, different tillage practices with reduced tillage intensities, crop residue management, use of organic manures and various soil and water conservation practices. In this context the present investigation was carried out in order to study the impact of various tillage practices and soybean based crop sequences on soil physical, chemical and biological properties in Inceptisol

Materials and Methods

Study Area

The present investigation was carried out at Integrated Farming System Research Project Farm, Dr. PDKV, Akola. Akola is situated in between 20°42'N and 77°02'E longitude at an altitude of 307.4 m above mean sea level and has a subtropical climate. The climate is characterized by three distinct season's *viz*., summer being hot and dry from March to May. Monsoon characterized as warm and rainy from June to October and winter with dry mild cold from November to February.

Experimental details

The effect of tillage practices and different soybean based crop sequences on soil physical, chemical and biological properties was studied under the field experiment conducted at Research Farm of Dr. Panjaabrao Deshmukh Krishi vidyapeeth, Akola at the end of third cropping cycle. The experimental soil was vertic haplustept (Inceptisol) and experimental net plot size was 4.6 x 2.7 m and gross plot size was 5 x 3.6 m. The treatments of field experiments comprised of four main plots of soybean based crop sequence *viz*., Soybean – Safflower (C1), Soybean – Chickpea (C2), Soybean – Mustard (C3) And Soybean – Rabi Sorghum (C4) while the sub plots of tillage practices comprised of No Tillage (T1), Minimum Tillage (T2), Conventional Tillage (T3) And Broad Bed Furrow Sowing (T4) having sixteen treatment combinations with three replications in the split design.

Soil samples were collected at 0-20 cm depth from sixteen treatment plots of all the three replications before sowing, after harvest of soybean crop and after harvest of Rabi crops. Soil samples were air dried in shade and stored in polythene bags for further analysis.

Statistical analysis

The data was analysed using analysis of variance (ANOVA) technique following the split plot design. The significane of the treatment effect was determined using F-test, and to compare significant difference between the two treatments, least significant differences (LSD) were estimated at 5 % probability level.

Result and Discussion

Soil Bulk Density

The bulk density was significantly influenced due to different tillage practices under study. The highest bulk density of soil after harvest of *rabi* crops at the end of third cycle was recorded to be 1.51 Mg m^{-3} under no tillage.

The higher bulk density in no tillage in comparison to other tillage practices implies that the restriction of tillage in these black swell-shrink soils may lead to compaction and results into high bulk density. The increase in bulk density due to reduction in tillage intensity was also reported by Acharya and Sharma (1994) [1]. The different cropping sequence did not show prominent effect on bulk density except at the before sowing of kharif crop. (Table1.)

Soil hydraulic conductivity

The hydraulic conductivity of soil influenced significantly due to different tillage practices. However, it was not significantly influenced due to cropping sequence. Hydraulic conductivity was reduced at no tillage and slightly improved in minimum tillage which was higher at conventional tillage (Table 2).

. It has shown the increasing trend from no tillage < minimum tillage < conventional tillage < broad bed furrow sowing. The higher hydraulic conductivity due to conventional tillage thus suggests that the water transmission characteristics of black clayey soils can be improved after provision of tillage however, reduction in tillage may deteriorate the soil quality in black soils. Severe reduction in hydraulic conductivity observed at no tillage has also been reported by Rajakanan *et al.* (2001) [13]. The higher hydraulic conductivity at broad bed furrow can be attributed to less compaction of soil resulting into better drainage and aeration. (Table 2)

Soil Mean Weight diameter

The mean weight diameter was significantly influenced due to tillage practices under study. The highest mean weight diameter value of soil was recorded to be 0.47 mm under no tillage as compared to other tillage practices (Table 3).

