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# Soil carbon dynamics and enzymatic activities under different resource conservation technologies in rice- green gram cropping system

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## ABSTRACT

*The effects of different resource conservation practiceson SOC pools, soil enzymatic activities were studied under tropical lowland rice (Oryza sativa L.)- green gram (Vigna radiata) soilsystem in a long-term experiment,which was established in 2012. Seven RCTs i.e., conventional farmer's practice, brown manuring, green manuring, wet direct drum seeding, zero tillage, green manuring plus real time nitrogen management by customized leaf colour chart and biochar application were broadly included in the experiment.Soil organic carbon (SOC) pools were significantly higher under Green manuring treatment compared to conventional control. Soil labile carbon fractions and enzymatic activities were significantly higher under RCTs over control. Soil organic carbon was significantly higher under zero tillage as compared to other resource conservation practices as well as conventional treatments and 13% more than that of conventional control. It can be concluded from the experimental data that resource conservation practices like zero tillage could offer carbon saving by increase soil carbon stock in tropical lowland rice-green gram soil.*

***Key words:*** *Resource conservation technology, rice-green gram, soil organic carbon pools, soil enzymes, soil health*

## INTRODUCTION

Rice-green gram cropping system is one of the most intensively cultivated cropping systems and there is a decline in productivity in intensive rice-rice systems due to the reduction in indigenous N supply over time (Dawe et al., 2000; Shahid et al., 2013; Roy et al., 2011; Kumar et al., 2016). In Eastern India, rice is grown during the rainyseason (*kharif*) from June to November and rice during winter season (*rabi*) from December to March/ April the land generally remains fallow between the harvests of rice. Greengram can be a sequential partner of this cropping system during summer (April-June) under assured irrigation facility. Traditionally rice is grown by hand transplanting of 25-30 day old seedling after puddling. Puddling destroys soil structure, which affects growth and development of succeeding upland crops in the rotation, thereby reducing system productivity (Hobbs et al., 2007). Continuous tillage in both *kharif* and *rabi* season is found tohave ill effects on the soil health and high energy requirement (Gupta et al., 2007).

Resource conservation technologies (RCTs) are considered as one of the key options to minimize agricultural problems in small farm holding in tropics (Hobbs 2007 and Guru et al., 2018). RCT practices like dry direct seeded rice, zero tillage are being promoted in rice-wheat areas of Indo-Gangetic plains. These practices like has added benefits of nutrient conservation and minimizing soil erosion from low economic input (Lal, 2004). However, such practices , affect soil microbial activity and community diversity , thereby, soil biological processes and biochemical properties (Marschner et al., 2003).

Soil enzymes mainly originate from soil microorganisms, which can indicate microbial activities in soil environment. Similarly, soil enzymes also play an important role in organic matter decomposition and nutrient cycling. The activities of enzymes are affected by abiotic conditions (e.g., temperature, moisture, soil pH, and oxygen content), by the chemical structure of the organic matter and by its location in the soil strata.

Several studies show that enzyme activities can be used as early indicators of changes in soil properties originated by management practices (e.g., fertilization, tillage, irrigation and grazing). Keeping the above facts, the objectives of this study was to study the effect of resource conservation practices on soil carbon pools and enzymatic activities under rice-green gram cropping system.

