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Tillage and nutrient management for improving soil quality Indicators and Indices under Rice (*Oryza sativa* L.) - Black gram (*Vigna radiata* L.) Cropping System in Oxisol soils of Ranchi Region

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Abstract

In an long-term tillage and nutrient management experiment with rice (B.G. 23-19) as a test crop at Ranchi, among all the soil quality indicators, organic carbon, dehydrogenase assay and microbial biomass carbon were found to be significantly influenced by the tillage and nutrient management treatments. Among the different tillage and nutreint management, the practices, Low tillage (LT)+ Use of weedicide + 1 Hand weeding + FYM 8 t ha^{-1} (Compost) could significantly improve the soil quality with a SQI value of 1.35 which was followed by CT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost) (1.34) and integrated application of FYM @ 4 t ha^{-1} + 20:15:10 kg NPK ha^{-1} (SQI 1.20), while the lowest was observed under application of 40:30:20 kg NPK ha^{-1} in inorganic form (SQI 1.17). Irrespective of the statistical significance, of all the treatments, practice of low tillage + weedicide application + 1 Hand weeding + FYM 8 t ha^{-1} (Compost) maintained the highest SQI of 1.35 which was at par with practice of conventional tillage + 2 Hand weedings + FYM 8 t ha^{-1} (Compost) (1.34) and low tillage + 2 Hand weedings + FYM 8 t ha^{-1} (Compost) both of which maintained SQI of 0.34. The average percent contribution of key soil quality indicators towards soil quality indices was: pH (10%), EC (6%), available K (35%), Mn (12%), DHA (7%) and LC (30%). It was observed that, among the key indicators, available K followed by labile carbon played a major role in influencing the quality of the soils under rice system in Oxisol soils of Ranchi Region.

Key worlds: Organic carbon, tillage, Compost, soil quality

Introduction

Rainfed Agriculture has a crucial role to play in the Indian economy and rural livelihoods. It is spread over 51.5% of net cultivated area, contributing about 40% to our national food basket. Rainfed area supports 40% of human and 60% of livestock population. Aggressive decline in soil quality is the principal cause of stagnation or decline in agricultural productivity under both irrigated and rainfed agriculture in India. Adoption of crop rotation which includes cereals and legumes is one of important strategies among the Resource Management Practices (RMPs) for rainfed agriculture. Shukla *et al*. (2006) reported that soil quality indicators can be used to evaluate sustainability of land-use and soil management practices in agro ecosystems. The recent approach in assessing soil quality includes normalisation of the data from measurements and conversion to a numeric value that is more than a static descriptor, called a 'soil quality index' (SQI), which can be used to compare various management practices or to assess management-induced changes over time. Keeping in view the above facts, we adopted a long term Experiment on Tillage and integrated nutrient management for rainfed semi-arid tropics under rice (*Oryza sativa*) - black gram (*Vigna radiata*) rotation at Ranchi centre of All India Coordinated Research Project for Dryland Agriculture (AICRPDA) .

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Materials and Methods

The experiment was initiated during the year 2000 in a split plot design with three main plots and three sub plot treatments in three replications using rice (BG 23-19) and Black gram as a test crops grown in rotation. The main plot treatments comprised of i) conventional tillage (CT) + 2 Hand weedings, ii) low tillage (LT) + 2 Hand weedings and iii) LT + weedicide + 1 Hand weeding. The sub treatments comprised of fertilizer sources viz., i) 100% through organic sources (FYM 8 t ha^{-1} (Compost), ii) 50% through organic (FYM 4 t ha^{-1} (Compost)) + 50% through inorganic (20:15:10 kg NPK ha^{-1}) sources and iii) 100% through inorganic source (40:30:20 kg NPK ha^{-1}). The treatment combination of two factors were labelled as: T1: CT + 2 Hand weedings + FYM 8 t ha^{-1} (Compost), T2: CT + 2 Hand weedings + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1}, T3: CT + 2 Hand weedings + 40:30:20 kg NPK ha^{-1}, T4: LT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost), T5: LT+ 2 Hand weedings + FYM 4 t ha^{-1} (Compost)+20:15:10 kg NPK ha^{-1}, T6: LT+ 2 Hand weedings+40:30:20 kg NPK ha^{-1}, T7: LT+ weedicide+1 Hand weeding + FYM 8 t ha^{-1} (Compost), T8: LT+ weedicide + hand weeding + FYM 4 t ha^{-1} (Compost)+20:15:10 kg NPK ha^{-1} and T9: LT+ weedicide + 1 hand weeding + 40:30:20 kg NPK ha^{-1}.

