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Long Term Effect of Tillage and Integrated Nutrient Management on Soil Quality and Productivity of Rainfed Cotton in Vertisols under Semi-Arid Conditions of Maharashtra

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ABSTRACT: A field experiment was conducted to study the effect of integrated nutrient management in conventional and reduced tillage system on soil quality and productivity of rainfed cotton in Vertisols at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. The experiment was carried out during 2005-06 to 2009-10 in Factorial Randomized Block Design with twelve treatment combinations and three replications. The treatments consisted of tillage (conventional and minimum), nutrient management *viz.,* 100% RDF, 50% RDF with graded doses of farmyard manure (5, 10 and 15 t/ha) and in situ green manuring with dhaincha (*Sesbania aculeata*). The pooled results revealed that numerically higher seed cotton yield and sustainable yield index (SYI) was recorded in minimum tillage as compared to conventional tillage. The application of 50% RDF + FYM @ 15 t/ha recorded significantly higher seed cotton yield, SYI and soil quality index (SQI) alongwith significant improvement in physical, chemical and biological properties of Vertisols. However, application of FYM @ 10 t/ha along with 50% RDF also sustained the cotton productivity and was on par with application of FYM @ 15 t/ha + 50% RDF in respect of cotton productivity and soil fertility. Hence, it is recommended that the integrated application of FYM @ 10 t/ha along with 50% RDF was beneficial in improving soil quality and sustaining the rainfed cotton productivity in Vertisols under semi-arid conditions of Maharashtra.

Key words: Integrated nutrient management, seed cotton, soil quality index, sustainable yield index, tillage, Vertisols

Cotton is one of the important cash crop and plays vital role in the economy of the farmer as well as country. India rank second in world as regard to area and production of cotton. Vidarbha is a major cotton and cotton-based cropping system growing region in central India where it is grown predominantly as rainfed crop on medium to deep Vertisols (Mandal *et al.,* 2005). The major production constraints of Vertisols are poor physical properties like high bulk density, low hydraulic conductivity, formation of wide and deep cracks and narrow range of moisture for field operation (Murthy, 1988). The low content of soil organic carbon in Vertisols in addition to low availability of N, P and Zn resulted in unsustainable productivity of cotton and cotton-based cropping system (Blaise *et al.,* 2005) and thereby deteriorating soil health.

When cotton is grown continuously, there is soil structural degradation, particularly due to shearing and compaction during tillage operations and fertility decline because of the wider nutrient removal use gap (Hullugalle *et al.,* 2007). Its low productivity in Vidarbha region is largely attributed to the quantity and distribution of rainfall, inadequate fertilizer schedule and poor fertilization which results in deterioration of soil health. Thus, the soil quality (physical, chemical and biological) of Vertisols in rainfed semi-arid tropical (SAT) conditions deteriorates and thereby results in low crop productivity. Because of rapid oxidation of organic matter, maintaining or improving organic carbon in tropical soil is difficult (Lal *et al.,* 2003), even though, maintaining or improvement in SOM is a prerequisite to ensuring soil sustainability, productivity and soil quality.

Now a days, the fertilizer requirements are increasing due to adoption of new high yielding hybrids in intensive cultivation. Therefore, to maintain crop productivity, the use of chemical fertilizers in balanced quantity is important. But looking into the continuous increasing prices of fertilizers, it becomes necessary to minimize the expenses on fertilizers by using alternative sources like farmyard manure, crop residues, green manuring along with reduced tillage practices for sustaining the crop yields and soil fertility. These practices not only increase the crop yield but also improve the physical, chemical and biological properties of soil. The long term integrated application of chemical fertilizers with organic manures improves soil physical, biological properties and soil fertility and crop yields. When integrated nutrient management through chemical fertilizers and different organic sources are applied on long term basis, they show beneficial impact on soil quality (Swarup, 2010).

