# A study on the Effect of organics, biofertilizers and crop residue applying on soil microbial activity in rice (*oryza sativa* ) – wheat (Triticum aestivum) and rice-wheat mungbean cropping systems in the Meerut region fields.

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**Abstract:** The objective of this study was to find the response of soil microbial parameters to nutrients management practices involving organic amendments, farmyard manure (FYM), vermicompost (VC), crop residues (CR) and biofertiliz ers (BF) in rice–wheat and rice–wheat–mung bean cropping system of the Meerut region fields India. Soil microbial biomass C ($C_{mic}$), basal respiration, ergosterol, glomalin, soil enzymes (glucosidases, phosphatases and dehydrogenases), FDA activity, organic carbon ($C_{org}$), $C_{mic}$-to-$C_{org}$ ratio and metabolic quotient ($qCO_2$) were estimated in soil samples collected at 0–15 cm depth. The highest $C_{org}$ (0.64%) and $C_{mic}$ (103.8 μg $g^{-1}$) soil levels occurred in the treatment receiving a combination of VC, CR and BF. Soil respiration, $C_{org}$ and $C_{mic}$-to-$C_{org}$ ratio were significantly enhanced by the input of CR to plots receiving FYM and VC. The $qCO_2$ was the highest in plots receiving a combination of FYM, CR and BF followed by control (no nutrient input) and least in plots receiving a combination of VC, crop residue and biofertilizer. These results show that the organic practices involving VC, CR and BF improved soil microbial characteristics and $C_{org}$ in rice–wheat systems.

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## ABOUT THE AUTHORS

The activity of our research group at the dept.Botany c.c.s.u. Meerut, is mainly related to the improvement of rice–wheat-based cropping systems in the Meerut region fields by integrated resource management (IRM) practice to minimize cost of production, reduce environmental damage in developing countries and improving food security in the developing countries. The research reported in the paper pertains to observe the effect of use of mixed organic fertilizers on soil enzyme activity, and hence soil fertility during rice–wheat cultivation. High input of resources like chemical fertilizers pollutes the environment and harms soil fauna. The present research shows that integrated use of various organic fertilizers improves soil enzymatic activity and overall microbial activity of soil and thus fertility of soil.

## PUBLIC BENEFITS

Public concerns against resource-intensive agriculture include excessive use of chemical fertilizers, which reportedly leach into soil and water and pollute them. Present study shows that mixed use of various organic fertilizers can reduce the dependence on chemical fertilizers besides improving soil enzyme fertility. We find that important soil enzyme activities like glucosidase, alkaline and acid phosphatase, which circulate carbon (C) and phosphorous (P), were increased with mixed use of organic fertilizers. An increase in soil microbial activity also observed. Oservations confirming increase in soil microbial activity and fertility. To check whether it affects the overall metabolic activity of soil fauna, soil respiration and soil microbial biomass carbon (SMBC), ergosterol content, soil glomalin content and FDA hydrolysis activity calculated.We observed that the overall enzyme activities of soil increased when organic fertilizers used as compared to control suggesting improvement of soil fertility.

**Subjects: Microbiology; Bioscience; Conservation – Environmental Microbiology ; Environmental Studies & Management,Microbial biotechnology**

**Keywords: crop residue management; Meerut region fields ; metabolic quotient; rice–wheat cropping system**

## 1. Introduction

Rice–wheat cropping systems (RWCS) are the main source of food and income for people of Meerut UP in India, but crop productivity is either stagnating (wheat) or declining (rice) besides applying the use of higher yielding cultivars (Padre-Tirol & Ladha, 2006). This raises major concerns over the long-term sustain ability of current farming practices and presents a threat to future food security against a background of climate change. Main factors responsible for deterioration in soil fertility and crop productivity include decline in soil organic matter (SOM) due to reduced inputs of bioresources and lack of an adequate rotation (Shibu, Van Keulen Leffelaar, & Aggarwal, 2010), negative macro and micro-nutrient balanc es, leading to depletion of soil fertility and nutrient deficiencies (Timsina & Connor, 2001), declining water availability and poorer quality water (Farooq, Kobayashi, Wahid, Ito, & Basra, 2009), and dete rioration in soil structure of continuously puddled soils in rice paddies (Saharawat et al., 2010). The decrease in the soil fertility, mainly due to the inadequate organic carbon ($C_{org}$) levels in soil, seems to be the most significant factor for decreased sustainability of the system.Introduction of summer legumes, such as mung bean, in the RWCS after the harvestof wheat and before the transplanting of rice can increase the productivity of these crops, inspite of improving the carbon and nitrogen status of soil (Prasad, 2011). After picking matured pods of mung bean, the plant biomass (3–4 t $ha^{-1}$ dry matter) can be used for in situ green manuring.Organic nutrient sources and crop residues (CR) are the primary source of C inputs (Lal, 2004), and the ways in which these are managed have a important effect on soil's physical, chemical and bio logical properties (Kumar & Goh, 2000). The incorporation of CR alters the soil's physicochemical environment (Prasad & Power, 1991) which in turn influences the microbial population/activity in the soil and subsequent nutrient transformations. In general, soil enzymes are good markers of soil fertility since they are involved in the cycling of the most important nutrients. Keeping the above facts in view, the aim of study was to find the effects of different organic manure, crop residue and biofertilizer applications on soil biological functionality as described by enzyme activities, microbial biomass carbon ($C_{mic}$) and microbial signature molecules such as ergos terol and glomalin content in RWCS and rice–wheat–mung bean cropping (RWMCS) systems.