About the study location

The experimental location viz. Ranchi center is located in Eastern plateau (Chotanagpur), and Eastern Ghats, Chotanagpur plateau and Garhjat Hills (AESR 12.3). Length of growing period is 150-180 days.

Soil sampling and analysis

Soil samples were collected from the plough layer (0.0-0.15 m depth) from the experimental sites. Soil samples passed through 8 mm sieve and retained on the 4.75 mm sieve, were used for aggregate analysis, while the samples passed through 0.2 mm sieve were used for estimating organic carbon (OC) as well as labile carbon (LC) and for remaining soil quality parameters, the soil samples passed through 2 mm sieve were used. The standard methods were followed for the laboratory analysis. (Sharma *et al* 2014) for determining different 19 soil quality parameters. Soil pH was measured in 1:2 soil water suspensions, where 10 g of soil was taken and stirred intermittently for 30 min with 20 ml water and measured with a pH meter Electrical conductivity (EC) was estimated in 1:2 soil water suspension using an EC meter. Soil organic carbon (SOC) was determined by the modified Walkley–Black wet digestion method. Available N was estimated by alkaline-KMnO4 method. Bicarbonate-extractable P was extracted with 0.5 M sodium hydrogen carbonate ($NaHCO_3$) (pH 8.5) and estimated calorimetrically. Available K was extracted with 1 M neutral N ammonium acetate solution and analyzed using an inductively coupled plasma spectrophotometer. Exchangeable Ca and Mg were determined by analyzing the 1 M ammonium acetate soil extract using an atomic absorption spectrophotometer. Sulfur (S) was extracted with 0.15% $CaCl_2$ reageant and was estimated turbidimetrically with a blue (340 nm) filter in the spectrophotometer. The micronutrients (Zn, Fe, Cu, and Mn) were estimated using the standard method suggested, using inductively coupled plasma spectrophotometer (model ICP-OES XP, Australia) while, boron (B) was estimated using diethylene-tri amine-penta acetate (DTPA)-sorbitol extraction method. BD was measured by soil core method. The distribution of water stable aggregates was determined by wet sieving technique using sieves of 4.75, 2, 1, 0.5, 0.25, and 0.1 mm sizes and mean weight diameter of soil aggregates (MWD) was computed after oven drying the different size fraction of soil. DHA was measured by triphenyl tetrazolium chloride method (TTC). The results are presented in mg triphenyl formazan formed per hour per gram soil. Soil microbial biomass carbon (SMBC) was determined using the chloroform fumigation incubation technique. Immediately after the collection, the portions of the 2 mm sieved samples were preserved in a horizontal refrigerator at 4–5°C. Before analyzing SMBC, these samples were taken out of the refrigerator and primed in biochemical oxygen demand (BOD) incubator at field capacity (15% w/w) moisture regime for 10 days at 25°C ± 1°C. Microbial biomass carbon (MBC) was calculated by using the following function (Equation 1) :

$$MBC\ (\text{ìg g}^{-1}\text{ of soil}) = (EC_F - EC_{UF}) / K_{EC} \quad \text{—(Equation 1)}$$

Where EC_F is the total weight of extractable carbon in the fumigated sample, EC_{UF} is the total weight of the extractable carbon in unfumigated samples and K_{EC} = 0.25 ± 0.05 represents the efficiency of extraction of microbial biomass carbon.

Soil labile carbon (SLC), which is also considered as one of the important biological soil quality indicators, was estimated using the method suggested by Weil *et al*. (2003) with slight modification. In this method, moist fresh air-dried soil was equilibrated with 20 ml 0.01 M $KMnO_4$ solution for 15 min. The soil-solution suspension was centrifuged and the absorbance was measured at 550 nm using Mini Spectrophotometer.