Doran and Parkin (1994) suggested that soil quality assessments could be used as a management tool or aid to help farmers select specific management practices and as a measure of sustainability. They adapted the use of a minimum data set (MDS) recommendations and proposed several soil physical, chemical, and biological characteristics that should be included as basic indicators of soil quality. The systematic assessment of soil quality in other parts of India was also reported by Chaudhury *et al.* (2005), Sharma *et al*. (2005; 2009), Singh (2007) and Masto *et al*. (2007). However, most of these studies are carried out in irrigated and rice-based cropping system. Such assessment on soil quality influenced by tillage and integrated nutrient management in cotton based cropping system in dryland Vertisols is limited. Therefore, considering the importance of soil quality under rainfed Vertisols in central India, the present investigation was carried out to find out the effect of tillage and integrated nutrient management on sustaining cotton productivity, physical, chemical and biological quality of Vertisol and identify the most suitable tillage and nutrient management practice under semi-arid conditions.

Materials and Methods

The experiment was conducted at Research Farm, Department of Soil Science and Agril. Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra during 2005-06 to 2009-10. The experimental site is located at 22°42′ N and 77°02′E and 307.4 m above mean sea level. The climate is hot semi-arid tropical with a mean annual rainfall of 750 mm. The mean maximum temperature ranges from 35.4 to 31.6°C during summer months and mean minimum temperature ranges from 12.5 to 13.2°C during the winter season. The mean annual maximum and minimum temperatures were 31.05 and 20.84°C, respectively. The mean annual rainfall is 693.7 mm (average of 5 years).

The soil of the experimental site is deep black with clay texture and classified as Typic Haplustert of Vertisols. The initial soil properties (2005) indicate that the soil is moderately alkaline in pH (8.1), low in available N (180 kg/ha) and P (12.10 kg/ha) and high in available potassium (365.5 kg/ha). The experiment was laid out in factorial randomized block design with twelve treatment combinations and three replications. The treatments consisted of tillage (conventional and minimum) and integrated nutrient management *viz.,* F1-100% RDF, F2-50% RDF, F3-50% RDF + FYM @ 5 t/ha, F4-50% RDF + FYM @ 10 t/ha, F5- 50% RDF + FYM @15 t/ha and F6-50% RDF + in situ green manuring of Dhaincha (*Sesbania aculeata*).

The farmyard manure was applied one month before sowing on oven dry basis. Dhaincha was sown in between two rows of cotton and buried 40 days after sowing. The recommended fertilizer dose 50: 25:00 kg N, P_2O_5 and K_2O per hectare was applied to cotton. Full quantity of the phosphorus was applied as a basal dose through single super phosphate. Nitrogen was applied through urea in two split application, half at the time of sowing and half at 30 DAS to cotton. Samples of Dhaincha were collected from one meter row length of the green manure plots and the dry matter was determined after oven drying at 65° C.

The soil samples (0-30 cm depth) were collected after the harvest of crop year wise, dried and ground. These samples were analysed for various parameters as per standard methods (Jackson, 1973). The fresh soil samples collected during grand growth stage of cotton were immediately used for estimating biological properties as per standard methods (Casida *et al.,* 1964, Jenkinson and Powlson, 1976 and Jenkinson and Ladd, 1981).

Soil quality assessment

The data on effect of tillage and integrated nutrient management on soil physical, chemical and biological indicators were tested for their level of significance using factorial randomized block design and the qualified variables were considered for computation of soil quality analysis using principal component analysis (PCA) and linear scoring technique (LST). The sustainable yield index was computed on the basis of the yield obtained from 2005-06 to 2009-10 and annual rainfall (Vittal *et al.,* 2002). The regression of mean yield with annual rainfall was derived, then the estimate of error (σ) was computed. Based on the following equation, SYI was calculated.

$$SYI = \frac{Y- \sigma}{Y_{max}}$$

Where, Y is the estimated average yield of a practice across the years, σ is its estimated standard error based on average rainfall of five years and Y_{max} is the observed maximum yield in the experiment during the years of cultivation.

