Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.5551

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (4):** 1760-1769 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Effect of Long Term Fertilizers and Organic Manures on Soil Quality and Sustainablity Yield Index in Rice - Rice Cropping System

M. Suresh*, G. Jayasree, M. Srilatha, S. Narender Reddy and G. Kiran Reddy

Dept. of Soil Science & Agricultural Chemistry, College of Agriculture

Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500030

*Corresponding Author E-mail: manchikunta.suresh5@gmail.com

Received: 12.07.2017 | Revised: 23.07.2017 | Accepted: 24.07.2017

ABSTRACT

A long-term experiment was conducted with the objective of assessing the effect of integrated use of organic and inorganic sources of nutrients on properties of soil quality and yield sustainability under Rice –rice crop rotation. A field experiment was conducted during rabi, 2015 and karif, 2016 at Regional Agricultural Research Station, Jagtial (India) on an ongoing long term (16 years) experiment which was initiated in kharif, 2000. Twelve treatments were laid out in randomized block design with four replications. The twelve treatments were 50 % NPK (T_1), 100 %NPK (T_2), 150 % NPK (T_3), 100 % NPK + HW (T_4), 100 % NPK + $ZnSO_4$ (T_5), 100 % NP (T_6), 100 % N (T_7), 100 % NPK + FYM (10 t FYM ha^{-1} in kharif) (T_8), 100 % NPK –S (T_9), FYM (10 t FYM ha in kharif and rabi) (T_{10}), Control (T_{11}) and Fallow (T_{12}). The long term yield data from 2000-01 to 2014-15 and 2015-16 of both seasons was used to study sustainability yield index which were found to be relatively high 100%NPK + FYM (0.617 and 0.615) followed by 150% NPK (0.615 and 0.605) and FYM, 100%NPK - S (0.610 and 0.598) during rabi and kharif seasons respectively. Soil quality assessment was done by identifying the key indicators using principal component analysis (PCA), soil quality indices (SQI), and relative soil quality indices (RSQI). Results revealed that most of the soil quality parameters were significantly influenced by the management treatments in the experiment. In experiment, during rabi soil quality indices varied from 1.83 to 2.41 across the treatments and during Kharif season soil quality indices varied from 1.74 to 2.50 across the treatments. Nutrient-management treatments played a significant role in influencing the SQI. Among the treatments, 100%NPK + FYM resulted in a greater soil quality index (2.41 and 2.50 during rabi and kharif season respectively) followed by only FYM treatment (2.35 and 2.34 during rabi and kharif season respectively), which was at par with 100%NPK + FYM. The results indicated that the combined use of organic and inorganic fertilizers maintained higher soil quality in the soil.

Key words: *Soil quality index, FYM, Cropping system, Sustainablity yield index, Chemical fertilizers.*

Cite this article: Suresh, M., Jayasree, G., Srilatha, M., Reddy, S.N. and Reddy, G.K., Effect of Long Term Fertilizers and Organic Manures on Soil Quality and Sustainablity Yield Index in Rice - Rice Cropping System, *Int. J. Pure App. Biosci.* **5(4):** 1760-1769 (2017). doi: http://dx.doi.org/10.18782/2320-7051.5551

INTRODUCTION

Soil is a key natural resource and soil quality is the integrated effect of management on most soil properties that determine crop productivity and sustainability. Good soil quality not only produces good crop yield, but also maintains environmental quality and consequently plant, animal and human health. With the advancement of intensive agriculture, soils are being degraded at an alarming rate by wind and water erosion, desertification, and salinization because of exploitative total farming practices for short term gains. Growing of crops without due consideration to total nutrient requirement has resulted in decline in soil fertility[2]. Soil quality assessment has been suggested as a tool for evaluating sustainability of soil and crop management practices[3].

Rice (*Oryza sativa* L.) is the principal food crop of the world, contributes to about 60% of the world's food. India ranks second in rice production with 110.9 million tonnes and productivity 2.28 t ha $^{-1}$ from an area of 39.47 million hectares. Telangana rice production is 12.9 million tonnes and productivity 3.22 t ha^{-1} from an area of 4.01 million ha [9]. Higher production requirements for the future to meet the demands of growing population need to be achieved, maintaining the soil quality and sustainability of the productivity at the same time. Increase in cropping intensity with optimum use of production inputs like seed, water and fertilizers and effective plant production measures are the key for sustained crop yields.