Soil quality assessment methodology

In order to assess the soil quality, the data obtained on 19 chemical, physical and biological soil quality parameters were statistically tested for their level of significance After the statistical analysis, the parameters which were found significant were considered for principal component analysis (PCA) (Andrews *et al,*. 2002, b; Doran and Parkin, 1994) using SPSS software (Version 12.0). The principal components (PC) which received eigen values ³ 1 (Brejda *et al.,* 2000) and explained at least 5% of the variation in the data (Wander and Bollero, 1999) and variables which had high factor loading were considered as the best representative of system attributes. Within each PC, only highly weighted factors (having absolute values within 10% of the highest factor loading) were retained for the minimum data set (MDS). Further, in order to reduce the spurious groupings among the highly weighted variables within each principal component, inter-correlations were worked out (Andrews *et al.,* 2002). Based on the inter-correlation values, variables were labelled as well-correlated variables when 'r' value was > 0.70. Among the well correlated variables, only one variable was considered for the MDS. However, in some cases as an exception, more than one variable were also retained for the MDS depending upon the important role of the variables in regulating the soil functions. When the correlations were not significant between the highly weighted variables, reflecting their independent functioning, then all the variables were considered important and retained for the MDS. As a check of how well the MDS represented the management system goals, multiple regressions were also performed considering the indicators retained in the MDS as independent variables and the functional goals such as long-term average yields of crop as dependent variable. The variables qualified under these series of steps were termed as the 'key indicators' and were considered for computation of soil quality index (SQI) after suitable transformation and scoring.

As suggested by Andrews *et al.* (2002), all the observations of each identified key MDS indicator were transformed using linear scoring technique. To assign the scores, indicators were arranged in order depending on whether a higher value was considered "good" or "bad" in terms of soil function. In case of 'more is better' indicators, each observation was divided by the highest observed value such that the highest observed value received a score of 1. For 'less is better' indicators, the lowest observed value (in the numerator) was divided by each observation (in the denominator) such that the lowest observed value received a score of 1. After the transformation of the data using linear scoring, the MDS indicators for each observation were weighted using the PCA results. Each PC explained a certain amount (%) of the variation in the total data set. This percentage, when divided by the total percentage of variation explained by all PCs with eigenvectors > 1, gave the weighted factors for indicators chosen under a given PC. After performing these steps, to obtain soil quality index (SQI), the weighted MDS indicator scores for each observation were summed up using the following function (Equation 2):

$$SQI = \text{å}\ (Wi\ X\ Si) \overset{n}{\underset{i=1}{\text{———}}} \quad (\text{Equation 2})$$

In this relation, Si is the score for the subscripted variable and Wi is the weighing factor obtained from the PCA. Here the assumption is that, higher index scores meant better soil quality or greater performance of soil function. For better understanding and relative comparison of the long-term performance of the conjunctive nutrient use treatments, the SQI values were reduced to a scale of 0-1 by dividing all the SQI values with the highest SQI value. The numerical values thus obtained, clearly reflect the relative performance of the management treatments, and hence were termed as the 'relative soil quality indices' (RSQI).

Statistical Analyses

Analysis of variance (ANOVA) was performed using SPSS 12.0 version. Randomized block design was used and the differences were compared by Least Significant Difference Test (LSD) to a significance level of $p < 0.05$ (Snedecor *et al.,* 1989). Principal component analysis was performed using SPSS 12 version

Results and Discussion

Soil quality indicators were monitored after sixth year of experimentation (during 2005). The results pertaining to the effect of tillage and nutrient management practices on soil quality parameters are presented in Tables 1 to 4, and are discussed in detail hereunder.

Data presented in Table 1 indicated that soil reaction of the tillage plots was slightly acidic with pH values ranging from 5.92 to 6.15. On an average, electrical conductivity of the soils was highest with the application of FYM 8 t ha^{-1} (Compost) (0.082 dS m^{-1}) followed by application of FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (0.076 dS m^{-1}). Organic carbon content in these soils ranged from 4.96 to 6.59 g kg^{-1}. The highest organic carbon content (6.59 g kg^{-1}) was recorded with the application of LT + weedicide +1 hand weeding + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} which was almost at par with LT+ weedicide + 1 Hand weeding + FYM 8 t ha^{-1} (Compost) (6.57 g kg^{-1}). Among the main treatments, on an average, LT + 2 Hand weedings recorded the highest organic carbon content of 6.11 g kg^{-1} followed by LT + weedicide + 1 hand weeding (6.09 g kg^{-1}). On an average, among the sub treatments, the application of FYM 8 t ha^{-1} (Compost) recorded the highest organic carbon content of 6.15 followed by application of FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (5.89 g kg^{-1})