The maximum data set (MDS) were identified as per the procedure suggested by Doran and Parkin (1994), Andrews *et al.* (2002) and followed by Sharma *et al.* (2008). Subsequently, the data were subjected to principal component analysis. As per the criteria suggested by Brejda *et al.* (2000), those principal components which received eigen values near to 1 which explained at least 5% of the variation in the data (Wander and Bollero, 1999) and which had high factor loading were considered as the best representative of system attributes.

Within each PC, only highly weighted factors were retained for MDS. After determining the MDS of indicators, every observation of MDS indicators was transformed using linear scoring method (Andrews *et al.,* 2002). Indicators were arranged in order depending on whether a higher value was considered "good" or "bad" in terms of soil function. 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 observation such that the lowest observed value received the score of 1.

After performing these steps, to obtain soil quality index (SQI), the weighted MDS indicator scores for each observation were summed up using the following relation (Sharma *et al.,* 2005):

$$SQI = \sum_{i=1}^{n} (W_i \times S_i)$$

Where,

S = Score for subscripted variable.

W = Factor loading derived from the PCA.

Results and Discussion

Effect of tillage and integrated nutrient management on seed cotton yield

The higher seed cotton yield was observed in minimum tillage as compared to conventional tillage (Table 1). However, results are statistically non-significant. Tennakoon and Hulugalle (2006) also observed non-significant effect on the cotton yield due to minimum tillage on a Vertisol.

The seed cotton yield was significantly affected due to the various nutrient management treatments during all the years of experimentation (Table 1). The highest seed cotton yield was obtained with the application of 50% RDF + FYM @15 t/ha which was superior over rest of the treatments during 2006-07 and 2007-08. However, during 2005-06, 2008-09, 2009-10 and in pooled mean the application of 50% RDF + FYM @10 t/ha was on par with this treatment. The application of 100% RDF through chemical fertilizers was on par with the integrated use of 50% RDF + 50% RDF + FYM @10 t/ha during first four years of study, while during fifth year and in pooled results, the difference was significant. This clearly indicated that the balanced nutrition through only chemical fertilizers did not sustain the cotton yield on long run compared with conjunctive use of organic and inorganic fertilizers. The pooled results indicated that the application of 50% RDF + FYM @ 15 t/ha recorded significantly highest seed cotton yield (16.04 q/ha) which was at par with the application of 50% RDF + FYM @ 10 t/ha (14.89 q/ha). The seed cotton yield obtained in treatment 100% RDF (13.58 q/ha) and 50% RDF + green manuring (12.60 q/ha) were statistically at par with each other and superior over only 50% RDF. The increase in the yield due to 50% RDF + FYM @ 15 t/ha was 7.72 and 18.11% higher over 50% RDF + FYM @ 10 t/ha and 100% RDF, respectively. In other treatments the yield trend was 50% RDF + FYM @ 10 t/ha ≥ 100% RDF ≥ 50% RDF + in situ green manuring. The lowest seed cotton yield (0.87 t/ha) was recorded in 50% RDF.

The interaction effect between tillage and nutrient management with respect to seed cotton was found to be non-significant.

Sustainability yield index

The data in respect of sustainable yield index (SYI) is presented in Table 2. The SYI was higher (0.32) in minimum tillage as compared to conventional tillage (0.30). Among the nutrient management treatments, highest SYI (0.56) was recorded with 50% RDF + FYM @ 15 t/ha followed by 50% RDF + FYM @ 10 t/ha (0.50). The application of FYM @ 10 t/ha along with 50% RDF recorded 16.28% higher SYI over 100% RDF. While, application of FYM @ 15 t/ha along with 50% RDF recorded 30.23% higher SYI over 100% RDF. Nayak *et al.* (2012) also observed highest SYI under rice- wheat system with NPK + FYM over NPK alone or NPK + crop residue.