Increase in mean weight diameter by reducing tillage intensity was also reported by Lal *et al.* (1989) [8]. There was considerable reduction in organic carbon of a soil in conventional tillage which discourages better aggregation of soil particles as a result of which lowest value of mean weight diameter was recorded under conventional tillage. Soil disturbance by continous conventional tillage degrade size distribution downward and decreasing aggregate MWD has also been reported by Unger (1997) [18]. This might be due to higher loss of organic matter under conventional tillage as reported by Potter *et al.* (1998) [12] and Potter (2006) [11]. Such tillage induced changes leads to the reduction of the binding force between soil particles and thus lower MWD.

Soil organic carbon (SOC)

Soil organic carbon was significantly influenced by both of the management options under study. The various tillage practices caused significant organic carbon content of soil (Table 4) and highest organic carbon content was recorded due to no tillage. The significant increase in organic carbon content of soil in no tillage can be attributed to the less disturbance of the soil under no tillage which might have helped in preservation of more carbon in soil by reducing the oxidation of organic carbon. On the contrary the organic carbon was observed to be drastically reduced under conventional tillage indicating that the intensive tillage involving ploughing coupled with harrowing leads to significant reduction in soil organic carbon. The intermediate values of soil organic carbon have been noticed at minimum tillage which also justifies the inverse relationship between intensity of tillage and soil organic carbon contents. The broad bed furrow sowing method was also found beneficial for the enhancement of soil organic carbon which can be attributed to the better physical condition of a soil facilitating for proper air and water relationship with enhanced moisture levels that are beneficial for preservation of soil organic carbon in soil. The enhancement in soil organic carbon in soil due to less intensity of tillage has also been reported by Dick (1983) [3]. The soil organic carbon showed decreasing trend from no tillage > minimum tillage > broad bed furrow sowing > conventional tillage.

The pronounced effect of various crop sequences was noticed on organic carbon content of soil. It was observed that soil organic carbon content was relatively higher at the end of third cycle in comparison to that of second cycle indicating that there is significant enhancement in soil organic carbon due to continuous soybean based cropping sequence. Such pronounced effect of cropping systems was also observed by Sharma *et al.* (1986) [15].

Soil available nitrogen

Soil available nitrogen was not found significantly influenced due to crop sequences but numerically higher values were recorded under soybean-chickpea crop sequence (Table 5). This implies the importance of inclusion of legumes in crop sequence. Beneficial effect of legume species in restoring soil fertility and increasing availability of nitrogen in soil was also emphasized by Sonar and Zende (1984) [16]. Profound influence of tillage practices on soil available nitrogen content was recorded amongst the different tillage practices under study. Highest available nitrogen content was recorded under no tillage practice as because of less mechanical disturbance to the soil there is accumulation of large amount of organic carbon in soil which is positively correlated with the available nitrogen of the soil. Similar results were recorded by the Dick (1983) [3].

Soil available phosphorus

Soil available phosphorus was found significantly influenced due to crop sequence (Table 6). Significant variation was observed in soil available phosphorus due to tillage practices. Highest available phosphorus was recorded in no tillage treatment as compared to other tillage practices under study. This implies that high organic carbon in soil due to no tillage discourages phosphorus fixation as a result of which more phosphorus becomes readily available in the soil. Increase in available phosphorus due to reduction in tillage intensity was also reported by Khakural *et al.* (1992) [6].

Soil available potassium

Soil available potassium was found significantly influenced due to crop sequence at the start of third cycle. The highest available potassium was recorded under soybean chickpea crop sequence (Table 7). Increase in available potassium due to soybean based crop sequence in three years was also reported by Ramesh *et al.* (2009) [14].

Soil available potassium was found significantly influenced due to tillage practices. Highest available potassium was recorded in broad bed furrow sowing method of tillage practices.