Table 1: Effect of tillage and nutrient management practices on physico-chemical soil quality parameters under Rice at Ranchi

Treatments	pH	EC(dS m^{-1})	OC(g kg^{-1})
T1	6.15	0.08	5.47
T2	5.96	0.08	4.96
T3	6.09	0.07	5.40
T4	6.00	0.07	6.42
T5	6.04	0.08	6.11
T6	5.92	0.09	5.80
T7	6.04	0.09	6.57
T8	6.07	0.08	6.59
T9	6.05	0.06	5.13
CD @ 0.05			
Between two main treatment means	0.06	NS	0.34
Between two sub treatment means	NS	0.007	0.22
Between two sub treatment means at same main treatment	NS	0.011	0.38
Between two main treatment means at the same or different sub treatments	NS	0.010	0.41

The data presented in Table 2 revealed that, available nitrogen content was not significantly influenced by different tillage and soil nutrient management practices . However, it ranged from 139.3 to 162.8 kg ha^{-1} within different management treatments. Available phosphorus in the soil ranged from 15.1 to 23.7 kg ha^{-1}. On an average, among the main treatments, LT+ weedicide+1 hand weeding recorded the highest phosphorus content of 22.17 kg ha^{-1} followed by CT + 2 Hand weedings (19.9 kg ha^{-1}). Among the sub treatments, application of FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} recorded the highest phosphorus content of 22.2 kg ha^{-1} followed by 40:30:20 kg NPK ha^{-1} (19.9 kg ha^{-1}). Available potassium content in the soils was medium and ranged from 130.75 to 152.44 kg ha^{-1} .Application of FYM 8 t ha^{-1} (Compost) recorded the highest potassium content of 150.26 kg ha^{-1} followed by 144.11 kg ha^{-1}. Exchangeable calcium, magnesium and available sulphur in these soils were recorded in the range of 2.48 to 3.42 cmol kg^{-1}, 0.60 to 0.78 cmol kg^{-1} and 11.19 to 13.23 mg kg^{-1} of soil respectively. On an average, main treatments did not show any significant effect on exchangeable calcium, magnesium and available sulphur content in these soils, while the sub treatments had significant effect on these nutrients. Application of FYM 8 t ha^{-1} (Compost) recorded the highest calcium and available sulphur contents of 3.21 cmol kg^{-1} and 12.63 mg kg^{-1} of soil respectively, while, application of FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} recorded the highest exchangeable magnesium content of 0.75 cmol kg^{-1} .

Main treatments as well as sub treatments did not show any significant influence on the content of Zn, Fe and Cu in these soils (Table 3). However, Zn, Fe and Cu contents in the soils were recorded in the range of 1.12 to 1.29, 22.2 to 28.6 and 1.22 to 1.33 mg kg^{-1} of soil respectively. Available manganese content varied from 28.0 to 40.7 mg kg^{-1} of soil. Application of FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} recorded the highest Mn content of 40.48 mg kg^{-1} of soil followed by FYM 8 t ha^{-1} (Compost) (30.86 mg kg^{-1} of soil). Main treatments had no significant effect on Mn as well as B content. On an average, application of FYM 8 t ha^{-1} (Compost) recorded the highest B content of 0.52 mg kg^{-1} of soil followed by FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (0.48 mg kg^{-1} of soil). However, the interactive effect of LT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost) showed the

Table 2: Effect of tillage and nutrient management practices on chemical soil quality indicators under Rice at Ranchi

