# Long term fertilizer management effect on nutrient dynamics in rainfed rice-lentil system in transect 4 of IndoGangetic plain


## Abstract

The present study analyzed the effect of different organic and inorganic fertilizers on soil nutrient dynamics in a long-term field experiment under rainfed rice-lentil system. The experiment was operative at Agricultural Research Farm, Institute of Agricultural Sciences, B.H.U Varanasi, Uttar Pradesh, India. Carbon dynamics was investigated on surface soil on the basis of distribution of Walkley & Black Carbon, in active pool (AP) or labile carbon (oxidisable at low concentration of $H_2SO_4$) *vis-a-vis* passive poll (PP) or non labile carbon (oxidisable at high concentration of $H_2SO_4$) and its indices carbon management index (CMI).. The effect of eight different treatments including T1 (unfertilized block) T2 (100% N FYM), T3 (100% RDF), T4 (50% RDF + 50 % N Foliar), T5 (50% RDF), T6 (50% RDF + 50% N FYM), T7 (50 % N FYM) and T8 (Farmers practices) *i.e*. application of 20kg N $ha^{-1}$ on availability & uptake of major nutrients were studied. The results revealed: that mixed application of inorganic fertilizers and FYM substantially increase the soil organic carbon pool, sustainability index over remaining treatments. Higher fertilizer application rates resulted in higher and sustained crop yields which had been reflected in sustainability Yield Index (SYI).A significant Pearson correlation was found between SOC, AP, PP, exchangeable $K_2O$ (AK) content, SMBC and SYI. (The result indicated to adopt conjunctive use of nutrient management which promote the SOC more labile and, induce availability of other nutrients coupled with SMBC that translate into higher crop yields.



Key Word: Labile carbon, Sustainability Yield Index, Carbon management Index, Active Pool and Passive Pool.

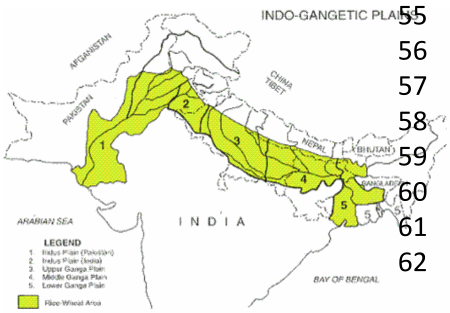

## 1. Introduction

Rainfed agriculture occupies about 51 percent of country's net sown area and accounts for nearly 40 percent of the total food production. Rainfed agriculture is complex, highly diverse and risk prone. The soils of these areas have an inherent low stock of soil organic carbon (C) on contrary these soils contain a significant amount of inorganic C, of a persistent nature, mainly present in the form of soil carbonates [1]. Given the almost nonexistent chance for expanding irrigation in most rainfed agro ecosystems, other ways of land use optimization need to be identified [2].

Soil organic carbon (SOC) dynamics play a major role in intensive agricultural and natural ecosystem. Pools of SOC are dynamic on time scales that can range from decades to millennium [3]. The factors controlling the rates and processes for SOC accumulation and loss include climate, topographic position, parent material, potential biota, time, and human activity; these are also the factors that govern soil formation in general. For soils and from a geographical perspective, a change in any of these state factors leads to a different SOC mass balance [3]. The proper management of this Soil C pool should make it possible to increase the efficiency of use of both soil and fertilizer nutrients. Management induced changes in total soil organic carbon (TSOC) are not easy to detect as its changes occur slowly and are relatively small because of large background levels and natural variability [4]. However, intensive cultivation could alter the dynamics of labile and active organic C pools in soil [5]. Total organic C in soil is comprised of several dynamic pools, broadly grouped as labile pool or active pool, slow pool and passive recalcitrant pool. The labile pools consist of soil microbial biomass C, water soluble C, water soluble carbohydrates etc [6]. These pools have been used as sensitive indicators for judging C dynamics in soil in short to medium term basis [7.8], and for this reason it can be used as an indicator of management quality and agriculture sustainability. [9] Proposed a C management index (CMI) the passive pools are comparatively more stable than labile pool and are slowly decomposable having a larger turnover period. So, instead of quantification of passive or slow C pools, C management index (CMI) derived by integrating labile and non-labile C fractions have been recently used as an indicator for C and nutrient dynamics and soil quality in response to soil management practices [10, 11, 12]. In the present study, we assessed the impact of nutrient management practices involving the application of inorganic fertilizers along with FYM for 12 years on CMI and changes in soil C pools in rice–Lentil system.