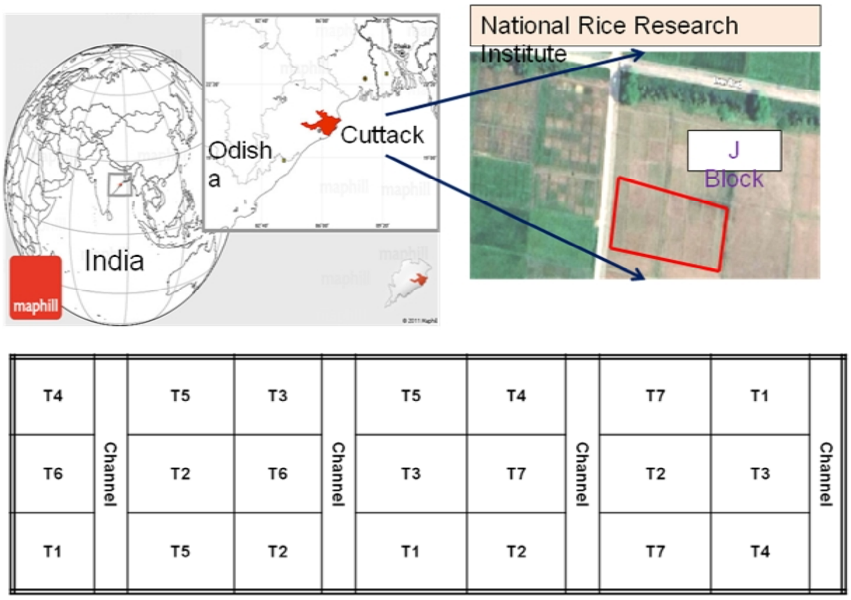
## MATERIALS AND METHODS

### Description of the study area

The study was conducted at experimental farm of ICAR -National Rice Research Institute, Cuttack, Odisha (Fig. 1) with the geo-codes of 20º 44' N, 85º 94' E and 24 m above mean see level. The climate of the study area is characterized by hot, moist, sub-humid type with mean annual rainfall of 1312 mm in 2015 and 1293 mm in 2016, of which more than 75% is received in the months from May to September. The soils is developed from alluvial deposits in a piedmont plain, belong to Aeric Endoaquept (Soil Survey Staff, 2010) with a sandy clay loam texture (32% clay, 12% silt and 56% sand). Soil of the experimental site had an organic carbon, Olsen P, and $KMnO_4$ extractable N (available N) contents of 5.2 g $kg^{-1}$, 22.8, 263 kg $ha^{-1}$, respectively.

### Experimental design and treatment details

The study was conducted during 2016 in the long-term experiment of resource conservation technologies, which was established in 2012. The experiment was laid out in randomized block design with seven treatments, which were replicated thrice (Table 1). The size of each experimental plot was 10 m × 9 m. Rice (*Oryza sativa* L.) variety, Pooja and green gram (*Vigna radiata* L.) variety, Samrat were sown at spacing of 20 cm × 15 cm for rice and 30 cm × 10 cm for green gram. Chemical fertilizers were applied as recommended dose of fertilizer (RDF) in this region, viz., at the rate of 80: 40: 40 kg $ha^{-1}$ ($N: P_2O_5: K_2O$) for wet season rice and 20: 40: 20 kg $ha^{-1}$ ($N: P_2O_5: K_2O$) for dry season green gram. Nitrogen (N) was applied as urea in three splits (50% basal + 25% each as two top dressings) in rice and in green gram; the entire N was applied as basal. Phosphorus and potassium were incorporated into the soil at the time of sowing through single superphosphate (SSP) and muriate of potash (KCl), respectively. Irrigation water (5±2 cm) was applied through check-basin method, where irrigation was given at every 3-5 days interval. Standard recommended practices were followed to control the weeds, insects and diseases.Agronomic and yield parameters were recorded as per the procedure described in Kumar et al., 2017.



| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| T4 | Channel | T5 | T3 | Channel | T5 | T4 | Channel | T7 | T1 | Channel |
| T6 | | T2 | T6 | | T3 | T7 | | T2 | T3 | |
| T1 | | T5 | T2 | | T1 | T2 | | T7 | T4 | |

**Fig. 1.** Location map, study site along with field layout of the experiment.

**Table 1**. Treatment details of the experiment.

| Treatments | Practice followed | |
|---|---|---|
| | Wet season (rice) | Dry season (green gram) |
| Conventional Practice (CP) | Manual wet direct sowing + Manual weeding + 100% RDF + Manual harvesting | Conventional tillage + Line sowing + Manual weeding |
| Brown Manuring (BM) | Dry direct sowing + Inter cropping Sesbania aculeata and knocking down of by 2,4-D at 25 days after sowing + 75% N + mechanical weeding + mechanical harvesting | Conventional tillage + Line sowing +Manual weeding |
| Green Manuring (GM) | Dry direct sowing + Inter cropping Sesbania aculeata and incorporation through cono-weeder at 25 days after sowing + 75% N + mechanical weeding + mechanical harvesting | Conventional tillage + Line sowing + Manual weeding |
| Wet Drum Sowing (WDS) | Wet direct sowing by drum seeder + mechanical weeding + 100% RDF + Mechanical harvesting | Conventional tillage +Line sowing + Manual weeding |
| Zero Tillage (ZT) | Zero tilled dry direct sowing + Residue retention (20 cm above the ground) + 100% RDF + Chemical weeding + Manual harvesting | Zero tillage + Line sowing+ chemical weeding |
| Green Manuring + CLCC-N (GM-CLCC-N) | Paired row dry direct sowing rice with seed drill with one row Sesbania aculeata intercropping and incorporation at 25 days through cono-weeder) + 75% N + CLCC based N management + mechanical weeding + Mechanical harvesting | Conventional tillage + Line sowing + Manual weeding |
| Biochar (BC) | Wet direct sowing by drum seeder + biochar (5 t/ha) + 100% RDF + mechanical weeding + Mechanical harvesting | Conventional tillage + Line sowing + Manual weeding |

## Soil sampling

Soil samples from each plot consisted of composite samples that were collected with a sample probe augur (0-15 cm) at various crop growth stages of crop cultivation i.e maximum tillering (MT), panicle initiation (PI), flowering (FL), grain filling (GF), maturity (M) of rice and vegetative (VG), flowering (FL) and pod filling (PF) of green gram. Collected soil was thoroughly mixed and composite samples were prepared.