Treatments	N	P	K	Ca	Mg	S
	Kg ha^{-1}			cmol kg^{-1}		mg kg^{-1}
T1: CT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost)	156.0	17.1	152.4	2.86	0.67	13.23
T2: CT+ 2 Hand weedings + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1}	147.0	21.8	138.0	2.65	0.68	11.33
T3: CT+ 2 Hand weedings+40:30:20 kg NPK ha^{-1}	162.8	20.8	138.3	2.73	0.64	12.18
T4: LT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost)	150.2	15.1	149.3	3.42	0.68	12.03
T5: LT+ 2 Hand weedings + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1}	139.3	21.1	148.3	3.43	0.78	11.19
T6: LT+ 2 Hand weedings+40:30:20 kg NPK ha^{-1}	148.4	17.5	130.7	2.48	0.60	11.95
T7: LT+ weedicide + 1 Hand weeding + FYM 8 t ha^{-1} (Compost)	145.7	21.2	149.0	3.35	0.74	12.64
T8: LT+ weedicide+1 hand weeding + FYM 4 t ha^{-1} (Compost)+ 20:15:10 kg NPK ha^{-1}	156.0	23.7	146.0	2.56	0.78	11.26
T9: LT+ weedicide+1 hand weeding + 40:30:20 kg NPK ha^{-1}	153.0	21.7	138.7	2.71	0.60	11.76
CD @ 0.05						
Between two main treatment means	NS	2.48	NS	NS	NS	NS
Between two sub treatment means	NS	1.36	6.34	0.41	0.06	0.93
Between two sub treatment means at same main treatment	NS	NS	NS	NS	NS	NS
Between two main treatment means at the same or different sub treatments	NS	NS	NS	NS	NS	NS

Table 3: Effect of tillage and nutrient management practices on chemical soil quality indicators (micronutrients) under Rice at Ranchi

Treatments	Zn	Fe	Cu	Mn	B
	mg kg^{-1}				
T1	1.23	25.3	1.28	31.7	0.50
T2	1.19	26.0	1.31	40.7	0.49
T3	1.18	25.7	1.22	30.1	0.45
T4	1.14	22.2	1.31	30.3	0.54
T5	1.13	27.3	1.33	40.6	0.44
T6	1.12	26.4	1.25	28.0	0.42
T7	1.29	24.0	1.27	30.5	0.52
T8	1.13	28.6	1.31	40.0	0.51
T9	1.07	27.7	1.24	29.8	0.42
CD @ 0.05					
Between two main treatment means	NS	NS	NS	NS	NS
Between two sub treatment means	NS	NS	NS	2.49	0.02
Between two sub treatment means at same main treatment	NS	NS	NS	NS	0.03
Between two main treatment means at the same or different sub treatments	NS	NS	NS	NS	0.03

highest (0.54 mg kg^{-1} of soil) available B content.

The data on biological and physical soil quality parameters has been presented in Table 4. Dehydrogenase assay in these soils ranged from 4.67 to 7.89 (mg TPF hr^{-1} g^{-1} soil). On an average, among the main treatments, low tillage + weedicide + 1 hand weeding recorded the highest dehydrogenase activity of 7.35 mg TPF hr^{-1} g^{-1} soil. On an average, among the sub treatments, application of FYM 8 t ha^{-1} (Compost) recorded the highest dehydrogenase activity of 7.49 mg TPF hr^{-1} g^{-1} soil followed by FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (6.31 mg TPF hr^{-1} g^{-1} soil). Among all the combinations of main and sub treatments, low tillage + weedicide + 1 hand weeding + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} recorded the highest dehydrogenase activity of 7.89 mg TPF hr^{-1} g^{-1} soil.

Microbial biomass carbon across the treatments ranged from 46.0 to 67.4 mg g^{-1} soil and was found to be very low. This could be due to the reason that MBC could not be estimated in the fresh samples. Main treatments did not have much significant effect on the microbial biomass activity while the sub treatments had significant effect on it. Among the sub treatments, FYM 8 t ha^{-1} (Compost) recorded the highest microbial biomass activity of 62.2 mg g^{-1} soil followed by FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (54.72 mg g^{-1} soil). Among all the combinations of main and sub treatments, LT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost) recorded the highest microbial biomass

Table 4: Effect of tillage and nutrient management practices on biological and physical soil quality indicators under Rice at Ranchi