In long term experiments, the treatments are applied for a long time sufficient to assess their impact on the resource base. Overall trends and cumulative impact of management systems are best studied through long term experiments. Long term experiments provide a reliable means to study the effect of continuous application of organic manures and inorganic fertilizers on the crop yields and productivity of the soil [8]. The importance of long term fertilizer experiments in studying the effect of continuous cropping and fertilizer or manure application on soil quality and sustainability of crop production is widely recognised.

In India, rice is cultivated round the year in one or other part of the country. It occupies 42.8 M ha with a production of 95.9 Mt and productivity of 2.23 t ha^{-1}. In Telangana and Andhra Pradesh, rice is grown in an area of 4.7 M ha with a production of 14.4 M t and productivity of 3.06 t ha^{-1} [1].

MATERIAL AND METHODS

The field experiment was conducted at Regional Agricultural Research Station, Jagtial, Karimnagar district of Telangana. The farm is geographically situated at 78^{0}45'E to 79 ^{0} 0'E Longitude and 18^{0}45' N to 19^{0}0' N Latitude. The climate of polasa, Jagtial was classified as subtropical. The southwest monsoon usually sets in during June-October second week giving 40-50 rainy days per year (IMD, 1978). Winter was generally milder at Jagtial and temperature begins to rise from January and reach it peak by May. Weather data were recorded at the meteorological observatory located at Regional Agricultural Research Station (RARS), Jagtial, Karimnagar district, Telangana. The present experiment is a part of All India Coordinated Research Project on Long Term Fertilizer Experiment initiated in *kharif* 2000-01. The present study was taken up in 2014-15 and 2015-16 (both in *rabi* and *kharif* seasons respectively) with a view to study the effect of Long term fertilizer management on soil quality. Twelve treatments were laid out in randomized block design with four replications. The twelve treatments were 50 % NPK (T_1), 100 %NPK (T_2), 150 % NPK (T_3), 100 % NPK + HW (T_4), 100 % NPK + $ZnSO_4$ (T_5), 100 % NP (T_6), 100 % N (T_7), 100 % NPK + FYM (10 t FYM ha^{-1} in *kharif*) (T_8), 100 % NPK –S (T_9), FYM (10 t FYM ha in *kharif* and *rabi*) (T_{10}), Control (T_{11}) and Fallow (T_{12}).

The experimental site was a typical clayey soil. The properties of the soil before the initiation of experiment (sample collected at the initiation of the experiment *i.e.*, before *kharif* 2000-01). The physico chemical properties revealed that the soil was alkaline

(8.22 pH) in reaction, non saline (0.47 dS m^{-1}) in nature and medium in organic carbon (0.79 g kg^{-1}). The soil under study was low in available nitrogen (107.6 kg N ha^{-1}), medium in available phosphorus (19.6 kg P_2O_5 ha^{-1}) and high in available potassium (364 kg K_2O ha^{-1}) at the initiation.

Soil Sampling and Analysis

Soil samples were collected during *rabi* and *kharif* from the plow layer (0.0–0.15 m depth) from both the experimental sites after the harvest of 2004 kharif (rainy season) crop. These samples were partitioned and passed through standard prescribed sieves for further use in a different kind of analysis. Soil samples that passed through the 8-mm sieve and were retained on the 4.75-mm sieve were used for aggregate analysis, while the sample that passed through the 0.2-mm sieve was used for estimating organic carbon (OC). For the rest of the soil quality parameters such as chemical [pH, electrical conductivity (EC), available N, available P, available K, exchangeable calcium (Ca), exchangeable magnesium (Mg), available sulfur (S), and micronutrients such as available zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), and biological dehydrogenase assay (DHA)] parameters acid and alkaline phosphates enzymes, soil samples that passed through 2-mm sieves were used.

Soil pH and electrical conductivity were measured in a 1:2.5 soil/water suspension Glass Electrode pH meter [4], OC by wet oxidation with sulfuric acid (H_2SO_4) + potassium dichromate ($K_2Cr_2O_7$) [17], available N by alkaline potassium permanganate ($KMnO_4$)–oxidizable N method [13], available P by 0.5 M sodium bicarbonate ($NaHCO_3$) method [10], and available K Neutral Normal Ammonium Acetate method using Flame photometer [5] and exchangeable Ca and Mg using the neutral normal ammonium acetate method. The available micronutrients (Zn, Fe, Cu, Mn) were extracted using DTPA (0.005 M) + triethanolamine (TEA) (0.1M) + calcium chloride ($CaCl2·2H_2O$) (0.01 M) reagent (pH 7.3) as suggested by Lindsay and Norvell (1978)[7] and determined by AAS. Bulk density was estimated by Keen's box method, aggregate stability was measured using the wet sieve technique [18], and mean weight diameter [15] was calculated. Biological soil quality parameters dehydrogenase activity was found by the triphenyl tetrazolium chloride method (TTC) [6].