## Soil carbon pools

Soil microbial biomass carbon (MBC) was estimated by modified chloroform fumigation-extraction method with fumigation at atmospheric pressure (Witt et al., 2000). Readily mineralizable carbon (RMC), extracted with 0.5 M $K_2SO_4$ in soil samples was estimated (Inubushi et al., 1991) by wet digestion method (Vance et al., 1987). The permanganate oxidizable C (KMnO4-C) content was determined by following theprocedure of Blair et al. (1995). The organic C content of soil was measured followed by the procedure proposed by Walkley and Black, 1934.

## Soil enzymes activities

Soil dehydrogenase enzymatic activity was done by reducing 2,3,5-triphenyl-tetrazolium chloride (Casida et al., 1964). Fluorescein diacetate (FDA) hydrolysis activity measurement was done by Schnurer and Rosswall (1982) method with the modification proposed by Adam and Duncan (2001). For estimating β-glucosidase activity method of Eivazi and Tabatabai (1988) was followed and urease activity was measured by following the method of Tabatabai and Bremner (1972).

## RESULTS AND DISCUSSION

## Soil carbon dynamics

### Readily Mineralizable Carbon

Readily mineralizable carbon (RMC) content under different treatments at all the rice growth stages (*i.e.,* MT, PI, FL, GF and M) in the wet season and at different stages of green gram (*i.e.,* VG, FL and PF) in the dry season was measured. RMC content was in the range of 105.55 - 255.68 µg C $g^{-1}$ soil in all the treatments under wet season (Table 2). It was more at PI stage as compared to all other stages at PI stage, highest RMC content was found under GM (255.68 µg C $g^{-1}$ soil) and lowest under CP (200.82 µg C $g^{-1}$ soil). However, in dry season under green gram cultivation the RMC content was observed at three different growth stages and it was in the range of 81.27 - 161.31 µg C $g^{-1}$ soil (Table 3). It was found that the RMC content was more at PF than VG and FL. At PF stage, RMC content was more under GM (161.31 µg C $g^{-1}$ soil) and less

**Table 2.** Readily mineralizable carbon (RMC) content during various rice growth stages under different resource conservation technologies in wet season.

| | Readily mineralizable carbon (µg $g^{-1}$ soil) | | | | |
|---|---|---|---|---|---|
| Treatments | MT | PI | FL | GF | M |
| CP | 151.35e | 200.82f | 162.41e | 119.24e | 105.55d |
| BM | 185.63b | 243.16b | 203.43b | 156.29b | 140.19b |
| GM | 199.12a | 255.68a | 216.06a | 168.60a | 152.20a |
| WDS | 159.67d | 209.30e | 170.33e | 125.88e | 111.49d |
| ZT | 170.13c | 217.74d | 179.00d | 134.78d | 120.30c |
| GM-CLCC N | 180.85b | 233.96c | 194.68c | 148.73c | 133.30b |
| BC | 167.64c | 219.73d | 180.93d | 136.45d | 121.86c |
| LSD at 5% | 7.61 | 8.17 | 7.93 | 7.41 | 7.15 |

**Table 3.** Readily mineralizable carbon (RMC) content during various green gram growth stages under different resource conservation technologies in dry season.

| | Readily mineralizable carbon (µg $g^{-1}$ soil) | | |
|---|---|---|---|
| Treatments | VG | FL | PF |
| CP | 81.27e | 99.25d | 117.76d |
| BM | 110.09bc | 130.60b | 147.06b |
| GM | 123.18a | 145.09a | 161.31a |
| WDS | 86.05e | 104.42d | 122.12d |
| ZT | 97.71d | 114.48c | 131.23c |
| GM-CLCC N | 106.20cd | 126.01b | 142.77b |
| BC | 119.32ab | 139.32a | 155.33a |
| LSD at 5% | 9.45 | 7.08 | 6.73 |

[Here, CP: conventional practice; BM: brown manuring; GM: green manuring; WDS: wet drum seeding; ZT: zero tillage; GM-CLCC-N: green manuring- CLCC-N; BC: biochar and VG: vegetative; FL: flowering; PF: pod filling stages]

under CP (117.76 µg C $g^{-1}$ soil).

## Microbial biomass carbon

Microbial biomass carbon (MBC) under different treatments in both the season (wet and dry) was observed and presented in Table 5 and 6, respectively. In wet season, MBC content was observed in all the rice growth stages and it was found more at PI stage than others. At PI stage, MBC content was ranged from 369.27 µg C $g^{-1}$ soil (CP) and 491.17 µg C $g^{-1}$ soil (GM), whereas in overall comprising all the stages it was ranged from 134.36-491.17 µg C $g^{-1}$ soil (Table 4). Similarly in dry season MBC content was more at PF stage than the other stages. It was in the range of 121.46-252.26 µg C $g^{-1}$ soilunder different treatments (Table 5).