Crop yield

Tillage practices although considered as useful in black soils for reduction of compaction and for improvement in water transmission characteristics was also found to be unfavorable for enhancing the carbon in soil due to its accelerated loss on oxidation under the disturbed soil conditions of intensive tillage practices. The higher soil organic carbon contents under no tillage were also found to favour the aggregation as evidenced by improved mean weight diameter of the soil. However, in view of the benefits of tillage in black soils at par yields (Table 8) obtained at all tillage practices can be justified. The crop yield showed a decreasing trend from BBF sowing> conventional tillage > minimum tillage> no tillage

The comparable yield under no tillage can be attributed to its unfavorable effect of tillage in respect of bulk density and hydraulic conductivity. The comparable yields recorded at BBF sowing implies that the favorable conditions created by BBF sowing in respect of lowering bulk density, improving hydraulic conductivity coupled with improved soil physico - chemical properties might have been useful for better growth and development (Naphade *et al.* 1993) [9]. Therefore the better management options of tillage in black clayey soils can be restriction of intensive tillage. The broad bed furrow method of sowing can be regarded as better alternative among the two extremes of no tillage and intensive conventional tillage which has been found to improve soil quality as well as crop yields in the present study. The crop yield as influenced by various tillage practices and crop sequences during the kharif and rabi has been presented in (Table 8 and 9). The yield of soybean was not significantly influenced due to different cropping sequence. However, the crop yield of rabi crops was significantly influenced under different cropping sequence.

Table 1: Soil bulk density as influenced by the tillage practice and soybean based crop Sequence

Treatments	Before sowing of *kharif* crop (Mg m^{-3})	After harvest of *kharif* (Mg m^{-3})	After harvest of *rabi* (Mg m^{-3})
Crop sequence			
C1 (Soybean-Safflower)	1.43	1.37	1.34
C2 (Soybean-Chickpea)	1.43	1.37	1.33
C3 (Soybean-Mustard)	1.45	1.35	1.34
C4 (Soybean-Rabi sorghum)	1.45	1.36	1.34
F Test	SIG	NS	NS
SE (m) ±	0.00	0.02	0.02
CD at 5%	0.01	-	-
Tillage			
T0 (No Tillage)	1.44	1.47	1.51
T1 (Minimum Tillage)	1.44	1.38	1.33
T2 (Conventional Tillage)	1.44	1.26	1.26
T3 (BBF sowing)	1.43	1.35	1.26
F test	NS	SIG	SIG
SE (m) ±	0.00	0.02	0.01
CD at 5%	-	0.05	0.04

Interaction			
F test	SIG	NS	NS
SE (m) ±	0.01	0.03	0.03
CD at 5%	0.02	-	-

Table 2: Soil hydraulic conductivity as influenced by the tillage practices and soybean based crop sequence

Treatments	Before sowing of *kharif* (cm hr^{-1})	After harvest of *kharif* (cm hr^{-1})	After harvest of *rabi* (cm hr^{-1})
Crop sequence			
C1 (Soybean-Safflower)	0.28	0.42	0.36
C2 (Soybean-Chickpea)	0.30	0.42	0.37
C3 (Soybean-Mustard)	0.28	0.37	0.38
C4 (Soybean-Rabi sorghum)	0.26	0.38	0.37
F Test	NS	NS	NS
SE (m) ±	0.02	0.03	0.01
CD at 5%	-	-	-
Tillage			
T0 (No Tillage)	0.19	0.26	0.22
T1 (Minimum Tillage)	0.26	0.34	0.33
T2 (Conventional Tillage)	0.41	0.53	0.44
T3 (BBF sowing)	0.26	0.47	0.49
F test	SIG	SIG	SIG
SE (m) ±	0.02	0.03	0.01
CD at 5%	0.05	0.07	0.04
Interaction			
F test	NS	NS	NS
SE (m) ±	0.03	0.05	0.03
CD at 5%	-	-	-

Table 3: Soil mean weight diameter as influenced by the tillage practices and soybean based crop sequence