RESULTS AND DISCUSSION

Identification of Key Indicators

After assessing the influence of the long-term conjunctive nutrient-management treatments on soil quality parameters, the data was utilized to compute the soil quality indices to ascertain the performance of the treatments in maintaining soil quality. After *rabi* to assess the soil quality indices of the treatments, out of the 25 soil quality parameters, 18 soil quality variables that were statistically significant were subjected to principal component analysis (PCA), whereas seven variables (viz., pH, EC, Particle density(PD), Poracity, available-K, available Cu and available Fe) were dropped from the data set as they were not significantly influenced by the management treatments. During *kharif* out of the 25 soil quality parameters, 20 soil quality variables that were statistically significant were subjected to principal component analysis (PCA), whereas five variables (viz., pH, Particle density(PD), Poracity, available Cu and available Fe) were dropped from the data set as they were not significantly influenced by the management treatments.

Data screening for assessment of soil quality indices (SQI)

To assess the soil quality indices after *rabi* season, in the PCA of 18 variables, four PCs had eigen values > 1 and explained 69.82% variance in the data set (Table 1). In PC1 as well as in PC3 and PC4 in each, 4, 5 and 3 variables were qualified respectively, as highly weighted variables, whereas in PC2, only a single variable has been qualified. A correlation matrix for the highly weighted variables under different PCs was run separately. In PC1, the variables qualified were Water holding capacity(WHC), Infiltration rate(IR), Hydraullic conductivity(HC) and available Mn which had a Correlation sum values of 2.937, 2.946, 3.009 and 2.906 respectively (Table 1) four variables were retained for the final MDS. In PC2, only one variable available N, hence it was retained for the final MDS. In PC3, among five OC, BD, IR the three highly weighted variables, available S and Mg had highly significant correlation among these two. Hence were retained for the final MDS. Hence, the final MDS included all. In PC4, the variables qualified were BD, acid-P and Zn. Among three acid-P and Zn were the highly weighted variables. acid-P and Zn had highly significant correlation among these two. Hence were retained for the final MDS. Hence, the final MDS included all.

To assess the soil quality indices after *kharif* season, in the PCA of 20 variables, five PCs had eigen values > 1 and explained 74.807% variance in the data set (Table 2). In PC1 as well as in PC3, PC4 and PC2 in each, 4, 4, 3 and 2 variables were qualified respectively, as highly weighted variables, whereas in PC5, only a single variable has been qualified. A correlation matrix for the highly weighted variables under different PCs was run separately. In PC1, the variables qualified were Infiltration rate(IR), Hydraullic conductivity(HC), available-P and Mn which had a Correlation sum values of 2.732, 2.666, 2.441 and 2.915 respectively (Table 2), which was < 0.70, and hence four variables were retained for the final MDS. In PC2, only two variables acid-p and CEC, hence it was retained for the final MDS. In PC3, among all four OC, BD, available S, Mg highly weighted variables, these variables were retained for the final MDS. Hence, the final MDS included all. In PC4, the variables qualified were BD, acid-P and alkaline-P. Among three acid-P and alkaline-P were the highly weighted variables. acid-P and alkaline-P had highly significant correlation among these two. Hence were retained for the final MDS. Hence, the final MDS included all. In PC5, only one variable EC, hence it was retained for the final MDS.

Computation of Soil Quality Indices

After selecting the key indicators (viz., OC, BD, WHC, HC,IR, available N, S, Mg, acid-P, Zn, and Mn), soil quality indices were computed. The soil quality indices varied from 1.83 to 2.41 across the management treatments in a rice-rice system during rabi season (Table 3 and Figure 1).