**Table 4.** Microbial Biomass Carbon (MBC) content during various rice growth stages under different resource conservation technologies in wet season.

| | Microbial biomass carbon (µg $g^{-1}$ C soil) | | | | |
|---|---|---|---|---|---|
| Treatments | MT | PI | FL | GF | M |
| CP | 241.58f | 369.27f | 282.77e | 194.28e | 134.36d |
| BM | 334.25b | 463.35b | 373.08b | 276.11b | 210.82b |
| GM | 359.06a | 491.17a | 400.98a | 303.20a | 236.85a |
| WDS | 254.04ef | 388.12e | 300.13e | 209.01e | 147.85d |
| ZT | 269.49de | 406.87d | 319.99d | 229.36d | 168.49c |
| GM-CLCC N | 309.85c | 442.91c | 353.98c | 259.55c | 195.82b |
| BC | 282.94d | 411.28d | 323.89d | 232.60d | 170.96c |
| LSD at 5% | 20.88 | 18.16 | 17.61 | 16.54 | 16.01 |

**Table 5.** Microbial Biomass Carbon (MBC) content during various green gram growth stages under different resource conservation technologies in dry season.

| | Microbial biomass carbon (µg g-1 C soil) | | |
|---|---|---|---|
| Treatments | VG | FL | PF |
| CP | 121.46d | 137.87d | 157.05d |
| BM | 185.25b | 207.28b | 222.21b |
| GM | 213.25a | 238.32a | 252.26a |
| WDS | 132.83d | 150.17d | 168.01d |
| ZT | 158.44c | 174.05c | 190.18c |
| GM-CLCC N | 176.67bc | 197.40b | 212.98b |
| BC | 205.69a | 227.64a | 241.63a |
| LSD at 5% | 19.483 | 16.026 | 15.166 |

[Here, CP: conventional practice; BM: brown manuring; GM: green manuring; WDS: wet drum seeding; ZT: zero tillage; GM-CLCC-N: green manuring- CLCC-N; BC: biochar and VG: vegetative; FL: flowering; PF: pod filling stages]

## $KMnO_4$ oxidizable carbon

$KMnO_4$-C content was in the range of 241.25-468 µg C $g^{-1}$ soil in the wet season overall all the treatments (Table 6). Comprising all the rice growth stages, it was observed higher $KMnO_4$-C content at PI stage and at PI stage, $KMnO_4$-C content was found to be more under GM (468 µg C $g^{-1}$ soil) and lower under CP (409 µg C $g^{-1}$ soil). However, in dry season $KMnO_4$-C content was ranged 231.75-408.0µg C $g^{-1}$ soil and it was more at PF stage as compared to all other growth stages (Table 7). At PF stage, highest $KMnO_4$-C content was found under ZT (468 µg C $g^{-1}$ soil) and lowest under GM-CLCC N (270 µg C $g^{-1}$ soil).

**Table 6.** $KMnO_4$ Oxidizable Carbon ($KMnO_4$-C) content during various rice growth stages under different resource conservation technologies in wet season.

| | $KMnO_4$ oxidizable carbon (µg $g^{-1}$ C soil) | | | | |
|---|---|---|---|---|---|
| Treatments | M T | PI | FL | GF | M |
| CP | 303.75d | 409.50d | 355.50d | 272.25d | 241.25d |
| BM | 362.25bc | 468.00bc | 414.00bc | 330.75bc | 299.75bc |
| GM | 385.50a | 491.25a | 437.25a | 354.00a | 323.00a |
| WDS | 315.75d | 421.50d | 367.50d | 284.25d | 253.25d |
| ZT | 393.75a | 499.50a | 445.50a | 362.25a | 331.25a |
| GM-CLCC N | 378.00ab | 483.75ab | 429.75ab | 346.50ab | 315.50ab |
| BC | 352.50c | 458.25c | 404.25c | 321.00c | 290.00c |
| LSD at 5% | 21.561 | 21.561 | 21.561 | 21.561 | 21.561 |

**Table 7.** $KMnO_4$ Oxidizable Carbon ($KMnO_4$-C) content during various green gram growth stages under different resource conservation technologies in dry season.

| | $KMnO_4$ oxidizable carbon (µg $g^{-1}$ C soil) | | |
|---|---|---|---|
| Treatments | VG | FL | PF |
| CP | 264.00c | 273.75c | 300.00d |
| BM | 322.50b | 335.25b | 351.75c |
| GM | 348.75a | 362.25a | 384.00b |
| WDS | 279.75c | 293.25c | 315.75d |
| ZT | 369.75a | 384.75a | 408.00a |
| GM-CLCC N | 231.75d | 246.00d | 270.00e |
| BC | 312.00b | 329.25b | 351.00c |
| LSD at 5% | 22.774 | 22.702 | 16.638 |

