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Soil quality and yield as influenced by tillage practices and soybean based crop sequence in inceptisol

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Abstract
The present investigation entitled was conducted at Integrated Farming System Research Project Farm, Dr. PDKV, Akola during the year 2009-2010 to study the impact of Tillage practices and Soybean based crop sequences on soil quality and yield of the crops under study. Soil samples were collected before sowing and after harvest of kharif and *rabi* crops and analyzed for the Soil Physical, Chemical and Biological properties for identifying soil quality indicators and evaluating Soil Quality Index. Thus soil organic carbon, available nitrogen, and hydraulic conductivity and mean weight diameter were identified as soil quality indicators amongst the all soil parameters. Soil quality index was significantly influenced due to tillage practices. The interaction effect of tillage practices and soybean based crop sequence was significant. The highest soil quality index (1.198) was recorded at no tillage under soybean-mustard crop sequence. 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.

Keywords: Soil quality, soil quality indicators, tillage, cropping sequence, Inceptisols

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. Sustaining Soil quality is the most appropriate method to ensure sufficient food to support life. Maintenance of soil organic carbon is the most important attribute of soil quality. Soil organic matter being a store house of all essential plant nutrients, plays an important role in crop production and soil organic matter together with physical properties has been proposed as indicator of soil quality (Doran and Parkin, 1994) [1]. Important indicators of soil quality in relation to soil organic carbon content are mean weight diameter (MWD) of aggregates, available water holding capacity, cation exchange capacity and bulk density. The relative importance of these indicators varies among different soils and therefore, site specific information is needed for qualitative assessment of soil quality (Lal *et al*., 1989) [2]. 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 is carried out in order to study the impact of various tillage practices and soybean based crop sequences on soil physical, chemical and biological properties and soil quality in Inceptisol.

Material and Method

A field experiment on different tillage and planting practices for soybean based crop sequences was initiated during 2007-08 at Integrated Farming System Research Project Farm, Dr. PDKV, Akola. The present investigation entitled "Soil quality and yield as influenced by Tillage Practices and soybean based Crop Sequences in Inceptisol" was conducted during 2009-10 (Third cycle) to study the impact of various tillage and crop sequences on soil quality and yield of the crops under study. The experiment was laid out in split plot design with three replications and 48 treatment combinations with main plot as soybean based crop sequence *viz*, C1- Soybean - Safflower, C2 - Soybean – Chickpea, C3 – Mustard, C4 – Soybean – Rabi Sorghum. While sub plot as Tillage practices *viz.* T0 –No tillage (Sowing without intercultivation and weed control by chemical method), T1 – Minimum Tillage (1 Harrowing + 1 Hoeing), T2- Conventional tillage. (2 harowing + 2 hoeing + 2 hand weeding) T3 – Broad bed furrow (1 harrowing + 2 hoeing + 2 hand weeding). 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. The air dried samples were carefully and gently ground with the wooden pestle to break soil lumps (clods) and were passed through sieve of 2 mm diameter. The sieved samples were mixed thoroughly and stored in polythene bags, properly labeled.

Soil quality index

Soil quality index was determined by linear scoring method from principle component analysis of variables described by Doran and Parkin (1994) [1].

For assessment of soil quality as influenced by various tillage practices and crop sequences the following steps were followed. First of all seventeen parameters were used for principle component analysis and the minimum data set was selected the scoring of minimum data set was done and the soil quality index was computed using following equation.

$$SQI = \frac{n}{I=1} \Sigma \, si. \, wi$$

Where,

S = score for subscripted variables

W = factor loading derived from PCA.

Statistical analysis

Statistical analysis will be carried out as per procedure prescribed by Panse and Sukhatme (1985) [3].

Result and Discussion

Crop yield as influenced by tillage practices

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. The no tillage practice was also found to favor the soil biological attributes. This has resulted into enhancement in soil quality under no tillage. However, in view of the benefits of tillage in black soils at par yields obtained at all tillage practices can be justified. The crop yield showed a decreasing trend from BBF sowing> conventional tillage > minimum tillage> no tillage.

Table 1: 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 2: 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

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 chemical and biological properties might have been useful for better growth and development.