From the perusal of the data, it was observed that though the application of 100%NPK + FYM showed the greatest soil quality index of 2.41, its performance was observed to be almost at par with FYM(T_{10}) treatment and significantly differed with other treatments. Irrespective of their statistical significance, the relative order of performance of the organic and nutrient management treatments influencing soil quality in terms of SQI was T8, 100%NPK + FYM (2.41) > T10>T3>T2=T12>T4>T9>T7>T1 and Control(T11). The average percentage contributions of key indicators to soil quality indices emerged in this experiment were HC,19.52%; WHC,19.51%; Mn,18.42%; available-N, 7.98%; IR, 7.5%; BD, 6.17%; Mg, 5.53%; OC, 4.43%; available S, 4.38%; acid-P, 3.93%; Zn, 2.63%(Figure 2).

The soil quality index was found to decrease in the order of NPK>NP>N>control indicating less aggregative effect of these treatments. Increasing the fertilizer levels also helped in maintaining the higher soil quality index (1.83 to 2.41). Sharma *et al.* (2005)[12] also reported that increasing levels fertilizers enhanced the soil quality index. It could be noticed that the balanced application of nutrients helped in improving the soil quality as compared to imbalanced use of nutrients.

After selecting the key indicators (viz., EC, OC, BD, CEC, IR, HC, available P, S, Mg, acid-P, Alkaline-P and Mn), soil quality indices were computed. The soil quality indices varied from 1.74 to 2.50 across the management treatments in a rice-rice system during *kharif* season (Table 3 and Figure 2).

From the perusal of the data, it was observed that though the application of 100%NPK + FYM showed the greatest soil quality index of 2.50, its performance was observed to be almost significantly differed with other treatments. Irrespective of their statistical significance, the relative order of performance of the organic and nutrient management treatments influencing soil quality in terms of SQI was T8, 100%NPK+ FYM (2.50)>T10>T3>T2=T4>T12>T5>T9>T6>T1 >T7 and Control(T11). Sharma et al. (2005)[12] achieved significantly higher SQI with the incorporation of organic along with inorganic fertilizer. The average percentage contributions of key indicators to soil quality indices emerged in this experiment were HC,17.94%; Mn,16.78%; IR, 14.59%, available-P, 12.91%; CEC, 7.47%; BD, 5.72%; Mg, 4.82%; OC, 4.27%; acid-P, 3.99%; available S, 3.98%; alkaline-P, 3.94%; EC, 3.59%(Figure 2). When we studied the nutrient-management treatments on soil quality, we observed that, despite being statistically nonsignificant, the relative order of performance of these treatments in influencing *relative* soil quality as indicated by RSQI values during *rabi* season was 100%NPK + FYM (0.94) > FYM (0.91) > 150% NPK (0.85) > 100%NPK= 100%NPK +Zn = Fallow = (0.82) > 100%NPK + HW (0.80) > 100%NPK - S (0.79) > 100%NP (0.78) > 100%N (0.75) > Control (0.71).

Relative soil quality as indicated by RSQI values during *kharif* season was 100%NPK + FYM (0.93) > FYM (0.87) > 150% NPK (0.86) > 100%NPK= 100%NPK + HW =(0.77) > Fallow = (0.76) > 100%NPK +Zn = (0.75) > 100%NPK - S (0.74) > 100%NP (0.71) > 50%N (0.67) >100%N (0.66) > Control (0.65).

The data pertaining to grain yield of rice during 2014-15 and 2015-16 are presented in Table 4.21 and Figure 4.17. The grain yield of rice ranged from 21.84 to 63.82 q ha^{-1} in *rabi* and 24.15 to 60.90 q ha^{-1} in *kharif*.

Grain yield

Application of 100% NPK along with FYM @ 10 t ha^{-1} resulted in 59.36 and 58.24 q ha^{-1} in *rabi* and *kharif* but slightly lower grain yield over 150% NPK (63.82 and 60.90 q ha^{-1} in *rabi* and *kharif*, respectively). As FYM directly adds appreciable amounts of macro and micro nutrients and FYM had a significant positive role in improving the soil environment. Similar results were also reported by [16] and [11].

The application of graded levels of NPK fertilizers significantly increased the grain yield. Application of optimum dose of NPK (120-60-40 kg ha^{-1}) exhibited beneficial effects. An additional increase of NPK resulted in further increase in yield.

Among the fertilizer treatments, grain yield increased by 108.43 and 79.50%, with 50% NPK, 136.72 and 128.12% with 100% RDF, 192.22 and 152.17% with 150% RDF over control during *rabi* and *kharif*, respectively (Table 4).