Effect of tillage and integrated nutrient management on soil quality indicators

The data on various soil quality indicators as influenced by various treatments are presented in Table 3. The results revealed that bulk density, hydraulic conductivity and mean weight diameter did not show significant improvement due to tillage practices. The infiltration rate was significantly higher

Table 1 : Seed cotton yield (q/ha) as influenced by various treatments

	Treatments	2005-06	2006-07	2007-08	2008-09	2009-10	Pooled mean
	(a) Tillage						
T_1	Conventional tillage	12.82	12.18	13.72	13.67	11.90	12.85
T_2	Minimum tillage	13.81	12.92	13.98	12.95	12.05	13.13
	SEm±	0.63	0.99	0.18	0.36	0.40	0.229
	CD (P=0.05)	NS	NS	NS	NS	NS	NS
	(b) Nutrient Management						
F_1	100% RDF	13.24	12.78	14.56	14.72	12.58	13.58
F_2	50% RDF	9.86	9.78	9.67	7.63	6.58	8.70
F_3	50% RDF + FYM @ 5 t/ha	11.94	11.78	12.64	13.25	11.04	12.13
F_4	50% RDF + FYM @ 10 t/ha	15.92	13.48	15.02	15.13	14.89	14.89
F_5	50% RDF + FYM @ 15 t/ha	16.40	15.47	16.97	16.72	14.94	16.04
F_6	50% RDF + GM (Dhaincha)	12.53	12.00	14.23	12.41	11.85	12.60
	SEm±	1.08	0.62	0.316	0.62	0.70	0.40
	CD (P=0.05)	3.19	1.82	0.928	1.83	2.05	1.17
	Interaction effect	NS	NS	NS	NS	NS	NS

Table 2 : Effect of tillage and nutrient management on sustainable yield index (SYI) of cotton

Treatments	CT	MT	Mean
	Sustainable yield index		
100% RDF	0.42	0.44	0.43
50% RDF	0.18	0.19	0.18
50% RDF + FYM @ 5 t/ha	0.35	0.37	0.36
50% RDF + FYM @ 10 t/ha	0.50	0.50	0.50
50% RDF + FYM @ 15 t/ha	0.55	0.56	0.56
50% RDF + GM (Dhaincha)	0.37	0.39	0.38
Mean	0.30	0.32	-

Table 3 : Effect of tillage and integrated nutrient management on soil quality indicators

Treatments	BD ($Mg\ m^{-3}$)	HC (cm/hr)	IR	AWC (cm/m)	MWD (mm)	pH (1:2.5)	EC (dS/m)	OC (g/kg)	Available nutrients (kg/ha) N	P	K	SMBC (mg/kg)	SMBN	DHA (µg/g 24/hr)
(a) Tillage														
Conventional tillage	1.31	0.70	2.69	19.10	0.66	8.00	0.32	5.58	223.1	13.08	378.9	237.1	33.1	47.2
Minimum tillage	1.32	0.68	2.47	21.02	0. 67	8.00	0.31	5.72	228.1	13.31	381.7	243.1	36.8	50.4
SEm±	0.006	0.01	0.017	0.527	0.01	0.013	0.008	0.07	2.21	0.29	2.74	1.96	0.82	0.91
CD (P=0.05)	NS	NS	0.051	1.55	NS	NS	NS	NS	NS	NS	NS	5.75	2.41	2.68
(b) Nutrient Management														
100% RDF	1.33	0.62	2.38	18.69	0.63	8.04	0.35	5.76	235.4	13.46	363.4	223.6	29.95	43.7
50% RDF	1.35	0. 59	2.18	15.81	0.53	8.05	0.36	4.28	159.5	11.43	349.2	195.1	25.12	38.6
50% RDF + FYM @ 5 t/ha	1.32	0.67	2.44	18.99	0.66	8.02	0.31	5.68	205.6	12.89	382.4	237.1	32.58	48.18
50% RDF + FYM @ 10 t/ha	1.32	0.73	2.79	21.93	0.72	7.99	0.29	6.03	250.2	13.72	396.1	263.5	40.05	55.05
50% RDF + FYM @ 15 t/ha	1.29	0.79	3.03	24.28	0.76	7.96	0.28	6.33	260.5	14.69	402.5	281.6	46.8	58.12
50% RDF + GM(Dhaincha)	1.31	0.73	2.66	20.66	0.70	7.97	0.31	5.83	242.5	12.98	388.6	239.7	35.25	49.11
SEm±	0.011	0.018	0.03	0.91	0.017	0.023	0.013	0.121	3.84	0.50	4.74	3.40	1.42	1.58
CD (P=0.05)	0.031	0.051	0.089	2.68	0.051	NS	0.039	0. 35	11.25	1.47	13.91	9.96	4.17	4.64
Interaction effect	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