## 2. Materials and methods

***2.(a) Study site and experimental design*** The field experiment was conducted in the research farm of Dept.Botany c.c.s.u.Meerut , India, during 2002–2003. . Summer months (May and June) are the hottest with the maximum temperature ranging between 41 and 48°C, while January is coldest with the minimumtemperature ranging between 3 and 7°C. The temperature rises slowly through the months of February and March and reaches a maximum during June, then falls slightly with the advent of south-west monsoon rain. The mean precipitation of Meerut is 650 mm which is mostly received dur ing July–September with occasional rain during winter. The soil of the experimental field is a sandy clay loam (typical Ustochrept) in texture, having 52.06% sand, 22.54% silt and 25.40% clay (pH 8.18, organic matter 1.25%). The physiochemical properties of the experimental field of Meerut region are given in Table 1. The experiment was laid out in a strip-plot design with three replications. No chemical pesticide/ disease/weed control agent was supplied in the field, and hence study was carried out totally in organic farming conditions. Treatments consisted of 14 combinations of 2 cropping systems, namely rice–wheat and rice–wheat–mung bean, and 7 combinations of organic manures, CR, referring to incorporation of crop residue from the previous crop and biofertilizers (BF):- ($T_1$) farmyard manure (FYM) equivalent to 60 kg N $ha^{-1}$, ($T_2$) vermicompost (VC) equivalent to 60 kg N $ha^{-1}$, ($T_3$) FYM + CR, ($T_4$) VC + CR, ($T_5$) FYM + CR + BF and ($T_6$) VC + CR + BF, as well as ($T_0$), a non-amended control.

These treatments were applied to all the crops, i.e. rice, wheat and mung bean, during the period 2002–2003. The cropping history of the experimental field and treatment details are listed in Table 2. The BF applied to the wheat, rice and mung bean crops consisted of azotobacter + cellulo lytic culture + phosphate-solubilizing bacteria (PSB), blue green algae + cellulolytic culture + phos phate-solubilizing bacteria and rhizobium + phosphate-solubilizing bacteria, respectively. For the present study, soil samples collected at the wheat harvest of 2002–2003, i.e. after completion of six cycles of the rice–wheat or RWMCS system.

| Year | Kharif | Rabi | Summer | Remarks |
|---|---|---|---|---|
| 2000-2001 | Rice | Wheat | — | Conventional formig |
| 2001-2002 | Rice | Wheat | ---- | |
| 2002-2003 | Rice (Organic) | Wheat (Organic) | — | Transitional period |
| 2003-2004 | Rice (Organic) | Wheat (Organic) | Mung bean (organic) | |
| 2004-2005 | Rice (Organic) | Wheat (Organic) | Mung bean (organic) | Organic forming |
| 2005-2006 | Rice (Organic) | Wheat (Organic) | Mung bean (organic) | |