Treatments	DHA(mg TPF hr^{-1} g^{-1} soil)	MBC (mg g^{-1} soil)	LC (mg g^{-1} soil)	BD (Mg m^{-3})	MWD (mm)
T1	7.52	54.64	277.9	1.36	0.70
T2	4.67	47.22	228.4	1.37	0.68
T3	6.34	54.32	219.1	1.41	0.67
T4	7.23	67.36	282.7	1.32	0.83
T5	6.38	55.22	240.3	1.34	0.77
T6	4.76	46.03	202.2	1.43	0.70
T7	7.70	64.50	280.0	1.36	0.75
T8	7.89	61.71	233.3	1.45	0.74
T9	6.46	48.99	204.8	1.48	0.69
CD @ 0.05					
Between two main treatment means	0.73	NS	NS	0.05	0.05
Between two sub treatment means	0.71	3.88	23.2	0.04	NS
Between two sub treatment means at same main treatment	1.23	6.72	NS	NS	NS
Between two main treatment means at the same or different sub treatments	1.15	8.27	NS	NS	NS

Table 5: Principal component analysis of the soil quality parameters under rice system at Ranchi

	PC1	PC2	PC3	PC4	PC5
Total Eigen values	5.470	2.186	1.524	1.347	1.172
% of Variance	36.467	14.571	10.162	8.982	7.810
Cumulative %	36.467	51.038	61.200	70.182	77.992
Eigen Vectors					
pH	0.296	-0.206	0.756	-0.330	-0.261
EC	0.335	-0.325	0.046	0.017	0.838
OC	0.708	0.159	-0.123	0.393	0.239
P	-0.247	0.641	0.507	0.267	0.274
K	0.826	0.058	0.131	0.006	-0.120
Ca	0.644	-0.061	0.084	-0.317	-0.204
Mg	0.634	0.496	0.287	-0.285	0.193
S	0.226	-0.774	0.460	0.000	0.177
Mn	0.115	0.813	0.111	-0.338	0.118
B	0.717	0.013	-0.092	0.184	0.001
DHA	0.695	0.061	0.241	0.547	-0.287
MBC	0.807	0.151	-0.169	0.353	-0.169
LC	0.859	-0.246	-0.023	-0.069	0.061
BD	-0.655	-0.024	0.415	0.364	-0.104
MWD	0.576	-0.008	-0.282	-0.348	-0.064

activity of 67.4 mg g^{-1} soil which was at par with LT + weedicide + 1 Hand weeding + FYM 8 t ha^{-1} (Compost) (64.50 mg g^{-1} soil). Labile carbon in these soils ranged from 202.3 to 282.7 mg g^{-1} soil across the treatments. It was observed that tillage did not show any significant influence on labile carbon, but the fertilizer sources showed a conspicuous influence. Application of 100 % N through organic sources (FYM 8 t ha^{-1}) recorded significantly highest amount of labile carbon (280.2 mg g^{-1} soil) while the sole inorganic sources recorded the least (208.7 mg g^{-1} soil). Bulk density and mean weight diameter of soil aggregates across the treatments ranged from 1.32 to 1.48 Mg m^{-3} and 0.67 to 0.83 mm respectively. On an average, low tillage + 2 Hand weedings recorded the lowest bulk density of 1.36 Mg m^{-3} and highest mean weight diameter of 0.77 mm.

Results of principal component analysis

In this experiment, of the 19 soil quality variables selected for the study, 15 were found to have been significantly influenced by the tillage and nutrient management practices while four variables viz., N, Zn, Fe and Cu were not significantly influenced and hence were not subjected to PCA. In the PCA of 15 soil quality variables, five PCs had eigen values >1 and explained a variability of 78.0 % variation in the data set (Table 5). Under PC_1, three variables viz., K, MBC and LC were highly weighted. A correlation matrix run for these variables revealed a significant positive relationship between each other (Table 6). Of these variables, LC was found to have the highest correlation sum and assumed to represent the group best and was retained for MDS. The next variable with the second highest correlation sum i.e. K, inspite of its correlation with LC, was also retained considering its relative

Table 6: Pearson's correlation matrix for highly weighted variables under PC's with high factor loading

Variables under PCs			
PC1	K	MBC	LC
K	1.00	0.571**	0.729**
MBC	0.571**	1.00	0.611**
LC	0.729**	0.611*	1.00
Correlation sum	2.30	2.182	2.34

** correlation is significant at 0.01 level

importance to the chemical quality of the soil. However, MBC with the lowest correlation sum was eliminated from the MDS. In the next four PCs, ie PC_2, PC_3, PC_4 and PC_5, only single variables viz., Mn, pH, DHA and EC were highly weighted respectively and hence were retained for the MDS. Hence, the final MDS under this rice-based system at Ranchi consisted of pH, EC, available K, Mn, DHA and LC as the key soil quality indicators. Of these variables, four variables viz., pH, Mn, DHA and LC showed a perfect coefficient of determination of 1.00 when regressed with rice yield as the management goals.