in conventional tillage compared to minimum tillage. Higher infiltration rate in deep tillage was attributed to reduced bulk density and increased porosity. Similarly, Patil and Sheelavantar (2006) also observed reduction in bulk density and increase in infiltration rate due to deep tillage in black soils of semi arid region. The available water capacity and mean weight diameter was significantly higher in minimum tillage compared to conventional tillage. These results indicated that even up to five years of minimum tillage had no significant changes in Vertisols of semi-arid region. Among the integrated nutrient management treatments, significantly lowest BD (1.29 $Mg\ m^{-3}$) was observed in treatment receiving 50% RDF + FYM @ 15 t/ha followed by in situ green manuring (dhaincha), application of FYM @ 10 & 5 t/ha along with 50% RDF which were found on par with each other. The significantly highest HC, IR, and AWC were noticed in treatment of 50% RDF + FYM @ 15 t/ha which was superior over rest of the treatments. While application of FYM @ 10 t/ha + 50% RDF was on par with FYM @ 15 t/ha + 50% RDF in respect of MWD. The improvement in HC in 50% RDF + FYM @ 15 t/ha treatment was 8.22, 8.22 and 17.91% higher than that of FYM 10 t/ha, green manuring and FYM 5 t/ha along with 50% RDF, respectively. In other treatments, the improvement in HC was in the order of 50% RDF + in situ green manure ≥ 50% RDF + FYM @ 10 t/ha > 50% RDF + FYM @ 5 t/ha.

The tillage practices did not show any significant change on pH, EC and organic carbon of soil. While, slight improvement in OC (5.72 g/kg) was observed in minimum tillage compared to conventional tillage. Lower organic C with intensive tillage is frequently reported in the literature, and appears to be due to rapid microbial decomposition by incorporation of crop residues during tillage (Doran *et al.*,1994).

The integrated nutrient management also did not influence the pH of soil indicating high buffering capacity of Vertisol having smectic minerals. The pH of soil ranged from 7.96 to 8.05. The application of FYM and in situ green manuring of dhaincha significantly lowered the EC of soil over 100% RDF through chemical fertilizers. The highest OC (6.33 g/kg) was observed in 50% RDF + FYM @ 15 t/ha followed by 50% RDF + FYM @ 10 t/ha (6.03 g/kg) which were found to be on par with each other. Organic carbon content of soil is an indication of organic fraction in soil from the microbial decomposition of organic residues and its amount depends upon the type and quality of organic matter and also stage of decomposition. Tolanur and Badanur (2003) also reported that organic carbon content in soils increased significantly with incorporation of FYM or green manuring in combination with 50% RDN through fertilizer as compared with recommended dose of fertilizers.