[Here, CP: conventional practice; BM: brown manuring; GM: green manuring; WDS: wet drum seeding; ZT: zero tillage; GM-CLCC-N: green manuring- CLCC-N; BC: biochar and VG: vegetative; FL: flowering; PF: pod filling stages]

## Soil organic carbon

Soil organic carbon was estimated among all the treatments in both the season (Table 8). In *kharif*, SOC content ranged from 0.55 (CP) - 0.66% (ZT). However, in *rabi*, SOC content was in the range of 0.54 (CP) - 0.63% (ZT).

**Table 8.** Soil organic carbon (SOC) under different resource conservation technologies in both the seasons.

| | Soil organic carbon (%) | |
|---|---|---|
| Treatments | *Rabi* 2015 | *Kharif* 2015 |
| CP | 0.52d | 0.53f |
| BM | 0.57b | 0.57cd |
| GM | 0.59ab | 0.60ab |
| WDS | 0.52d | 0.54ef |
| ZT | 0.61a | 0.61a |
| GM-CLCC N | 0.59b | 0.59bc |
| BC | 0.55c | 0.56de |
| LSD at 5% | 0.02 | 0.02 |

[Here, CP: conventional practice; BM: brown manuring; GM: green manuring; WDS: wet drum seeding; ZT: zero tillage; GM-CLCC-N: green manuring- CLCC-N; BC: biochar]

## Soil enzymatic activities

### Dehydrogenase activity

Soil enzymatic activity was influenced by different treatments in both the season. The DHA activity was measured in different treatments with respect to both seasonal experiments. In wet season with rice cultivation, the dehydrogenase activity was in the range of 80.82-485.87 µg TPF $g^{-1}$ $d^{-1}$ (Fig. 2). DHA content was found to be more at PI stage than other growth stages and at PI stage it was in the range 305.28-

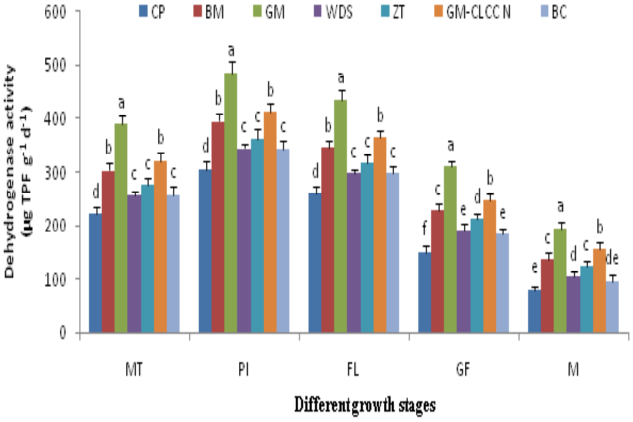


**Fig. 2.** Dehydrogenase (DHA) activity during various rice growth stages under different resource conservation technologies in wet season.

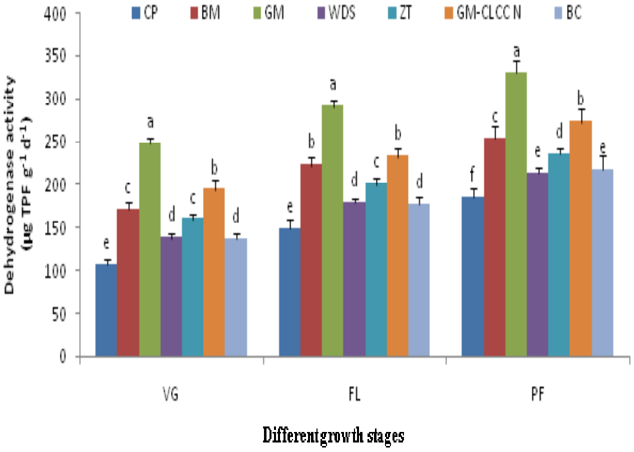


**Fig. 3.** Dehydrogenase (DHA) activity during various green gram growth stages under different resource conservation technologies in dry season. [Here, CP: conventional practice; BM: brown manuring; GM: green manuring; WDS: wet drum seeding; ZT: zero tillage; GM-CLCC-N: green manuring-CLCC-N; BC: biochar and VG: vegetative; FL: flowering; PF: pod filling stages]

485.87 µg TPF g$^{-1}$ d$^{-1}$. Considering different treatments, DHA content was observed higher under GM and it was ranged from 194.45- 485.87 at all the growth stages. However, in dryseason DHA content was in the range 106.59- 329.98 µg TPF g$^{-1}$ d$^{-1}$, and it was observed more at PF stage as compared to all other growth stages (Fig. 3). At PF stage, DHA content was more under GM (329.98 µg TPF g$^{-1}$ d$^{-1}$) and less under CP (185.65 µg TPF g$^{-1}$ d$^{-1}$).