### *2(b). Microbiological analysis*

Soil was sampled manually from all the plots at 0–15 cm using a tube auger. Fifteen sub-samples per plot were taken and carefully mixed. Soil biological analyses were carried out on moist samples in triplicate and the results were expressed on a dry weight basis. The microbial biomass content of the soil was determined using the fumigation–extraction method of Vance, Brookes, and Jenkinson (1987). The levels of four enzymatic activities in soil were measured: dehydrogenase (EC 1.1.1.) (Casida, Klein, & Santoro, 1964), alkaline phosphomonoesterase (EC 3.1.3.1), acid phosphomonoesterase (EC 3.1. 3.2) (Tabatabai, 1994; Tabatabai & Bremner, 1969) and β-glucosidase (EC 3.2.1.21) (Eivazi & Tabatabai, 1988). The estimation of total glomalin (T-GRSP) was done by the procedure of Wright and Upadhyaya (1998) and the protein content was expressed as µg per g dry weight of soil. Soil microbial activity expressed as fluorescein diacetate (FDA) hydrolysis was determined following the method of Green, Stott, and Diack (2006). The soil respiration (SR) was measured by the alkali entrapment method (Stotzky, 1965) and the metabolic quotient was computed as respiratory activity in relation to micro bial biomass (Anderson & Domsch, 1993). The $C_{mic}$-to-$C_{org}$ ratio and the metabolic quotient ($qCO_2$) were calculated by dividing the C of $CO_2$ released from sample in 1 h by the $C_{mic}$ content (Šantrucková & Straškraba, 1991). Soils were also analysed for the fungal biomarker, ergosterol. Ergosterol is a mem brane-bound molecule commonly used as a fungal biomarker (Bååth & Anderson, 2003). Ergosterol was extracted from the samples by the microwave-assisted extraction method and determined by HPLC analysis (Young, 1995). The $qCO_2$, i.e. the respiration to biomass ratio, was calculated from $qCO_2$ = Basal respiration × 1000/$C_{mic}$ (Insam & Haselwandter, 1989).

### *2.(c). Statistical analysis*

A two-factor analysis of variance (ANOVA)  performed to determine the effects of nutrient man agement/organic amendments, cropping systems and their interactions on soil biological and bio chemical properties. Data analysis for all soil parameters  performed using the SAS software. For statistical analysis of data, least significant difference (LSD at $p = 0.05$) was used to determine whether means differed significantly.

## 3. conclusions and discussion

### *3.(a). Phosphatases*

Alkaline phosphomonoesterase (ALP) activity was higher in control than in the treatments (except in VC + CR + BF treatment in RWCS) with organic amendments, apparently leading to enhanced miner alization of native organic P fraction in soil (Table 3). Plots receiving a combination of VC + CR + BF in RWCS showed maximum ALP activity (though not significantly greater than control).The acid phosphatase (ACP) activity was significantly high in plots receiving FYM + CR + BF and VC + CR + BF in RWCS and VC, CR and VC + CR + BF in RWMCS (Table 3) than in the control plots.ACP activity was stimulated by the application of BF compared with the control in both RWCS and RWMCS except FYM and FYM + CR treatments of RWCS.

### *3.(b).* β*-glucosidases*

In RWMCS, application of all combinations of organic nutrient sources significantly improved the enzyme activity compared with the control, whereas in RWCS, plots treated with FYM or VC were comparable to control plots (Table 3). Plots receiving VC alone or in combination with CR showed the highest stimulation of β-glucosidase activity in the RWMCS. The magnitude of increase in β-glucosidase activity over the control ranged from 43.8 to 55.5% in RWCS. While in RWMCS, the values ranged from 21.5 to 77.4%.

Table 3. Treatment details.

**Cropping systems**

| Treatment | Rice | | Wheat | | Treat ment | Rice | | Wheat | | Mung bean | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Organic nutrients | | Organic nutrients | | | Organic nutrients | | Organic nutrients | | Organic nutriets | |
| No. | Manures & com post | Biofertil izer | Manures & com post | Biofertilizer | No. | Manures & com post | Biofertilizer | Manures & com post | Biofertilizer | Manu res & com post | Biofe rtilize r |
| 1 | FYM[1] | — | FYM | — | 2 | FYM | — | FYM | — | — | --- |
| 3 | VC[2] | — | VC | — | 4 | VC | — | VC | — | — | -- |
| 5 | FYM + C R[3] | — | FYM + C R | — | 6 | FYM + C R | — | FYM + C R | — | CR | -- |
| 7 | VC + CR | — | VC + CR | — | 8 | VC + CR | — | VC + CR | — | CR | -- |
| 9 | FYM + C R | BGA + Ce l lulo lytic cul ture + PS B | FYM + C R | Azoto bacter + Cel lulolytic culture + PS B | 10 | FYM + C R | BGA + Cel lulolytic cul ture + P SB | FYM + C R | Azoto bacter + Cel lulolytic culture + PS B | CR | Rhiz obiu m+P SB |
| 11 | VC + CR | BGA + Ce l lulo lytic cul ture + PS B | VC + CR | Azoto bacter + Cel lulolytic culture + PS B | 12 | VC + CR | BGA + Cel lulolytic cul ture + P SB | VC + CR | Azoto bacter + Cel lulolytic culture + PS B | CR | Rhiz obiu m+P SB |
| 13 | — (control) | — (control) | — (control) | — (control) | 14 | — (control) | — (control) | — (control) | — (control) | — (control) | — (contr ol) |

[1]FYM: Farmyard manure (equivalent to 60 kg N ha$^{-1}$).