## 2. Material and Method

**2.1 Description of the long-term experiment** The experiment was carried out in rainfed condition at Agricultural Research Farm, Institute of Agricultural Sciences, B.H.U Varanasi (82.52$^{0}$E longitude and 25.10 $^{0}$N latitude and 76.19 m above mean sea level), the experiment was started in 1984 Uttar Pradesh, In the present study data from 2006 to 2017 were analyzed and interpreted. The soil of the transect 4 of the Gangetic plain region is alluvial *Typic Ustochrept* (Soil taxonomy of USDA, 1999) with particle composition of (28 % Clay.32% Silt 12% Sand 59.68%. Selected soil properties were measured at the start of the experiment (in Table 1).




The annual average precipitation was 1080 mm with nearly all occurring between June and September and the annual average temperature was 26.1°C. The experiment utilized the Randomized block design (RBD).There were eight treatments and the experimental area was 0.40 ha. Each plot was 10m X 10m The eight treatments were (1) T1-Unfertilized control, (2) T2 100% N (FYM) where 100 % Nitrogen applied through FYM (3)T3-100% RDF(80 N, 40 $P_2O_5$ & 40 $K_2O$ Kg ha$^{-1}$)Recommended dose of fertilizer (RDF) through inorganic fertilizer (4) T- 50% RDF (Soil) + 50 % N (Foliar) where 50 % of RDF were applied though soil and remaining 50 % through foliar spray (5) T5- 50% RDF where only 50 % of recommended dose of fertilizer applied from inorganic source (6) T6-50% RDF + 50% N (FYM) where 50 % of dose applied through inorganic source and remaining 50 % through FYM (7) T7-50 % N (FYM) where only 50 of N dose was applied and the source through FYM (8) T8-Farmers practices of applied 20kg N/ha only

**2.2. Soil sampling and chemical analyses** Soil samples were collected from the top soil layer (0–15 cm) of each plot once a year after the rice crop harvested, samples were mixed to make composite sample by quartering method for each field replicates. Soil samples were stored in refrigerator (4°C) for measurement of soil microbial biomass carbon (SMBC).Slow pool of organic C, i.e., Walkley and Black oxidizable carbon (WBC) content was determined by wet digestion method [13]. Different fractions of soil organic Carbon (SOC) were determined under an increasing gradient of oxidizing condition using three sulphuric acid concentration (H2SO4)-aqueous solution ratio of 0.5:1, 1:1 and 2:1 respectively [14]. The amount of carbon thus estimated leads to partition of SOC into the following four different organic carbon pools of decreasing oxidisability. Fraction I (very labile): organic carbon oxidisable under 0.5:1 $H_2SO_4$ Fraction II (labile): the difference in carbon oxidisable under 1:1 and 0.5:1 $H_2SO_4$ Fraction III (less labile): the difference in carbon oxidisable under 2:1 and 1:1 $H_2SO_4$ Fraction IV (non-labile): the difference between Soil organic Carbon and carbon oxidisable under 2:1 $H_2SO_4$ . Active pool of organic carbon was computed by adding fraction I and fraction II, whereas, passive pool of organic carbon was determined by addition of fraction 3 and fraction 4. Active pool of organic carbon represents amount of organic carbon present in easily oxidisable form in soil. Whereas, passive pool of organic carbon is resistant to decomposition. The other soil nutrient viz., potassium permanganate oxidizable soil N ($KMnO_4$-N) [15], available phosphorus [16], available potassium [17], of soil was estimated standard techniques.