Treatments	Before sowing of *kharif* crop (mm)	After harvest of *kharif* (mm)	After harvest of *rabi* (mm)
Crop sequence			
C1 (Soybean-Safflower)	0.29	0.34	0.35
C2 (Soybean-Chickpea)	0.29	0.36	0.32
C3 (Soybean-Mustard)	0.28	0.33	0.32
C4 (Soybean-Rabi sorghum)	0.27	0.34	0.30
F Test	NS	NS	NS
SE (m) ±	0.01	0.01	0.01
CD at 5%	-	-	-
Tillage			
T0 (No Tillage)	0.35	0.47	0.42
T1 (Minimum Tillage)	0.28	0.34	0.33
T2 (Conventional Tillage)	0.25	0.25	0.25
T3 (BBF sowing)	0.29	0.31	0.29
F test	SIG	SIG	SIG
SE (m) ±	0.01	0.01	0.01
CD at 5%	0.03	0.03	0.03
Interaction			
F test	SIG	NS	NS
SE (m) ±	0.02	0.02	0.02
CD at 5%	0.060	-	-

Table 4: Soil organic carbon as influenced by the tillage practices and soybean based crop sequence

Treatments	Before sowing of *kharif* crop (g kg^{-1})	After harvest of *kharif* (g kg^{-1})	After harvest of *rabi* (g kg^{-1})
Crop sequence			
C1 (Soybean-Safflower)	5.8	7.1	6.4
C2 (Soybean-Chickpea)	6.0	6.8	6.7
C3 (Soybean-Mustard)	5.9	6.5	7.1
C4 (Soybean-Rabi sorghum)	5.7	7.5	6.6
F Test	NS	SIG	SIG
SE (m) ±	0.01	0.01	0.01
CD at 5%	-	0.05	0.02
Tillage			
T0 (No Tillage)	6.8	8.9	8.1
T1 (Minimum Tillage)	5.9	6.4	7.5
T2 (Conventional Tillage)	5.1	5.5	5.3
T3 (BBF sowing)	5.3	7.3	5.9
F test	SIG	SIG	SIG

SE (m) ±	0.02	0.02	0.01
CD at 5%	0.06	0.07	0.03
Interaction			
F test	NS	NS	SIG
SE (m) ±	0.04	0.05	0.02
CD at 5%	-	-	0.25

Table 5: Soil available nitrogen as influenced by the tillage practices and soybean based crop sequence

Treatments	Before sowing of *kharif* crop (kg ha^{-1})	After harvest of *kharif* (kg ha^{-1})	After harvest of *rabi* (kg ha^{-1})
Crop sequence			
C1 (Soybean-Safflower)	165.73	176.71	169.03
C2 (Soybean-Chickpea)	177.81	188.78	176.71
C3 (Soybean-Mustard)	174.51	175.61	167.93
C4 (Soybean-Rabi sorghum)	163.54	174.52	174.52
F Test	NS	NS	NS
SE (m) ±	4.74	4.74	6.67
CD at 5%	-	-	-
Tillage			
T0 (No Tillage)	214.03	222.81	230.49
T1 (Minimum Tillage)	182.20	189.88	193.17
T2 (Conventional Tillage)	140.49	144.88	136.10
T3 (BBF sowing)	144.88	158.06	128.42
F test	SIG	SIG	SIG
SE (m) ±	3.76	4.26	4.06
CD at 5%	10.98	12.44	11.84
Interaction			
F test	SIG	NS	NS
SE (m) ±	7.52	8.52	8.12
CD at 5%	21.96	-	-

Table 6: Soil available phosphorus as influenced by the tillage practices and soybean based crop sequence