## Fluorescein diacetate activity

At PI stage, FDA activity was observed higher under GM (254.38 µg fluorescein g$^{-1}$d$^{-1}$) and lower under CP (220.64) in the wet season (Fig. 4). Overall in all the treatments at different rice growth stages, FDA activity was in the range of 125.21 - 254.38 µg fluorescein g$^{-1}$d$^{-1}$. However, in dry season FDA activity was ranged 52.95 - 109.09 µg fluorescein g$^{-1}$d$^{-1}$ and represented in the Fig. 5. It was observed more at PF stage as compared to all other growth stages and at PF stage, FDA activity was found more under GM-CLCC N (109.09 µg fluorescein g$^{-1}$d$^{-1}$) and less under ZT (78.13 µg fluorescein g$^{-1}$d$^{-1}$).

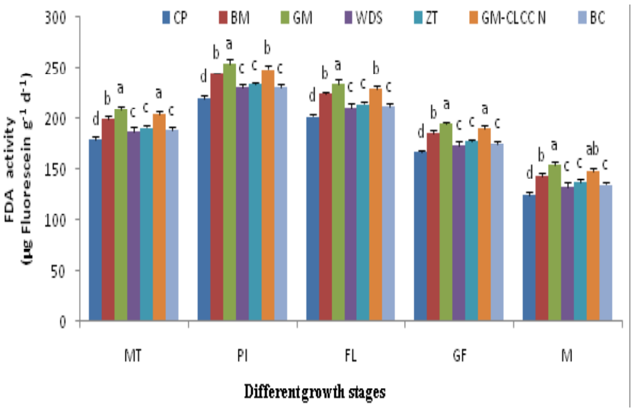


**Fig. 4.** Fluorescein diacetate (FDA) activity during various rice growth stages under different resource conservation technologies in wet season.

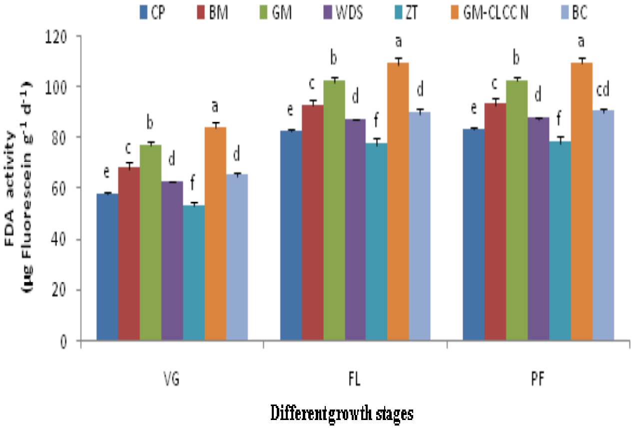


**Fig. 5.** Fluorescein diacetate (FDA) activity during various green gram growth stages under different resource conservation technologies in dry season. [Here, CP: conventional practice; BM: brown manuring; GM: green manuring; WDS: wet drum seeding; ZT: zero tillage; GM-CLCC-N: green manuring- CLCC-N; BC: biochar and VG: vegetative; FL: flowering; PF: pod filling stages]

## β-glucosidase activity

β-glucosidase activity was in the range of 23.48 - 118.85 µg p-nitrophenol g$^{-1}$ h$^{-1}$ in the wet season and it was found more at PI stage (Fig. 6). At PI stage, β-glucosidase activity content was ranged from 88.08 - 118.85 µg p-nitrophenol g$^{-1}$ h$^{-1}$. Similarly, in dry season β-glucosidase activity content was ranged from 28.08-

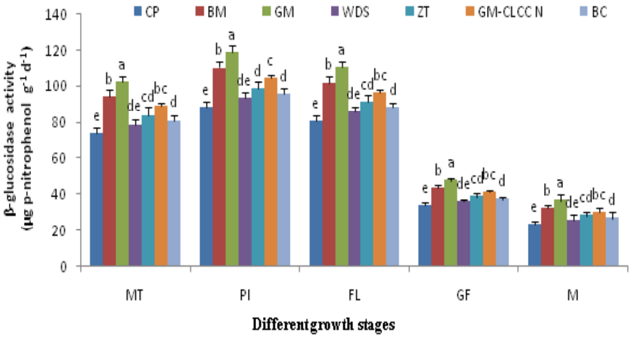


**Fig. 6**. β-glucosidase activity during various rice growth stages under different resource conservation technologies in wet season.