Swarup *et al.* (1998) [14] while reviewing the yield trends of Long Term Fertilizer Experiments revealed that crop yields show decline when input levels are kept constant and there is a need for application of higher doses of fertilizers to obtain same yield under continuous intensive cropping system.

The highest yield was recorded with the application of 150% NPK in both the seasons (63.821 and 60.90 q ha^{-1} in *rabi* and *kharif*, respectively). Continuous application of only nitrogen every year resulted in reduced yields compared to 100% NP (68 and 36.87 per cent in *rabi* and *kharif*, respectively) and 100% NPK (62.83 and 41.04 per cent in *rabi* and *kharif*, respectively) emphasizing the need of balanced fertilization.

Sustainable Yield Index of Treatments

The data pertaining to SYI have been presented in Tables 4. From the viewpoint of SYI values, 100% NPK+FYM (T9) was superior for rice with maximum SYI of 0.617, 0.615 during *rabi* and *Kharif* seasons respectively. Lowest SYI was noticed in 100%N (0.508) and control (0.564) treatments in *rabi* and *kharif* seasons respectively. This further justifies that, FYM alone or non-application of fertilizers (control) could not sustain the yields of rice-rice cropping system in long run.

Although 150% RDF recorded higher SYI (next to 100%NPK + FYM) the need based use of micronutrients and sulphur would be more appropriate in the context of balanced nutrition. However, use of either organic manure @ 10 t ha^{-1}, under nutrition at 50-75 % of the recommended NPK or imbalanced supply of N alone or NP or NPK (-S or -Zn) led to unsustainability and a gradual reduction in productivity over period of cropping (Fig. 3). This may be ascribed to the decline in soil fertility leading to nutritional deficiencies in crop plant.

Table 1: Correlation matrix for highly weighted variables under PC's with high factor loading for rabi season

Variables	WHC	I.R	H.C	Mn	
PC1 variables					
Pearson's correlations					
WHC	1.00	0.635**	0.734**	0.568**	
I.R	0.635**	1.00	0.624**	0.687**	
H.C	0.734**	0.624**	1.00	0.651**	
Mn	0.568**	0.687**	0.651**	1.00	
Correlation sums	2.937	2.946	3.009	2.906	
	Avail. N				
PC2 variables					
Avail. N	1.00				
	OC	**BD**	**I.R**	**Avil.S**	**Mg**
PC3 variables					
OC	1.00	-0.369**	0.670**	0.000	0.025
BD	-0.369**	1.00	-0.294*	0.020	0.012
I.R	0.670**	-0.294*	1.00	0.308*	0.345*
Avil.S	0.000	0.020	0.308*	1.00	0.474**
Mg	0.025	0.012	0.345*	0.474**	1.00
	BD	**Acid -P**	**Zn**		
PC4 variables					
BD	1.00	-0.195	0.086		
Acid-P	-0.195	1.00	0.418**		
Zn	0.086	0.418**	1.00		

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level.

Table 2: Correlation matrix for highly weighted variables under PC's with high factor loading for Kharif season

Variables	I.R	H.C	Avail.P	Mn
PC1 variables				
	Pearson's correlations			
I.R	1.00	0.607**	0.439**	0.686**
H.C	0.607**	1.00	0.416**	0.643**
Avail.P	0.439**	0.416**	1.00	0.586**
Mn	0.686**	0.643**	0.586**	1.00
Correlation sums	2.732	2.666	2.441	2.915
	CEC	**Acid-P**		
PC2 variables				
CEC	1.00	-0.185		
Acid-P	-0.185	1.00		
	OC	**BD**	**Avil.S**	**Mg**
PC3 variables				
OC	1.00	-.402**	0.162	0.185
BD	-0.402**	1.00	0.047	0.023
Avil.S	0.162	0.047	1.00	0.546**
Mg	0.185	0.023	0.546**	1.00
	BD	**Acid -P**	**Alkaline-P**	
PC4 variables				
BD	1.00	-0.224	-0.032	
Acid-P	-0.224	1.00	0.684**	
Alkaline-P	-0.032	0.684**	1.00	
	EC			
PC5 variables				
EC	1.00			

**Correlation is significant at the 0.01 level (*P*=0.01).
* Correlation is significant at the 0.05 level (*P*=0.05).

Table 3: Effect of long term fertilizer and manure application on SQI of post –harvest soils of rice