[2]VC: Vermicompost (equivalent to 60 kg N ha$^{-1}$).

[3]CR: Crop residue (incorporation of crop residue of previous crop in succeeding crop.

The observed low activity of the β-glucosidase in FYM-treated plots corresponded with low-soil acid phosphatase in RWCS, dehydrogenase activity in both RWCS and RWMCS and glomalin content in RWMCS (Tables 3–5).

Table 4. Interactive effect of cropping system and nutrient management practices on glucosidase, alkaline phosphatase and acid phosphatase activities in soil.

| **Cropping system/ Nutrient management** | **Glucosidose (µg pNPG per g$^{-1}$ soil h$^{-1}$)** | | **Alkaline phosphatase (µg pNPP g$^{-1}$ soil h$^{-1}$ )** | | **Acid phosphatase (µg pNPP g $^{-1}$ soil h$^{-1}$)** | |
|---|---|---|---|---|---|---|
| | Rice-Wheat | Rice-Wheat-Mung | Rice-Wheat | Rice-Wheat-Mung | Rice-Wheat | Rice-Wheat-Mung |
| Control | 13.7 | 16.7 | 530 | 523 | 120 | 97 |
| FYM | 14.6 | 20.3 | 359 | 296 | 111 | 108 |
| Vermicompost (VC) | 14.9 | 27.3 | 297 | 411 | 147 | 136 |
| FYM+ crop residue(CR) | 19.7 | 24.0 | 200 | 386 | 112 | 127 |
| VC+RC | 20.6 | 27.8 | 374 | 322 | 139 | 104 |
| FYM+CR+Biofertilizer(B) | 21.0 | 22.1 | 253 | 383 | 158 | 123 |
| VC+CR+B | 21.3 | 23.8 | 536 | 289 | 156 | 165 |
| Mean | 18.0 | 23.2 | 364 | 373 | 135 | 123 |
| LSD(P=0.05) | Cropping system (CS): NS<br>Nutrient management (NM): 5.0<br>CS × NM: 3.2 | | Cropping system (CS): NS<br>Nutrient management (NM): 69<br>CS × NM: 50 | | Cropping system (CS): NS<br>Nutrient management (NM): 14.8<br>CS × NM: 29.3 | |

Note: Values are mean of the data (*n* = 3) and are statistically significant at $p < 0.05$. Data analysed by Two-way ANOVA at LSD < 0.05.

Table 5. Interactive effect of cropping system and nutrient management practices on SR, ergosterol and glomalin content activities in soil of Meerut region fields.

| **Cropping system/ Nutrient management** | FDA hydrolysis | | Dehydrogenose activity | | **Microbiol biomass ( µg MBC g$^{-1}$ soil)** | |
|---|---|---|---|---|---|---|
| | Rice-Wheat | Rice-Wheat-Mung bean | Rice-Wheat | Rice-Wheat-Mung bean | Rice-Wheat | Rice-Wheat-Mung bean |
| Control | 319 | 280 | 1285 | 954 | 51.6 | 62.8 |
| FYM | 295 | 291 | 1065 | 881 | 66.9 | 87.9 |
| Vermicompost (VC) | 391 | 257 | 968 | 1370 | 80.5 | 63.0 |
| FYM+ crop residue(CR) | 290 | 293 | 1169 | 1157 | 103.3 | 67.9 |
| VC+RC | 333 | 331 | 1253 | 905 | 54.9 | 102.5 |
| FYM+CR+Biofertilizer(B) | 302 | 347 | 1152 | 1022 | 55.4 | 69.4 |
| VC+CR+B | 335 | 251 | 1234 | 810 | 105.5 | 102.0 |
| Mean | 309 | 393 | 1161 | 1014 | 74.0 | 79.3 |
| LSD(P=0.05) | Cropping system (CS): NS<br>Nutrient management (NM): 13.6<br>CS × NM: 47 | | Cropping system (CS): 89<br>Nutrient management (NM):133<br>CS × NM: 109 | | Cropping system (CS): NS<br>Nutrient management (NM):7.2<br>CS × NM: 9.3 | |

**Note:** Values are mean of the data (*n* = 3) and are statistically significant at $p < 0.05$. Data analysed by Two-way ANOVA at LSD < 0.05.