2.3. Carbon management index (CMI)

The CMI was estimated by using the empirical equation given by [9],

$$CMI = CPI \times LI \times 100 - - - - - (1)$$

Where, CPI is the C pool index and LI is the lability index. The CPI and the LI were estimated as follows,

$$\text{CPI} = Total\ soil\ organic\ C\ in\ treated\ \ ample / Total\ soil\ organic\ C\ in\ the\ control \quad (2)$$

Where Total Soil Organic Carbon is Walkley Black carbon (SOC)

$$LI = Lability\ of\ C\ in\ treated\ sample / Lability\ of\ C\ in\ the\ control; - - (3)$$

Where, Lability of C (L) = $C\ Fraction\ I\ (very\ labile): organic\ carbon\ oxidisable\ under\ 12.0\ N\ H2SO4\ + Fraction\ II\ (labile): the\ difference\ in\ carbon\ oxidisable\ under\ 18.0\ N\ and\ 12.0\ N\ H2SO4)/ III\ (less\ labile): the\ difference\ in\ carbon\ oxidisable\ under\ 24.0\ N\ and\ 18.0\ N\ H2SO4\ Fraction\ IV\ (non - labile): the\ difference\ between\ SOC\ and\ carbon\ oxidisable\ under\ 24.0\ N\ H2SO4; - - - (4)$

2.4. Sustainable yield index

The sustainable yield index (SYI) [18] was estimated as

$$SYI = Y - sd/Ymax - - - - - - (5)$$

Where, Y is the average yield of rice over year, and sd refers to the standard deviation from mean and Ymax is the observed maximum yield in the experiment.

## 2,5. Statistical analysis

All ANOVA, regression, and multivariate analyses were conducted in SAS 9.3. Treatments were analyzed by one-way ANOVA and significant differences between means were judged by Duncan's Multiple Range test Pearson's correlations matrix was used to evaluate the relationships between different pools of organic C.

## 3. Results and discussion

### 3, 1 Yield and sustainable yield index

The fertilizers application alone or in combination with FYM was substantially increased in the yield of the rice over time in all the treatments, moreover the yield obtained from treated plot was significantly higher than control (no fertilizer) vis-à-vis farmers practices (20 kg $ha^{-1}$) over time domain. The highest increase of yield was recorded in T2 100% N through Farm yard Manure (FYM) followed by T6 conjunctive use of fertilizer of inorganic fertilizer 50% and FYM 50% and T3 which obviously inorganic fertilizer increase the crop yield (Figure 1).This obviously indicate with progression of the years of cultivation the confirm effect of inorganic + FYM was more effective for yield increase [19,20,21].

Sustainable yield index as a quantitative measure to assess sustainability of an agricultural system and is the derivative of actual yield over years. SYI values were higher in 100% FYM, 50% RDF + FYM treatments compared with other treatment (Figure 1). The 100% FYM treated plot and T6 conjunctive use of fertilizer of inorganic fertilizer 50% and FYM 50% showed SYI value higher than 0.6 that indicating that the yield of these treatments was sustainable. Lowest SYI value was recorded in farmer's practices followed by control. Higher value of SYI in the FYM indicating better soil health in terms of supplying providing nutrients and better soil physical environment.

3,2 Soil organic carbon (SOC)

The SOC content of soil varied from 3.03 ± 0.02 to 4.77 ± 0.02 g kg−1 under different nutrient management treatments at 0–15 cm depth (Table 1). Applications of FYM and FYM + RDF significantly increased the SOC over control and farmers practices. The highest was maintained in 100% (N) FYM. and in 50%(N) FYM +50% RDF. Higher SOC concentrations in FYM and FYM +RDF fertilized plots compared to control and farmers practices on surface soil resulted for greater input of root and shoot biomass from FYM as well as from the growing crops. Higher yield and associated greater amount of root residues and higher rhizosphere activities resulted in significantly greater SOC in FYM and FYM+RDF Plot. The results were consistent with many other earlier studies [22,23, 5].