Treatments	SQI		RSQI	
	Rabi	***Kharif***	***Rabi***	***Kharif***
50% NPK	1.88	1.83	0.73	0.67
100%NPK	2.12	2.08	0.82	0.77
150% NPK	2.19	2.31	0.85	0.86
100%NPK + HW	2.06	2.08	0.80	0.77
100%NPK + Zn	2.11	2.03	0.82	0.75
100%NP	2.00	1.92	0.78	0.71
100%N	1.92	1.79	0.75	0.66
100%NPK + FYM	2.41	2.50	0.94	0.93
100%NPK - S	2.02	1.99	0.79	0.74
FYM	2.35	2.34	0.91	0.87
Control	1.83	1.74	0.71	0.65
Fallow	2.12	2.06	0.82	0.76
S. Em. ±	0.03	0.028	0.01	0.01
CD (0.05)	0.087	0.080	0.034	0.03

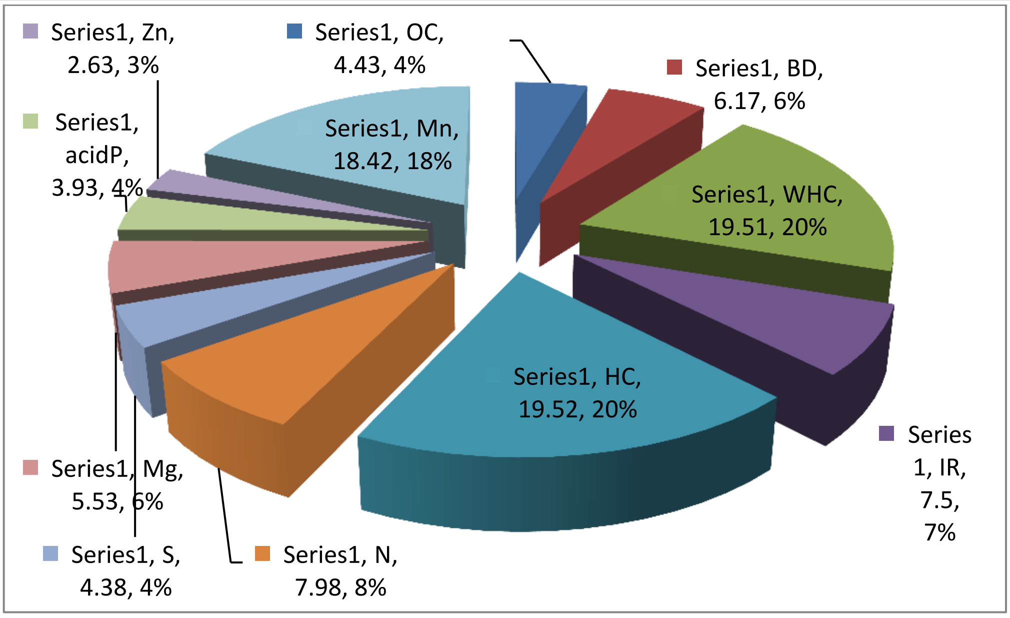

Fig. 1: Percent contributions of key indicators towards soil quality indices as influenced by different soil management practices under Rice-rice cropping system during *Rabi* season