Treatments	Before sowing of *kharif* crop (kg ha^{-1})	After harvest of *kharif* (kg ha^{-1})	After harvest of *rabi* (kg ha^{-1})
Crop sequence			
C1 (Soybean-Safflower)	17.86	17.01	17.28
C2 (Soybean-Chickpea)	19.26	19.03	19.13
C3 (Soybean-Mustard)	18.31	18.52	18.73
C4 (Soybean-Rabi sorghum)	17.57	17.68	17.37
F Test	SIG	SIG	NS
SE (m) ±	0.28	0.35	0.46
CD at 5%	0.96	1.19	-
Tillage			
T0 (No Tillage)	22.17	22.40	23.46
T1 (Minimum Tillage)	18.53	18.31	19.29
T2 (Conventional Tillage)	14.59	14.97	14.34
T3 (BBF sowing)	17.69	16.56	15.42
F test	SIG	SIG	SIG
SE (m) ±	0.36	0.47	0.38
CD at 5%	1.06	1.36	1.10
Interaction			
F test	NS	NS	NS
SE (m) ±	0.72	0.93	0.75
CD at 5%	-	-	-

Table 7: Soil available potassium as influenced by the tillage practices and soybean based crop sequence

Treatments	Before sowing of *kharif* (kg ha^{-1})	After harvest of *kharif* (kg ha^{-1})	After harvest of *rabi* (kg ha^{-1})
Crop sequence			
C1 (Soybean-Safflower)	371.03	372.37	374.41
C2 (Soybean-Chickpea)	378.85	380.81	381.93
C3 (Soybean-Mustard)	370.19	374.72	376.32
C4 (Soybean-Rabi sorghum)	366.56	371.29	369.48
F Test	SIG	NS	NS
SE (m) ±	1.26	2.48	2.65
CD at 5%	4.37	-	-
Tillage			
T0 (No Tillage)	355.29	358.51	359.08
T1 (Minimum Tillage)	368.31	376.73	373.54
T2 (Conventional Tillage)	378.68	381.23	383.10

T3 (BBF sowing)	384.36	382.72	386.41
F test	SIG	SIG	SIG
SE (m) ±	1.19	2.59	2.23
CD at 5%	3.48	7.57	6.50
Interaction			
F test	SIG	NS	NS
SE (m) ±	2.39	5.19	4.46
CD at 5%	6.97	-	-

Table 8: Yield of soybean as influenced by the different tillage practices and soybean based crop sequences.

Treatments	Yield (q ha^{-1})	
	Grain	Straw
Crop sequence		
C1 (Soybean-Safflower)	15.10	38.88
C2 (Soybean-Chickpea)	14.00	38.15
C3 (Soybean-Mustard)	13.55	40.25
C4 (Soybean-Rabi sorghum)	14.06	40.26
F Test	NS	NS
SE (m) ±	1.14	2.61
CD at 5%	-	-
Tillage		
T0 (No Tillage)	14.21	39.07
T1 (Minimum Tillage)	14.52	39.39
T2 (Conventional Tillage)	14.72	37.85
T3 (BBF sowing)	13.26	41.43
F test	NS	NS
SE (m) ±	0.56	1.28
CD at 5%	-	-
Interaction		
F test	NS	NS
SE (m) ±	1.12	2.56
CD at 5%	-	-

Table 9: Yield of rabi crops (q ha^{-1}) as influenced by the different tillage practices and crop sequences

Treatments	Rabi yield (q ha^{-1})	
	Grain	Straw
Crop sequence		
C1 (Soybean-Safflower)	19.69	37.31
C2 (Soybean-Chickpea)	19.09	30.56
C3 (Soybean-Mustard)	8.81	27.11
C4 (Soybean-Rabi sorghum)	29.22	76.82
F Test	0.97	1.85
SE (m) ±	3.36	6.42
CD at 5%	17.49	14.94
Tillage		
T0 (No Tillage)	16.91	37.81
T1 (Minimum Tillage)	18.05	40.79
T2 (Conventional Tillage)	20.15	45.39
T3 (BBF sowing)	21.71	47.81
F test	0.71	0.91
SE (m) ±	2.41	3.06
CD at 5%	12.88	7.32

Conclusion

It can be concluded that soybean-chickpea crop sequence is beneficial for improving soil fertility status however, the broad bed furrow method of sowing can be regarded as better alternative among the two extremes of no tillage and intensive conventional tillage which has been found to improve soil physico – chemical properties of soil as well as crop yields.

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