The residual soil fertility (available N, P and K) was slightly enhanced in minimum tillage. However, the improvement was not significant over conventional tillage. The significantly highest availability of N (260.5 kg/ha) was observed with the application of 50% RDF + FYM @ 15 t/ha which was superior over rest of the treatments. The increase in available N might be due to direct addition of N through FYM and green manure to the available pool of soil (Tolanur and Badanur, 2003). The highest available P (14.69 kg/ha) was observed in treatment 50% RDF + FYM @ 15 t/ha followed by application of 50% RDF + FYM @ 10 t/ha which were on par with each other. While, in case of availability of K, the application of FYM @ 10 t/ha and in situ green manuring of dhaincha was on par with FYM @ 15 t/ha + 50% RDF. The availability of phosphorus in conjunctive use of organics and inorganic might be due to minimization of P fixation in soil and direct addition of P in soil. Singh *et al*. (2001) explained that significant increase in available K content has been due to either FYM or green manure along with fertilizers N, suggesting that FYM and green manure helped to maintain the supply of K by releasing the K from reserve source.

The tillage practices had significant influence on biological properties of soil. Significant improvement in these properties was observed in minimum tillage compared to conventional tillage. Among the various nutrient management treatments, significantly highest improvement in SMBC (281.6 mg/kg) and SMBN (46.8 mg/kg) was noticed under the plots receiving 50% RDF + FYM @ 15 t/ha which was superior over rest of the treatments. While, in case of DHA, the application of 50% RDF + FYM @ 10 t/ha was found on par with the application of 50% RDF + FYM @ 15 t/ha.

Selection of indicators

The effect of tillage and integrated nutrient management on various soil properties are presented in Table 4. The tillage had significant influence on five variables (IR, AWC, SBMC, SMBN and DHA) among 14 variables studied. While, a significant influence of integrated nutrient management was observed on all variables except pH. All parameters were retained for PCA analysis considering their importance.

Table 4 : Principal component analysis (PCA) of soil parameters based on 12 treatment combinations

Soil parameters	Factor loading		
	PC1	PC2	PC3
Total eigen values	8.777	1.313	0.834
Variance (%)	62.695	9.376	5.959
Cumulative variance (%)	62.695	72.071	78.030
Eigen vectors			
Bulk density	-0.091	-0.617	-0.429
Hydraulic conductivity	0.367	0.832	0.126
Infiltration rate	0.372	0.726	0.316
Mean weight diameter	0.697	0.482	0.336
Available water capacity	0.436	0.602	0.369
pH	-0.110	-0.849	-0.121
EC	-0.237	-0.491	-0.480
Org. carbon	0.448	0.496	0.559
Available N	0.491	0.455	0.599
Available P	0.281	0.143	0.900
Available K	0.736	0.552	0.162
SMBC	0.783	0.453	0.322
SMBN	0.886	0.135	0.222
DHA	0.876	0.106	0.227

Results of principal component analysis

In PCA 14 variables were used. The first three principal components (PC) accounted far more than 78% variability of data and eigen values near 1. The PCs which explained more than 5% of the variation within the measured data with eigen value near to 1 were retained (Table 4). Highly weighted variables under PC1 included SMBC, SMBN, DHA and available K. A correlation matrix for the highly weighted variables under different PC1, PC2 and PC3 was run separately (Table 5). Among these highly weighted four variables in PC1, the variable SMBC having highest correlation sum was selected for MDS on the basis that the variable having the highest correlation sum best representing the group. In PC2 HC, IR and pH were highly weighted variables. Among these variables, HC has highest correlation sum, hence selected and other two were dropped. Under PC3 available P, N and OC were highly weighted variables. Among these variables, available N has highest correlation followed by OC. In this PC, the OC was retained for MDS considering its central position in all soil parameters and importance in productivity and also high correlation with available N. Andrews *et al.* (2002) reported that choice among well-correlated variables could also be based on the practicability of the variables. Thus, the final variables for MDS were SMBC, HC and OC. When all the above indicators that were retained in the MDS were regressed as independent variables with data on management goal as dependent variable, the coefficient of determination (R^2) with average yield of cotton was 0.79.