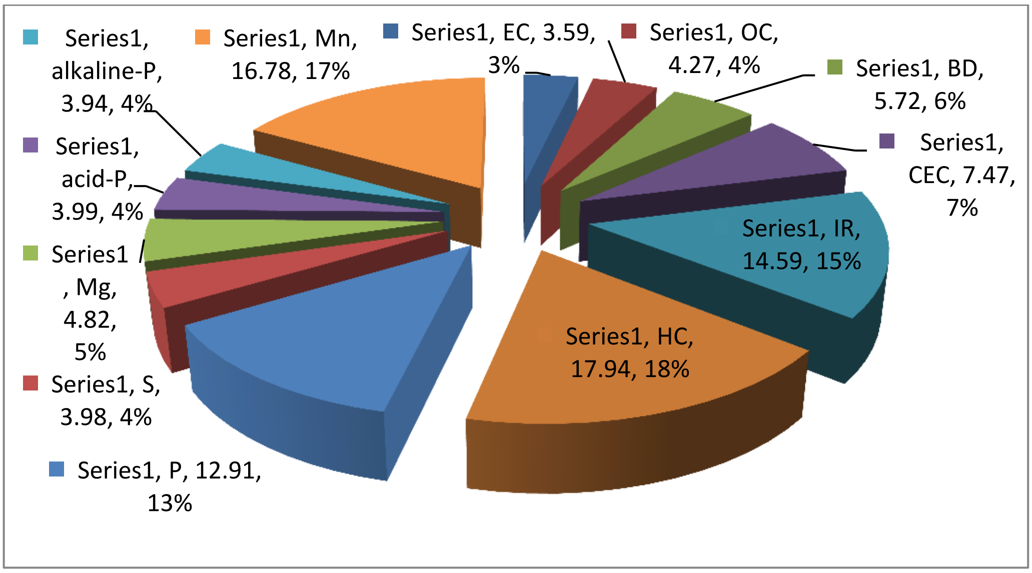

Fig. 2: Percent contributions of key indicators towards soil quality indices as influenced by different soil management practices under Rice-rice cropping system during *kharif* season

Table 4: Effect of long term fertilizer and manure application on crop yield and sustainable yield index (SYI) of post –harvest soils of rice

	grain yield(q ha^{-1})		sustainable yield index	
Treatments	***Rabi***	***Kharif***	***Rabi***	***Kharif***
50% NPK	45.52	43.35	0.601	0.571
100%NPK	51.70	55.09	0.608	0.595
150% NPK	63.82	60.90	0.615	0.605
100%NPK + HW	55.48	57.78	0.608	0.582
100%NPK + Zn	54.80	57.61	0.609	0.596
100%NP	53.34	53.46	0.600	0.582
100%N	31.75	39.06	0.508	0.571
100%NPK + FYM	59.36	58.24	0.617	0.615
100%NPK - S	51.83	54.41	0.595	0.598
FYM	39.42	47.22	0.610	0.586
Control	21.84	24.15	0.542	0.564
S. Em. ±	2.85	2.24	-	-
CD (0.05)	8.27	6.51	-	-

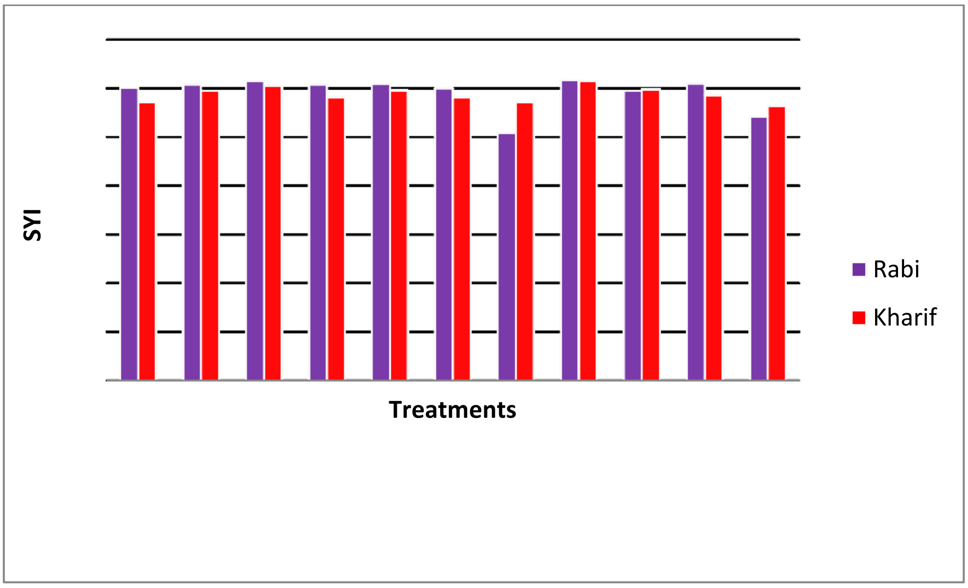

Fig. 3: Graphical representation of sustainable yield index (SYI) values of the selected MDS variables for each treatment during *rabi* and *kharif* season

CONCLUSION

The indicators thus identified in the present study can be used for periodical assessment of soil quality. Appropriate management strategies can be adopted to improve these indicators. Integrated use of inorganic fertilizers and organic manure found better under the long term which enhanced soil quality in rice- rice cropping system. Organic manure (FYM) along with recommended dose of fertilizers (100%NPK+FYM) found to be viable options in maintenance of soil quality and achieving the sustainable productivity in long term cropping systems. A soil quality assessment is a tool that can used to evaluate the effects of land management practices on soil function. The SQI rating was highest for FYM-treated plots. Soil quality was degraded in the control and N-only treatments relative to the reference soil. A common fertilizer strategy among Indian farmers is to apply only urea (N) fertilizer. The soil degradation in the Nonly treatment in the present study gives an early warning about the possibility of soil degradation in these farmers' fields.