### 3.(c). FDA hydrolysis

A significant increase in FDA activity was observed in the VC + CR + BF (5%) in RWCS and FYM + CR + BF (23.9%) in RWMCS over their respective controls, while FDA activity was reduced compared with the control in all organic treatments except with VC + CR and VC + CR + BF in RWCS. On the other hand, FDA activity was increased in RWMCS except with VC and VC + CR + BF (Table 4).

### 3.(d). Dehydrogenase activity

Only soils receiving VC (43.6%) and FYM + CR (21.3%) in RWMCS were found to have significantly higher dehydrogenase activity among the fertilizer treatments over the control, while with RWCS, all dehydrogenase activity levels were lower than the control except VC + CR and VC + CR + BF. Nevertheless, this activity was not consistently correlated with other parameters such as $CO_2$ production or microbial biomass.

### 3.(e). Microbial biomass C

Overall, the MBC values ranged from 51.6 to 105.5 μg $g^{-1}$ soil in RWCS and 62.8 to 102.5 μg $g^{-1}$ soil in RWMCS (Table 4). The results indicated statistically significant ($p < 0.05$) differences in the level of soil MBC between various combinations of organic fertilizers, their interaction with the croppingsys tems but not between the two cropping systems. The MBC values were significantly higher in the plots receiving organics (FYM, CR, C, BF and their combinations) than in the control except with VC + CR or FYM + CR + BF in RWCS and VC, FYM + VC or FYM + CR + BF in RWMCS, reflecting possibly qualitative and quantitative differences in the microbial communities, i.e. 6.4 to 104.5% increase as compared to control in RWCS and up to 63.2% increase in RWMCS, with different organic combinations. In RWCS, MBC with FYM was significantly lower than with VC, while in RWMCS, MBC with FYM was significantly higher than with VC. Application of CR significantly enhanced the soil MBC in conjunction with FYM in RWCS and with VC in RWMCS. The magnitude of increase recorded over control by the application of FYM alone and FYM + CR was 6.4 and 99%, respectively, in RWCS and 39.9 and 8.1%, respectively, in RWMCS. However, the increase of MBC by VC alone and VC + CR + BF was 56 and 104.5%, respectively, over control in RWCS and in RWMCS, increase was 63.2 and 62.4% over control with VC + CR and VC + CR + BF, respectively. A combination of VC + CR + BF was the best treatmentas it enhanced microbial biomass significantly over the control in both RWCS and RWMCS, though FYM + CR in RWCS and VC + CR in RWMCS showed almost similar increase as observed in case of VC + CR + BF.

### 3.(f). Basal respiration

Microbial biomass alone does not provide information on microbial activity.. Input of organic nutrient sources significantly improved the SR activity over the control (Table 5). A comparison of the two cropping systems revealed a significant difference in soil $CO_2$ emission following the input of VC, as in RWCS, significant increase (31.6%) was observed, but in RWMCS, it was slightly lower than the respective control. These differences can be explained on the basis of differences in the C:N ratio of the rhizospheric soil.. In our experi ment, respiratory activity was significantly increased with all treatments in RWCS. In RWMCS also, all organic treatments showed significant increase in SR except VC. The addition of CR stimulated the soil $CO_2$ emission in RWMCS. The SR increased significantly by the residue incorporation and the effect was more apparent where the FYM/VC either singly or in combination with CR was applied, though VC alone did not make any improvement in SR in RWMCS. A corresponding increase in the soil MBC content was also recorded. Carbon mineralization is known to be affected by the complexity of chemical constituents (lignocelluloses content) of organic amendments.

### *3.(g). Metabolic quotient ($qCO_2$)*

The elevated $qCO_2$ values detected with various organic treatments in RWCS except VC + CR and FYM + CR + BF and FYM + CR and FYM + CR + BF in RWMCS suggest less efficient microbial utilization

of C compared to control. The treatment VC + CR in RWCS recorded the highest (5.9 μg $CO_2$-C μg$^{-1}$ bio

mass C h$^{-1}$) (Table 6) followed by FYM + CR + BF (5.3 μg $CO_2$-C μg$^{-1}$ biomass C h$^{-1}$) (Table 6), while in

RWMCS, the highest value of $qCO_2$ is recorded in treatment FYM + CR followed by FYM + CR + BF.