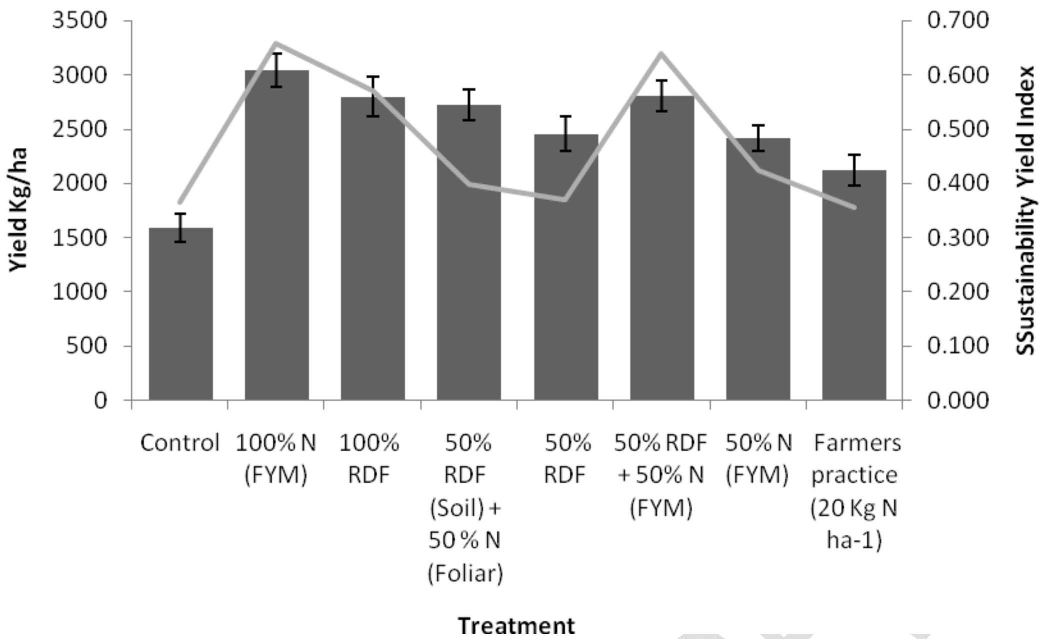



Figure 1 Yield and Sustainable Yield index of Paddy as affected by conjunctive use of fertilizer.

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**3.3. Organic carbon fractions of different degree of oxidisability**

Highest value of oxidisable fraction in C found in 50% N Through FYM followed by 50%RDF+50% (N) FYM followed by 100%(N) FYM treatment respectively 57, 57 and 52% increase over control treatment indicating that application of FYM alone or combination with fertilizer considerably increase the highly oxidisable C fraction. The highest value of Fraction II C was found in the treatment comprising 50% RDF + 50%(N) FYM (Table.1) followed by 100% (N) FYM and 50% (N) FYM the more oxidisable carbon over control was found in the treatment comprising FYM i.e 100% (N) FYM and 50% (N) FYM and the remaining treatment showing decrease in oxisable carbon fraction compare to the control. The less labile carbon had a different kind of pattern and it was found that the highest value (0.154±0.010) was found in the 50% RDF and lowest in the control. The non labile Carbon fraction IV was highest in 50% (N) FYM +50%RDF (0.149±0.008) followed by 100% (N) FYM and (0.135 ±0.035) owing to the highest SOC in these treatment. Considerable variation was also found in the active and passive pool of soil organic carbon as a result of variation of management module induces differences among different carbon fraction.