REFERENCES

1. CMIE. Executive Summary-GDP growth. Centre for Monitoring Indian Economy (CMIE) Pvt. Ltd. Mumbai. (Dec, 2011).
2. Ghosh, B.N., Vedprakash., Kundu, S., Singh, R.D and Gupta, H.S. Distribution and build up of oxidizable and non oxidizable soil organic carbon in soil profiles under Long term fertilizer trial in the Mid hills of N-W Himalayas. *Journal of the Indian Society of Soil Science*.**51 (3)**: 298-301 (2003).
3. Hussain, I., Olson, K.R., Wander, M.M and Karlen, D.L. Adaptation of soil quality indices and application to three tillage systems in southern Illinois. *Soil Till. Res*. **50:** 237–249 (1999).
4. Jackson, M. L. Soil chemical analysis. *Prentice Hall of India Private Limited*. New Delhi. (1967).
5. Jackson, M.L. Soil chemical analysis. Prentice Hall India Pvt. Ltd., New Delhi. p. 498. (1973).
6. Lenhard, G. Die dehydrogenase-activitat des Bodens als Mass fur die mikroorganismentatigkeit im Boden. Zeitschrift fur Pflanzenernaehr. *Dueng und Bodenkd* **73**:1–11 (1956)
7. Lindsay,W. L., andW. A. Norvell, Development of a DTPA soil test for zinc, iron manganese, and copper. *Soil Science Society of America Journal* **42:** 421–428 (1978).
8. Manna, M.C., Swarup,A., Wanjari,R.H., Ravankar,H.N., Mishra,B., Saha,M.N., Singh,Y.V., Sahi, D.K. and Sarap,P.A. Long term effect of fertilizer aand manure application on soil organic carbon storage, soil quality and yield sustainability under sub humid and semi arid tropical India. *Field crop Research*.**93:** 264 -280 (2005).
9. Ministry of Agriculture, Government of India. (2011).
10. Olsen, S.R., Cole, C.V., Waltanabe, F.S and Dean, L.A. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular number* 939 (1954).
11. Selvi, D., Santhy, P and Dakshinamoorthy, M. Effect of inorganics alone and in combination with farm yard manure on physical properties and productivity of Vertic haplstepts under long – term fertilization. *Journal of the Indian Society of Soil Science*. **53(3):** 302-307 (2005).
12. Sharma, K.L; Mandal, U.K; Srinivas, K; Vittal, K.P.R; Mandal, B; Grace, J.K and Ramesh, V. Long-term soil management effects on crop yields and soil quality in a dryland Alfisol. *Soil Tillage Res.* **83:**246–259. doi:10.1016/j.still.2004.08.002 (2005).
13. Subbiah, B.V and Asija, G.L. A rapid procedure for the determination of available nitrogen in soils. *Current Science*. **25:** 259-260 (1956).
14. Swarup, A., Emerging soil fertility management issues for sustainable crop productivity in irrigated systems. In: Swarup, A., Reddy, D.D., Prasad, R.N. (Eds.), Proceedings of the National Workshop on Long-term Soil Fertility Management through Integrated Plant Nutrient Supply. Indian Institute of Soil Science, Bhopal, India, pp. 54–68 (1998).
15. Van Bavel, C. H. M. Mean weight diameter of soil aggregates as a statistical index of aggregation. *Soil Science Society of America Proceedings* **14:**20–23 (1949).
16. Verma, G., Mathure, A.K and Verma, A. Effect of continuous use of organics and inorganics on nutrient status of soil and yield under maize – wheat intensive cropping system in an Inceptisol. *Journal of Soils and Crops.* **22(2):** 280 -286 (2012).
17. Walkley, A and Black, C.A. Estimation of organic carbon by chromic acid titration method. *Soil Science*. **37:** 29-38 (1934).
18. Yoder, R. E. A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. *Journal of American Society of Agronomy* **28:** 337–351 (1936).