Table 6. Interactive effect of cropping system and nutrient management practices on SR, ergosterol and glomalin content activities in soil of Meerut region fields.

| **Cropping system/ Nutrient management** | **SR(mg $co_2$ (100g)$^{-1}$ siol/week)** | | **Ergosterol(μg g$^{-1}$ soil)** | | **Glomalin content (μg/kg)** | |
|---|---|---|---|---|---|---|
| | Rice-Wheat | Rice-Wheat-Mung bean | Rice-Wheat | Rice-Wheat-Mung bean | Rice-Wheat | Rice-Wheat-Mung bean |
| Control | 43.3 | 44.3 | 15.96 | 1.10 | 43.3 | 94.3 |
| FYM | 50.0 | 50.3 | 13.48 | 7.12 | 72.0 | 62.3 |
| Vermicompost (VC) | 57.0 | 43.2 | 2.97 | 2.35 | 61.0 | 103.3 |
| FYM+ crop residue(CR) | 57.1 | 59.0 | 10.29 | 1.04 | 92.3 | 102.0 |
| VC+RC | 54.3 | 56.3 | 7.50 | 3.14 | 85.3 | 103.0 |
| FYM+CR+Biofertilizer(B) | 49.6 | 50.8 | 1.30 | 8.46 | 91.3 | 64.0 |
| VC+CR+B | 53.0 | 54.2 | 3.53 | 6.63 | 76.7 | 102.7 |
| Mean | 52.0 | 51.2 | 7.83 | 4.26 | 74.6 | 90.2 |
| LSD(P=0.05) | Cropping system (CS): NS<br>Nutrient management (NM): 4.3<br>CS × NM: 6.0 | | Cropping system (CS): 0.05<br>Nutrient management (NM):0.38<br>CS × NM: 0.72 | | Cropping system (CS): NS<br>Nutrient management (NM):15.8<br>CS × NM: 30.7 | |

Note: Values are mean of the data ($n = 3$) and are statistically significant at $p < 0.05$. Data analysed by Two-way ANOVA at LSD < 0.05.

### *3.(h). Total glomalin content*

. In RWCS, the highest value of glomalin content was observed in treatment FYM + CR (92.3 μg kg$^{-1}$) followed by FYM + CR + BF (91.3 μg kg$^{-1}$). FYM + CR and FYM + CR + BF applications had the maximum and significant ($p < 0.05$) impact in enhancing glomalin content (110.8–113.2%) over the control treatment in RWCS (Table 5). In contrast, in RWMCS, plots receiving FYM alone and FYM + CR + BF caused a significant reduction in this soil protein. the nature of organic amendment was found to influence glomalin levels; for instance, application of FYM alone failed to improve soil glo

malin content in RWMCS over the control, whereas VC application exerted a positive effect on soilglomalin content in both RWCS and RWMCS (Table 5).

***3.(i). Ergosterol***

The RWCS and RWMCS, nutrient management and their interactions significantly influenced soil ergosterol content. Ergosterol is the main endogenous sterol of fungi, actinomycetes and some microalgae. Its concentration is an important indicator of fungal growth on organic compounds and mineralization activity. In the present study, the application of manure in combination with the CR in RWMCS favours fungal growth as the fungi are dominant decomposers in the soil. However, when bacterial biofertilizer is added along with the FYM + CR and VC + CR in RWCS, a lowered fungal/bacterial ratio may result in the observed decline in the soil ergosterol content.

***3.(j). Soil organic carbon***

. In the present study, the treatmentVC + CR + BF emerges as the best option in improving the soil organic carbon status for our experimental crops: rice, wheat and mung bean. Results indicated that at the end of nine years of crop rotation, application of FYM or VC either alone or in combination with CR increased the SOC (0.56–0.68%) compared to the control plot, where no organics were applied (Table 7). The application of FYM + CR + BF caused 34.04, 35.41 and 32.69% increase over their respective controls in rice, wheat

**Table 7.**Effect of treatment on organic corbon of soil (2005-2006)

| **Treatment** | **Soil organic carbon (%)** | **Soil organic carbon (%) After harvest of mung bean (RWMCS)** | **Soil organic carbon (%) After harvest of mung bean (RWMCS)** |
|---|---|---|---|
| **Cropping system (in Meerut)** | | | |
| Rice-wheat | 0.56 | 0.58 | 0.60 |
| Rice-wheat-Mung bean | 0.60 | 0.63 | 0.68 |
| LSD P(=0.05) | *0.02* | *0.03* | *0.04* |
| **Nutrient sources** | | | |
| Control | 0.47 | 0.48 | 0.52 |
| FYM | 0.56 | 0.58 | 0.61 |
| VC | 0.57 | 0.62 | 0.65 |
| FYM+CR | 0.58 | 0.61 | 0.65 |
| VC+CR | 0.59 | 0.65 | 0.68 |
| FYM+CR+B | 0.63 | 0.65 | 0.69 |
| VC+CR+B | 0.64 | 0.67 | 0.71 |
| LSD P(=0.05) | 0.03 | 0.04 | 0.06 |

and mung bean crops and VC + CR + BF caused 36.17, 39.58 and 36.54% increase over their controls in rice, wheat and mung bean crops, significantly higher over all other organic sources. A combination of CR with FYM or VC was the next best alternative source of organics.Present studies suggest that FYM or VC, in combination with CR and BF, could be used as an effective mechanism to sequester SOC and improve soil nutrient status.Increase in the amount of C associated with micro bial biomass is more important.