3.4. Carbon management index

CMI value was calculated to obtain indications of the C dynamics of the system and provide an integrated measure for quantity and quality of SOC [9]. Soils with higher CMI values are considered as better managed [24]. We found that CMI values of 100% (N) FYM (206.94) was more than double over control (100) followed by the 50%RDF+ 50% FYM(149.8) and 50 % FYM (141.65)(Table 2) lowest was recorded in farmers practice that indicating that need to improve the soil management practices. The value itself is not important but the differences reflect how different treatments are affecting the systems [9] (Blair et al., 1995). The regular addition of organic matter in case of FYM addition proved increased potential to increase the CMI by increased inputs and lower losses [25], Similarly, [26] showed that long term balanced fertilization (organic amendments combined with chemical fertilizers) significantly enhanced CMI over chemical fertilizer alone under both maize-wheat and rice-wheat systems. Application of FYM with 100% dose resulting in increased of Lability Index (LI) over

Table 1. Organic carbon fractions (g $kg^{-1}$ soil) (Mean ± SD) of different degree of oxidisability of surface soil affected by different fertilizer management practices.

| Treatments± | SOC | SE | Fraction I | SE | Fraction II | SE | Fraction III | SE | Fraction IV | SE | AP | SE | PP | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.303 | ±0.015 | 0.382 | ±0.300 | 0.089 | ±0.010 | 0.046 | ±0.031 | 0.097 | ±0.028 | 0.160 | ±0.013 | 0.143 | ±0.002 |
| 100% N (FYM) | 0.477 | ±0.008 | 0.469 | ±0.384 | 0.199 | ±0.000 | 0.058 | ±0.027 | 0.135 | ±0.035 | 0.284 | ±0.000 | 0.193 | ±0.008 |
| 100% RDF | 0.341 | ±0.023 | 0.375 | ±0.307 | 0.113 | ±0.013 | 0.134 | ±0.013 | 0.026 | ±0.023 | 0.181 | ±0.013 | 0.160 | ±0.010 |
| 50% RDF (Soil) + 50 % N (Foliar) | 0.333 | ±0.015 | 0.184 | ±0.157 | 0.143 | ±0.004 | 0.071 | ±0.063 | 0.089 | ±0.056 | 0.173 | ±0.008 | 0.160 | ±0.007 |
| 50% RDF | 0.386 | ±0.023 | 0.264 | ±0.247 | 0.166 | ±0.007 | 0.154 | ±0.010 | 0.033 | ±0.023 | 0.200 | ±0.010 | 0.186 | ±0.012 |
| 50% RDF + 50% N (FYM) | 0.477 | ±0.008 | 0.051 | ±0.017 | 0.210 | ±0.012 | 0.097 | ±0.026 | 0.149 | ±0.008 | 0.231 | ±0.026 | 0.247 | ±0.033 |
| 50% N (FYM) | 0.462 | ±0.008 | 0.527 | ±0.462 | 0.154 | ±0.043 | 0.107 | ±0.026 | 0.119 | ±0.008 | 0.236 | ±0.026 | 0.226 | ±0.018 |
| Farmers practice (20 Kg N ha-1) | 0.333 | ±0.015 | 0.225 | ±0.184 | 0.131 | ±0.017 | 0.127 | ±0.001 | 0.034 | ±0.001 | 0.172 | ±0.017 | 0.161 | ±0.002 |
| CD at 5% | 0.494 | | 0.344 | | 0.619 | | 1.001 | | 0.995 | | 0.574 | | 0.437 | k |

Table 2. Carbon Pool, Liability index and carbon management index of soil affected by different fertilizer management practices.

| Treatments | CPI | LI | CMI |
|---|---|---|---|
| Control | 1.00 | 1.00 | 100.00 |
| 100% N (FYM) | 1.58 | 1.31 | 206.94 |
| 100% RDF | 1.13 | 1.01 | 113.41 |
| 50% RDF (Soil) + 50 % N (Foliar) | 1.10 | 0.96 | 105.88 |
| 50% RDF | 1.28 | 0.96 | 121.82 |
| 50% RDF + 50% N (FYM) | 1.58 | 0.95 | 149.80 |
| 50% N (FYM) | 1.53 | 0.93 | 141.65 |
| Farmers practice (20 Kg N ha-1) | 1.10 | 0.95 | 104.25 |

control there was negligible increase in LI in 100% RDF treatment and remaining all the treatment there was less LI values compare to the control. Carbon management index is a cumulative index that can be effectively used as a sensitive indicator in C dynamics study in response to nutrient management [27,11]. If the value of CMI is greater than 100, then management practices is considered sustainable and impart good soil quality [9].