It thus becomes apparent here that the tillage practice seems to be necessary in black clayey soils for improving certain physical characteristics of soil like bulk density and hydraulic conductivity. It is due to the very high clay contents generally more than 50 per cent in black clayey swell shrink soils that for better physical properties in order to facilitate better water transmission and reduce compaction the tillage practices are beneficial. However, at the same time the intensive tillage practices may lead to loss of organic carbon due to wide exposure under intensive tillage which leads to deterioration in soil quality. 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 1 and 2). 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.

Soil Quality as influenced by Tillage practices and Soybean based crop sequence

A) Assessment of soil quality

For assessing the soil quality as influenced by various treatments the following steps were followed

Selection of indicators

Seventeen parameters were used for principle component analysis.

Selection of minimum data set (MDS)

The soil parameters (physical, chemical and biological) which are most sensitive to management practices were determined and principle component analysis (PCA) was carried out. Minimum data set was retained based on the factor loadings these parameters were called as soil indicators.

Scoring of minimum data set indicators

After determining the MDS of indicators, every observation of MDS indicators was transformed using linear scoring method. Indicators were arranged in order depending on weather a higher value was considered “good” or ”bad” in terms of soil functions. For more is better indicators each observation was divided by the highest value such that the highest observed value received a score of 1. For less is better indicators, the lowest observed value was divided by each observations such that he lowest observed value received the score of 1.

Soil quality index (SQI)

SQI was determined by using the following equation

$$SQI = \frac{n}{i=1} \Sigma(Wi\ Si)$$

Where,
S = Score for subscripted variable.
W= Factor loading derived from the PCA.

Results of Principle Component Analysis

In PCA seventeen variables were used. The PC1, PC2 and PC3 which explained about 5% variability within the measured data were retained. Highest weighted variables under PC1, PC2 and PC3 included Soil organic carbon, fungi population during kharif, bacterial population during rabi, soil microbial biomass carbon (SMBC) during kharif, hydraulic conductivity, fungi during rabi, mean weight diameter and actinomycetes during rabi respectively.

Table 3: Principle component analysis (PCA) of soil parameters

Soil Parameters	Factor loading		
	PC1	PC2	PC3
Soil organic carbon	0.277	0.107	0.144
Soil available N	0.264	-0.221	-0.176
Soil available P	0.257	0.213	-0.274
Soil available K	-0.258	0.084	0.210
Soil bulk density	0.270	-0.085	-0.287
Mean weight diameter	0.251	-0.057	-0.446
Hydraulic conductivity	-0.111	0.559	0.057
Water retention(%)33kpa	0.284	-0.015	0.052
Water retention(%) 1500kpa	0.28	-0.102	0.384
SMP Fungi kharif	-0.279	-0.084	0.005
SMP Bacteria kharif	0.214	0.349	0.158
SMP Actinomycetes Kharif	-0.091	0.394	-0.140
SMP fungi rabi	-0.189	0.417	-0.160
SMP Bacteria rabi	-0.273	-0.165	0.133
SMP Actinomycetes rabi	0.243	-0.010	0.469
SMBC kharif	0.264	0.217	-0.020
SMBC rabi	0.263	0.148	0.292
5% variation from the highest factor value			

Table 4: Correlation matrix under PC’s with high factor loading

PC1	Variables	SOC	Avail N	Bulk density	Water retention (33kpa)	Fungi kharif	Bacteria rabi	SMBC kharif
	SOC	1						
	Avail N	0.749	1					
	BD	0.646	0.813	1				
	WR	0.309	0.376	0.215	1			
	Fungi kharif	0.003	-0.019	0.067	-0.071	1		
	Bacteria rabi	-0.036	-0.150	0.074	-0.563	0.007	1	
	SMBC Kharif	0.7667	0.738	0.707	0.328	-0.066	-0.240	1
	Correlation sum	3.7037	3.138	2.063	1.962	1.073	1.24	1
PC2	Variables	HC	Fungi rabi					

	HC	1						
	Fungi rabi	-0.286	1					
	Correlation sum	1.286	1					
PC3	Variables	MWD	Actinomy-cetes rabi					
	MWD	1						
	Actinomycetes rabi	-0.105	1					
	Correlation sum	1.105	1					

Was assumed that the variables having the highest correlation sum best represented the group. Thus soil organic carbon, available nitrogen, hydraulic conductivity and mean weight diameter were identified as soil quality indicators amongst the all soil parameters.