## 4. Discussion

Among the soil enzyme activities studied, alkaline phosphatase (ALP) activity was the only enzyme activity not stimulated by addition of organic nutrient sources Demand for P by plants and soil micro-organisms can be responsible for the stimulation of the synthesis of this enzyme (Garcia, Hernandez, Roldan, & Albaladejo, 1997).**phosphatase activity was found strongly correlated with extractable P (Nottingham et al., 2015), suggesting that increased microbial synthesis of phosphatases was a direct response to low available phosphate (Turner & Wright, 2014).**The hydrolysis products of β-glucosidases are believed to be important energy sources for soil micro-organisms (Tabatabai, 1994).

glucosidase enzyme activity increases with the use of organic nutrients which subse quently results in high available C in the soil and improves the microbial population in soil.

enzymes that adhere to the colloids of the organic compost can be another factor to increase the rate of FDA hydrolysis in the organic cultivation (Nannipieri et al., 2003).

the present results are in disagreement with observations where soil amended with organics also exhibits the greatest dehydrogenase activity (Liang, Si, Nikolic, Peng, & Chen, 2005). The observed dissimilar enzymatic activity response to fertilizer treatments (Table 4) may be the result of the resiliency of the respective enzymes to external inputs.The carbon of the microbial biomass (MBC) is one of the most important variables that reflects dif ferences between organic and conventional areas (Monokrousos, Papatheodorou, & Stamou, 2008). present results are supported by observations of previous workers (Albiach, Canet, Pomares, & Ingelmo, 2000), where they found that organic residues enhanced microbial population, soil microbial biomass and their activity. It has been reported that organic sources like FYM, green manure, CR and BF decompose slowly, resulting in or ganic carbon accumulation in soil (Sharma, Bali, & Gupta, 2001). Experiments conducted in Punjab, India, in the RWCS showed that the incorporation of CR increased SOC compared to their removal from field (Singh, Singh, Meelu, & Khind, 2000). Present results highlight the importance of the input of CR along with VC in order to increase the microbial biomass carbon in soil. An increase in MBC is linked to changes in the nutrient-supplying capacity of organic matter (Gunapala &Scow, 1998).

CR supplies C as an energy source for micro-organisms and increases the microbial activity (Rousk & Baath2007;Smith,Papendick, Bezdicek, & Lynch, 1993).Karmegam and Rajasekar (2012) have reported that microbial population in VC differs qualitatively and quantitatively from that of the com post, and VC is an efficient medium to support the growth of bioinoculants. Interestingly, the highest value of soil microbial biomass carbon was recorded following VC + CR + BF in both RWCS and RWMCS, indicating efficient incorporation of C in the microbial cell mass.The metabolic quotient ($qCO_2$) evaluates the efficiency of soil microbial biomass in using the organic C compounds (Anderson & Domsch, 1989). The greater $qCO_2$ values in these treatments could reflect an increase in the ratio of active:dormant components of the microbial biomass.

A high microbial quotient generally implies a ready supply of fresh organic residues (Anderson & Domsch, 1989).

In the present study, FYM-receiving plots showed the highest level of fungal popula tion as measured by the ergosterol content. Microbiota of the r-strategy ecotype would thrive under such conditions (Insam, 1990) The increase of glomalin levels is usually related to greater AMF (arbuscular mycorrhizal fungi) activity in systems with organic substances (Oehl et al., 2004). Overall, the nature of organic amendment was found to influence glo malin levels. Greater availability of mineral nutrients in VC and their rich microbial populations ac count for the beneficial effects on the mycorrhizal fungi (Arancon, Edwards, Bierman, Welch, & Metzger, 2004). The greater pore volume in VC-amended soils possibly increased the availability of both water and nutrients to micro-organisms including mycorrhizal fungi in soils (Scott, Cole, Elliott, & Huffman, 1996). Addition of organic nutrient sources is known to significantly stimulate mycorrhizal development (Castillo, Rubio, Contreras, & Borie, 2004).The correlation coefficients between different soil biological properties under RWCS and RWMCS are furnished in Table 8 and 9. correlations between microbial biomass and enzyme activity are influenced by many factors (Stark, Condron, Stewart, Di, & O'Callaghan, 2007)