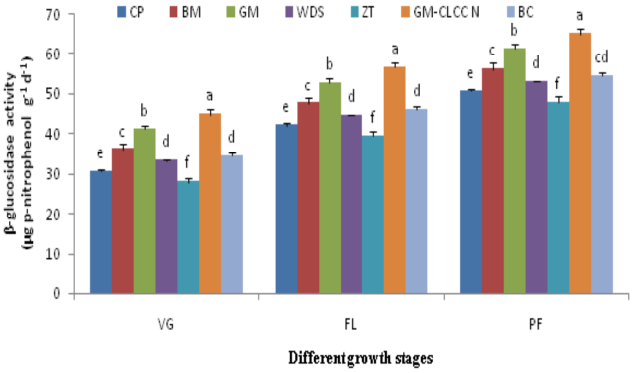


**Fig. 7.** β-glucosidase activity during various green gram growth stages under different resource conservation technologies in dry season. [Here, CP: conventional practice; BM: brown manuring; GM: green manuring; WDS: wet drum seeding; ZT: zero tillage; GM-CLCC-N: green manuring- CLCC-N; BC: biochar and VG: vegetative; FL: flowering; PF: pod filling stages]

65.02µg p-nitrophenol $g^{-1}$ $h^{-1}$(Fig. 7). Considering the three growth stages, it was found more at PF stage and more under GM-CLCC N (65.02 µg p-nitrophenol $g^{-1}$ $h^{-1}$) and less under ZT (48 µg p-nitrophenol $g^{-1}$ $h^{-1}$).

### Urease activity

In the wetand dry season, urease activity was estimate at all the rice growth stages. The urease activity was higher at PI stage and lower at M stage as compared to all other rice growth stages in the wet season. At PI stage it was in the range of 288.19-384.28 µg urea $g^{-1}$ $h^{-1}$ and atmaturity stage, it was ranged from 142.61-222.42 µg urea $g^{-1}$ $h^{-1}$ (Fig. 8). However, urease activity was ranged from 71.91 - 193.35 µg urea $g^{-1}$ $h^{-1}$ soil in dry season (Fig. 9). Comprising all growth stages, more urease activity was found under GM-CLCC N (ranged from 115.95- 193.35 µg urea $g^{-1}$ $h^{-1}$) and lower in ZT (ranged from 71.91- 145.58 µg urea $g^{-1}$ $h^{-1}$).

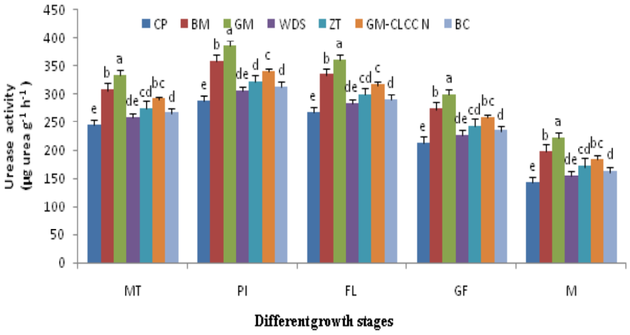


**Fig. 8.** Urease activity during various rice growth stages under different resource conservation technologies in wet season.

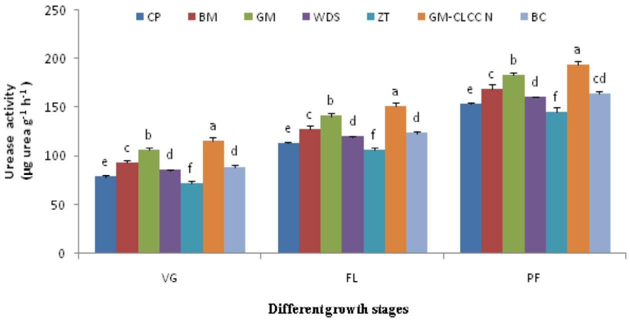


**Fig. 9.** Urease activity during various green gram growth stages under different resource conservation technologies in dry season. [Here, CP: conventional practice; BM: brown manuring; GM: green manuring; WDS: wet drum seeding; ZT: zero tillage; GM-CLCC-N: green manuring- CLCC-N; BC: biochar and VG: vegetative; FL: flowering; PF: pod filling stages]