Table 5: Soil quality index as influenced by tillage practices and soybean based crop sequence

Treatments	**Soil quality index**
Crop sequences	
C1 (Soybean-Safflower)	1.123
C2 (Soybean-Chickpea)	1.116
C3 (Soybean-Mustard)	1.116
C4 (Soybean-Rabi sorghum)	1.09
F Test	NS
SE (m) ±	0.02
CD at 5%	0.06
Tillage	
T0 (No Tillage)	1.145
T1 (Minimum Tillage)	1.120
T2 (Conventional Tillage)	1.040
T3 (BBF sowing)	1.141
F test	**SIG**
SE (m) ±	0.01
CD at 5%	0.03
Interaction	
F test	SIG
SE (m) ±	0.023
CD at 5%	0.069

Table 6: Soil quality index as influenced by interaction of tillage practices and soybean based crop sequence

Interaction	**Crop sequence**			
Tillage	**C1 (Soybean-Safflower)**	**C2 (Soybean-Chickpea)**	**C3 (Soybean-Mustard)**	**C4 (Soybean-Rabi Sorghum)**
T0 (No tillage)	1.160	1.064	1.198	1.160
T1 (Min. tillage)	1.108	1.152	1.110	1.109
T2 (Conv. tillage)	1.074	1.084	1.008	0.995
T3 (BBF sowing)	1.150	1.164	1.148	1.101
F Test	SIG	-	-	-
SE (m) ±	0.023	-	-	-
CD at 5%	0.069	-	-	-

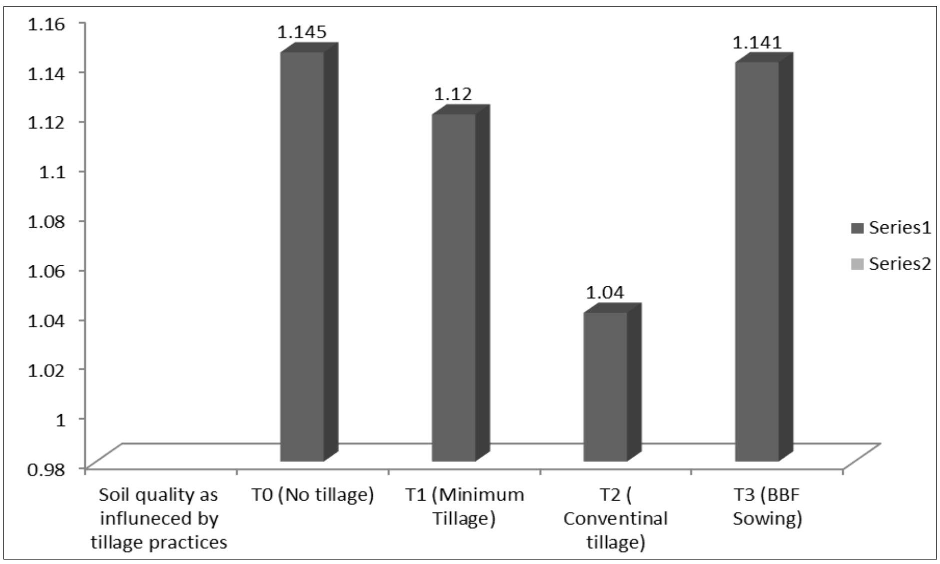

Fig 1: Soil Quality as influenced by tillage practices

Soil quality index was not influenced significantly due to various crop sequence but it was significantly influenced due to tillage practices. The interaction effect of tillage practices and soybean based crop sequence was significant. The highest soil quality index (1.198) was recorded at no tillage under soybean-mustard crop sequence. Soil Quality Index was observed to be drastically reduced under conventional tillage at all the crop sequences indicting that there is severe soil quality deterioration as compared to no tillage. However, the BBF sowing was found useful in respect of soil quality index and recorded the values on par with those obtained at no tillage.

Conclusion

It can be concluded that, no tillage was found useful for enhancement in soil quality and the soil organic carbon, available N, hydraulic conductivity and mean weight diameter were found as most predominant soil quality indicators in swell shrink soils. While 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.

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