3.5. Nutrient Dynamics

The exchangeable $K_2O$ (AK) was significantly affected by the conjunctive use of nutrient. The highest AK was recorded under 100% N through FYM (Fig.2) followed by 100% RDF *i.e* all the Nutrient was supplied through the said treatment inorganic Fertilizers. The AK content was higher where treatment FYM alone or combination with inorganic fertilizer as compare to only inorganic fertilizer. The increment was due to higher solubilization of K from non-exchangeable sources and increase and due to addition of FYM [28].

Alkaline $KMnO_4$-N at surface soil was significantly higher in all treatments as compared to control (Figure 2).. Availability of N was also increased in 100% FYM plot ( 232 kg $ha^{-1}$) in comprision to the control 106 kg $ha^{-1}$ ). As incorporation of FYM enhanced N status by to gradual build up of SOC [29] with time.

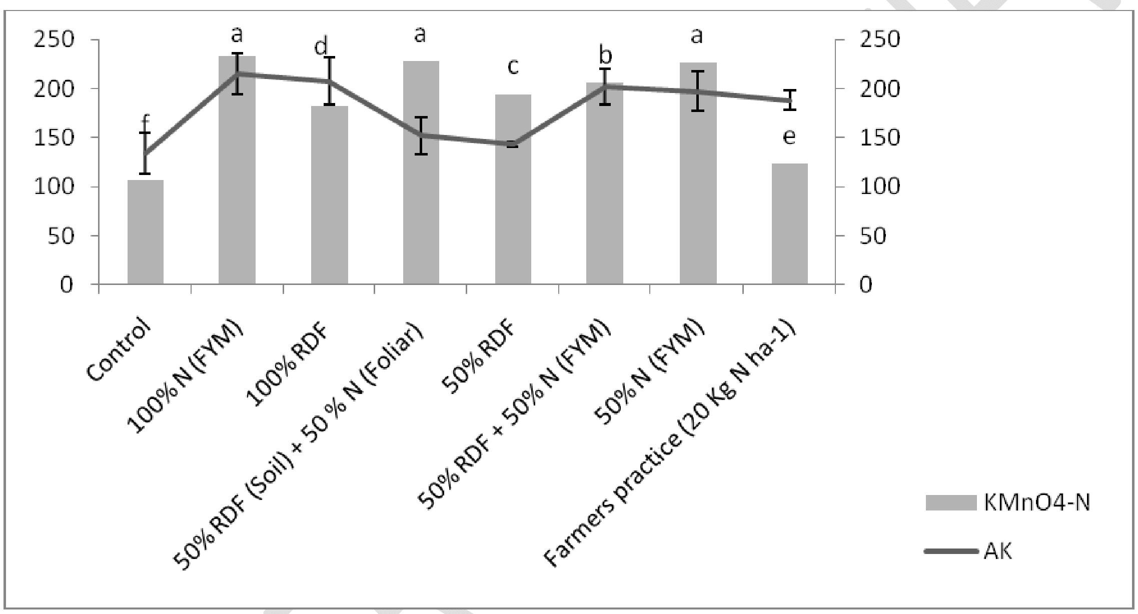


Figure 2. Available Nitrogen and Pottash as affected by fertilizer.

Available P was varied from 8.9 to 16.9 kgha$^{-1}$(Figure.3). At surface soil layer (0-15cm), 100% FYM maintained significantly higher P level (16.9.5 kg $ha^{-1}$) followed by 100% NPK. The lowest available P was recorded in unfertilized plot. A significant build up of available P was noted in soil under conjunctive use of nutrients. Application of 100% NPK + FYM had greater influence on availability of AP which was reported by [7].