## Effect of RCTs on soil C pool

Application of organic manures has been reported to significantly affect SOC and its fractions due to addition of C input of varying turnover rate (Nayak et al., 2012). It is well known the status of soil MBC indicates the rate of soil organic matter decomposition and nutrient cycling in soil. It could be used as mirror of labile C fraction of soils, which is sensitive to management intervention and climate change. Major practices of RCTs, like tillage, residue management and green manuring affect the dynamics of MBC in the lowland flooded soil (Bhattacharyya et al., 2012a, 2013, 2015; Bhatt, 2017). Primary effect of green manuring could be sought as the enhancement of C-assimilation, which leads to increase in C availability through higher labile C content in soil (Dash et al., 2017). RCTs like zero tillage with residue retention or incorporation having a high C/N ratio decomposes slowly due to limited N availability causing net C immobilization (Bhattacharyya et al., 2012a). But when rice straw incorporation is associated with green manuring, the labile C source supports the growth of microbial biomass, which in turn promotes the priming effect of soil organic matter resulting into higher decomposition (Dash et al., 2017). Green manure or rice residue decomposes to produce acetate, which is the key component for growth of micro organisms. In this study also, labile C pools such as RMC, MBC and $KMnO_4$- C in soil showed significantly higher values under green manuring, brown manuring techniques. Similar results were also reported by (Ghani et al., 2003). The application of organic amendments can affect mineralization rates of soil organic matter and contribute to increases in soil organic C content by increasing residue input with increased crop production (Iqbal et al., 2009). Wetland rice fields, which are predominantly anoxic, generally had higher fraction of permanganate oxidizable carbon, but low content of water soluble C (Blair et al., 2006a, b). The $KMnO_4$- C fraction represents a large part of SOC compared to WSC, and less responsive to changes in the soil environment. Therefore, $KMnO_4$- C is more likely to be an integrative measure of long term changes. Our results suggested that RCT practices where biomass incorporation was done reported higher $KMnO_4$- C, and indicated a long term benefit under that technique. In general, increase in C in lowland paddy was due to the low rate of C decomposition and higher net ecosystem production (Nayak et al., 2012; Bhattacharyya et al., 2014), which further could be enhance by intervention of RCTs (Garcla-orenes et al., 2010). However, application of manures and other organic materials provides a means of recycling nutrients, which leads to a greater labile C pool in soil, which could lead to increased SOC.

### Effect of RCTs on soil enzymes

The enzyme activity depends on the activity of soil labile C and N pools. The more the content of C and N pools the higher the activity of enzymes due to availability of suitable substrates for growth and activity of microorganisms (Bhattacharyya et al., 2012a, b). Soil dehydrogenase assay has been used as an indicator of biological activities in soil which depends on metabolic state of soil microorganisms. It could effectively be used for judging the microbial activities and physico-chemical conditions of flooded soils (Bhattacharyya et al., 2012a, b). In our study, a significant increase in dehydrogenase activity in green manuring treatment was due to increased microbial activity. Green manuring affect the dynamics of soil microbial biomass in the flooded soil. With the primary effect of green manuring being in the enhancement of C-assimilation, the microbial biomass may benefit the most from increased C availability through higher labile C content in soil. The highest activity at PI stage was attributed to the most active stage of the rice crop growth and higher amount of root exudations into the soil (Bhattacharyya et al., 2012a, b). Fluorescein diacetate (3, 6- diacetyl fluorescein) hydrolysis assay evaluates the potential activity of ester-cleaving enzymes and can be used to measure microbial activity in soils (Schimel and Weintraub, 2003). The activities of this enzyme depend on the taxonomic structure of microbial community and interference of other physicochemical processes. FDA hydrolysis activity was increased significantly under green manure treatment owing to the abundance of increased soil labile C content (Bhattacharyya et al., 2012a, b). The β-glucosidase is widespread in nature, and is synthesized by soil microorganisms in response to the presence of suitable substrate. This enzyme catalyses the hydrolysis of cellobiose, and thus plays a major role in the initial phase of the decomposition of organic compounds. Furthermore, their action is fundamental in order to liberate nutrients, to reduce the molecular size or organic structures and thus facilitate future microbial enzyme activities. In this study, green manuring also increased β- glucosidase activity due to the increase of soil labile C content. Increased labile C inputs into the soil in response to green manuring stimulated microbial activity which enhanced β-glucosidase activity. That appeared to be a sensitive indicator for changing belowground C turnover. Urease enzyme is responsible for the hydrolysis of urea fertilizer applied to the soil into $NH_3$ and $CO_2$. Conversion of organic N to inorganic N through hydrolysis of urea to ammonia and $CO_2$ is an important pathway of N transformation in soils. This in turn, results in a rapid N loss to the atmosphere through $NH_3$ volatilization and reflects the N availability in soil.

## CONCLUSION

The results obtained from the present investigation indicate that carbon fractions like RMC, MBC and $KMnO_4$- C and soil enzymatic activity were significantly changed over the resource conservation practices. Soil organic carbon pools and enzymatic activities more under green manuring treatments where as soil organic carbon was 13% higher under zero tillage practices. It can be concluded from the experimental data that resource conservation practices like green manuring treatment have greater value of soil carbon fractions and enzymatic activities, while zero tillage could offer carbon saving by increase soil carbon stock in tropical lowland rice-green gram soil. Moreover this work symbolized with a cutting-edge concept of minimization of resource (agricultural inputs) to achieve food production more economic and sustainable while maintaining a C-rich healthy soil.

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