Table 8. correlation coefficients between different soil biological properties under rice-wheat cropping system in Meerut region fields.

| GLC | | AP | ACP | FDA | DHA | MBC | SR | ERG | GLO |
|---|---|---|---|---|---|---|---|---|---|
| GLC | 1000 | | | | | | | | |
| AP | -0.192 | 1000 | | | | | | | |
| ACP | 0.530 | 0.108 | 1000 | | | | | | |
| FDN | 0.391 | 0.760 | 0.375 | 1000 | | | | | |
| DHA | 0.375 | 0.539 | -0.027 | 0.766* | 1000 | | | | |
| MBC | 0.318 | -0.091 | 0.024 | -0.115 | -0.156 | 1000 | | | |
| SR | 0.397 | -0.565 | 0.163 | -0.259 | -0.458 | 0.631 | 1000 | | |
| ERG | -0.608 | 0.281 | -0.901 | -0.047 | 0.301 | -0.245 | -0.507 | 1000 | |
| GLO | 0.833* | -0.621 | 0.201 | -0.084 | 0.010 | 0.288 | 0.553 | -0.471 | 1000 |

*$p < 0.05$.

*$p < 0.01$.

Note: GLC, glucosidase; AP, alkaline phosphatase; AcP, acid phosphatase; FDA, fluorescein diacetate; DHA, dehydrogenase activity; MBC, microbial biomass; SR, soil respiration; ERG, ergosterol; and GLO, glomalin content.

Table 9. correlation coefficients between different soil biological properties under RWMCS cropping system in Meerut region fields (U.P).

| GLC | | AP | ACP | FDA | DHA | MBC | SR | ERG | GLO |
|---|---|---|---|---|---|---|---|---|---|
| GLC | 1000 | | | | | | | | |
| AP | -0.464 | 1000 | | | | | | | |
| ACP | 0.383 | -0.421 | 1000 | | | | | | |
| FDN | 0.040 | -0.059 | -0.524 | 1000 | | | | | |
| DHA | 0.382 | 0.419 | -0.085 | -0.168 | 1000 | | | | |
| MBC | 0.332 | -0.817* | 0.225 | 0.047 | -0.156 | 1000 | | | |
| SR | 0.339 | -0.585 | 0.182 | 0.338 | -0.458 | 0.538 | 1000 | | |
| ERG | -0.091 | -0.605 | 0.287 | 0.288 | 0.301 | -0.399 | 0.084 | 1000 | |
| GLO | 0.485 | 0.158 | 0.311 | -0.480 | 0.010 | 0.092 | 0.147 | -0.724 | 1000 |

*$p < 0.05$.

Note: GLC, glucosidase; AP, alkaline phosphatase; AcP, acid phosphatase; FDA, fluorescein diacetate; DHA, dehydrogenase activity; MBC, microbial biomass; SR, soil respiration; ERG, ergosterol; and

GLO, glomalin content.



A strong negative correlation between soil ergosterol and glomalin content in RWMCS may be explained by the input of organic nutrient sources in the soil which perhaps stimulate the fungal populations, thereby improving the available plant nutrients. These conclusion indicate that under identical nutrient management conditions, cropping system determines the soil microbial indices. This is supported by the observations that the above ground plant influences the composition and biomass of microbial communities (Jones, Hodge, & Kuzyakov, 2004) because rhizodeposits or organic compounds released by plant roots can be highly specific for a given plant species or even a particular cultivar (Prieto, Bertiller, Carrera, & Olivera, 2011).

A strong positive correlation between soil glomalin and glucosidase is expected because soil glomalin contains 37% carbon and3–5% nitrogen, and contributes to the storage of soil carbon (3%), and the glucosidase enzymecatalyses the conversion of the complex carbonaceous polymers into simpler carbon compounds, thereby improving C availability.The all above discussion establishes that organic amendments improve soil microbial activities. Soil microbial activities are directly related to soil biological properties and hence soil fertility. Thus, ap plication of organics, biofertilizer and CR improves soil microbial activity in rice–wheat and rice–wheat–mung bean cropping systems in the Meerut region fields

## 5. Conclusions

The overall microbial activity had been significantly enhanced in soils treated with VC or compost in combination with CR. In result, compost or VC application in combination with CR was found to be beneficial in terms of improving the soil biological parameters in RWCS and RWMCS. The finding from study possesses specific implications in agricultural, ecological and soil ecosystem restora tion perspectives pertaining to maintenance of soil fertility. It is suggested that inclusion of legumi nous crop (wheat–mung bean–rice cropping system) is better than wheat–rice cropping system for maintaining soil productivity under Meerut region fields .

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