Soil quality index

The data on SQI computed using key indicators identified for rainfed cotton are presented in Table 6. It revealed that tillage did not influence SQI significantly. The higher SQI was obtained in minimum tillage compared to conventional tillage. The main effect of integrated nutrient management on SQI was significant. The SQIs as influenced by various integrated nutrient management treatments ranged from 1.56 to 2.10. The integrated use of FYM @ 15 t/ha along with 50% RDF significantly obtained highest SQI (2.10) which was superior over rest of the treatments. The next best nutrient management treatments in aggrading soil quality was application of FYM @ 10 t/ha along with 50% RDF (2.00) followed by in situ green manuring of sesbania along with 50% RDF (1.95) which were on par with each other. The 50% RDF through chemical fertilizer alone recorded lowest SQI (1.56). The relative order of performance of these INM treatments in aggrading soil quality was FYM @ 15 t/ha + 50% RDF > FYM @ 10 t/ha + 50% RDF ≥ in situ green manuring of sesbania + 50% RDF > 50% RDF + FYM @ 5 t/ha > 100% RDF through chemical fertilizers > 50% RDF through chemical fertilizers. The interaction between tillage and integrated nutrient management was found to be non-significant.

In the present study, the soil parameters identified as key indicators had a great relevance in improving soil quality of rainfed Vertisol under semi-arid tropics which are low in organic carbon and with poor hydraulic conductivity. The contribution of SMBC was substantial in this study. Microorganisms regulate the nutrient flow in the soil by assimilating nutrients and producing soil biomass (immobilization) and converting C,

Table 5 : Correlation matrix (Pearson's coefficients) under PC's with high factor loading

PC 1	Variables	SMBC	SMBN	DHA	Avail. K
	SMBC	1	0.811397	0.768256	0.874527
	SMBN	0.811397	1	0.826318	0.707318
	DHA	0.768256	0.826318	1	0.694062
	Avail. K	0.874527	0.707318	0.694062	1
	Correlation sum	3.454181	3.345034	3.288637	3.275907
PC2	**Variables**	**HC**	**IR**	**pH**	
	HC	1	0.795205	0.663704	
	IR	0.795205	1	0.613276	
	pH	0.663704	0.613276	1	
	Correlation sum	2.458908	2.408481	2.27698	
PC 3	**Variables**	**Avail. P**	**Avail. N**	**OC**	
	Avail. P	1	0.683189	0.598313	
	Avail. N	0.683189	1	0.882036	
	OC	0.598313	0.882036	1	
	Correlation sum	2.281502	2.565225	2.480349	

N, P and S to mineral forms (mineralization) (Jenkinson and Ladd, 1981, Wani and Lee, 1995). The changes in soil organic C contents are also directly associated with changes in microbial biomass carbon and biological activity in the soil. Besides living plant roots and organisms, soil microbial biomass is a living portion of soil organic matter. Microbial biomass contains labile fraction of organic C and N, which are mineralized rapidly after the death of microbial cells.

Table 6 : Effect of tillage and nutrient management on soil quality index (SQI)

	Treatments	SQI
	(a) Tillage	
T_1	Conventional tillage	1.87
T_2	Minimum tillage	1.88
	SEm±	0.01
	CD (P=0.05)	NS
	(b) Nutrient Management	
F_1	100% RDF	1.78
F_2	50% RDF	1.56
F_3	50% RDF + FYM @ 5 t/ha	1.85
F_4	50% RDF + FYM @ 10 t/ha	2.00
F_5	50% RDF + FYM @ 15 t/ha	2.10
F_6	50% RDF + GM (Dhaincha)	1.95
	SEm±	0.022
	CD (P=0.05)	0.063
	Interaction	NS

The contribution of HC to SQI is likely derived from this soil's hard setting tendencies, crust formation and poor water retention. Further, HC is also important for these soils, as it influences the predominant soil functions such as water infiltration rate, aeration, porosity, conductance and transmission of water etc.

Conclusion

In view of the above, it is recommended that the integrated application of FYM @ 10 t/ha along with 50% RDF through chemical fertilizers was beneficial in improving soil quality index and sustaining the cotton productivity in rainfed Vertisols under semi-arid region of Maharashtra.

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