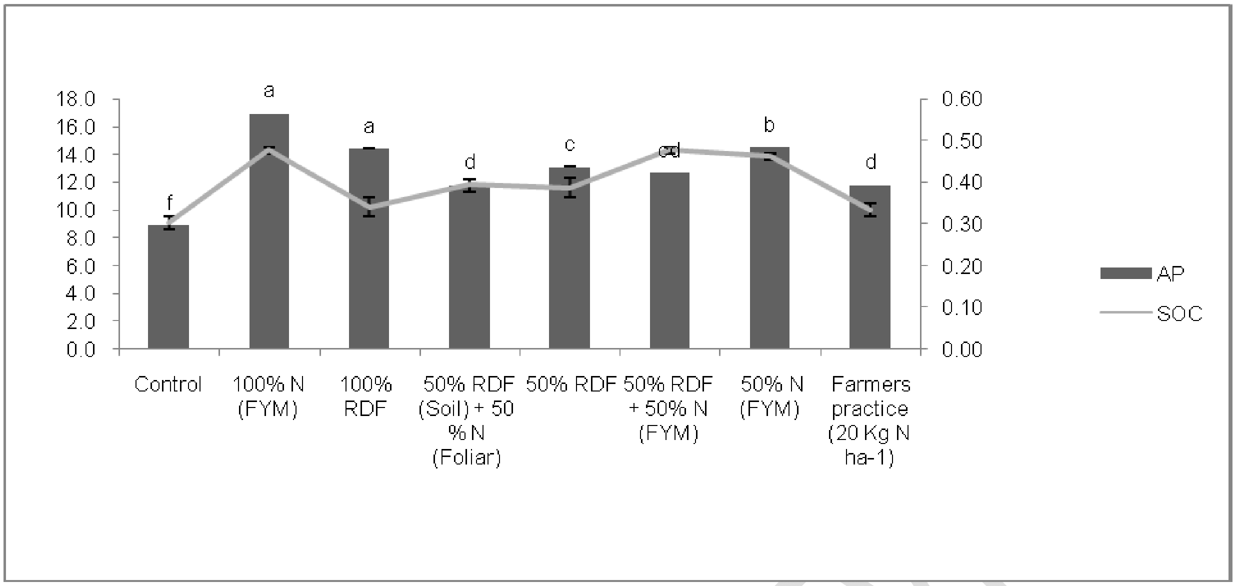


Figure 3. Available Phosphorus and Soil organic Carbon as affected by conjunctive use of fertilizer.

3.6. Correlation matrix

Data on Pearson's correlation matrix revealed significant and positive correlation among different soil C pools (Table 3). In our study higher correlation values of Active Pool LBC and SMBC with SOC indicated that these C pools mostly affected by long term nutrient management practices.

**Table 3. Pearson correlation coefficients indicating relationship among the soil roperties and sustainable yield index of paddy.**

| | SOC | Active Pool | Passive Pool | AK | $KMnO_4$-N | AP | SMBC | SYI |
|---|---|---|---|---|---|---|---|---|
| SOC | 1.000 | 0.9351** | 0.917* | 0.459 | 0.692 | 0.507 | 0.847* | 0.789* |
| Active Pool | | 1.000 | 0.701 | 0.679 | 0.685 | 0.483 | 0.705 | 0.369 |
| Passive Pool | | | 1.000 | 0.786 | 0.585 | 0.452 | 0.436 | 0.486 |
| AK | | | | 1.000 | 0.467 | 0.490 | 0.406 | 0.139 |
| $KMnO_4$-N | | | | | 1.000 | 0.874* | 0.654 | 0.146 |
| AP | | | | | | 1.000 | 0.417 | 0.121 |
| SMBC | | | | | | | 1.000 | 0.160 |
| SYI | | | | | | | | 1.000 |

## 4. CONCLUSIONS

The results of the present study indicated that the CMI could be used to identify management practices will a have positive effects on soil organic carbon build up in soil . The use of the CMI as a tool can help in differentiating the good agricultural practices that improve the soil carbon pool and yielded into a sustainable production. In the present study, application FYM and FYM with inorganic fertilizer comprising half each translated into substantially good SYI, Soil carbon pool and nutrient status.

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