Soil quality indices

The soil quality indices as influenced by different tillage and nutrient management practices under Rice at Ranchi were computed using the key indicators viz., pH, EC, available K, Mn, DHA and LC and the indices varied from 1.14 to 1.35 across the management treatments. Of the nutrient management practices, application of sole organic sources of nutrients in the form of FYM @ 8 t ha^{-1} could significantly improve the soil quality with a SQI of 1.35 which was followed by integrated application of FYM @ 4 t ha^{-1} + 20:15:10 kg NPK ha^{-1} (SQI 1.20) while the lowest was observed under application of 40:30:20 kg NPK ha^{-1} in inorganic form (SQI 1.17). The interaction effects of tillage as well as the conjunctive nutrient use treatments did not show any significant influence in aggrading the soil quality. Irrespective of the statistical significance, of all the treatments, practice of low tillage + weedicide + 1 Hand weeding + FYM 8 t ha^{-1} (Compost) maintained the highest SQI of 1.35 which was at par with practice of conventional tillage + 2 Hand weedings + FYM 8 t ha^{-1} (Compost) (1.34) and low tillage + 2 Hand weedings + FYM 8 t ha^{-1} (Compost) both of which maintained SQI of 0.34.

This study clearly established that irrespective of the statistical significance, the relative order of performance of tillage and nutrient management treatments in terms of maintaining higher SQI was: T7: LT+ weedicide + 1 Hand weeding + FYM 8 t ha^{-1} (Compost) (1.35) > T1: CT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost) (1.34) = T4: LT+ 2 Hand weedings + FYM 8 t ha^{-1} (Compost) (1.34) > T5: LT+ 2 Hand weedings + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (1.22) = T8: LT+ weedicide+1 hand weeding + FYM 4 t ha^{-1} (Compost)+20:15:10 kg NPK ha^{-1} (1.22) > T3: CT+ 2 Hand weedings+40:30:20 kg NPK ha^{-1} (1.19) > T9: LT+ weedicide +1 hand weeding + 40:30:20 kg NPK ha^{-1} (1.17) > T6: LT+ 2 Hand weedings+40:30:20 kg NPK ha^{-1} (1.15) > T2: CT+ 2 Hand weedings + FYM 4 t ha^{-1} (Compost) + 20:15:10 kg NPK ha^{-1} (1.14).

The RSQI values varied from 0.82 to 0.97 across the management treatments. The average percent contribution of key soil quality indicators towards soil quality indices was: pH (10%), EC (6%), available K (35%), Mn (12%), DHA (7%) and LC (30%). It was observed that, among the key indicators, available K followed by labile carbon played a major role in influencing the quality of the soils under rice system in oxisols of Ranchi Region.

The methodology of identifying the key indicators of soil quality and computation of SQI for each management treatment/ practice and results of the study will be highly useful to the researchers, students, NGOs, land managers and other stake holders.

Table 7: Results of multiple regressions of the minimum data set (MDS) components using management goal attributes at different probability (*P*) levels

Goal or Function	R^2 **	Most Significant MDS Variables	P
Rice yield	1.00	pH, Mn, DHA, LC	> 0.000, >0.000, >0.000, >0.000
Rice SYI	0.936	—	—

** Significant at $P = 0.01$ level

Table 8: Effect of tillage and nutrient management practices on soil quality indices under Rice at Ranchi

Treatments	SQI	RSQI
T1	1.34	0.97
T2	1.14	0.82
T3	1.19	0.86
T4	1.34	0.96
T5	1.22	0.88
T6	1.15	0.83
T7	1.35	0.97
T8	1.22	0.88
T9	1.17	0.84
CD @ 0.05		
Between two main treatment means	NS	
Between two sub treatment means	0.05	
Between two sub treatment means at same main treatment	NS	
Between two main treatment means at the same or different sub treatments	NS	

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