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Effect of Long Term Application of Fertilizers and Manures on Slow and Passive Pools of Organic Carbon under Rice-Rice Sequence

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ABSTRACT

A field experiment entitled "Carbon sequestration and soil health under long term soil fertility management in rice-rice cropping system" was carried out under field conditions during both kharif and rabi seasons of 2016-2017 and 2017- 2018 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, West Godavari district in the ongoing All India Coordinated Research Project on Long Term Fertilizer Experiment Project. The results reported that the higher passive pools (HAC and FAC) were observed in only organic plot i.e. application FYM @ 10 t ha^{-1} and it was significantly superior over other treatments. Application of 100 % RDF along with $ZnSO_4$ @ 40 kg ha^{-1} and Application of 100 % RDF were not significant. Slow pools (POC) were observed with the application of 100% RDF in combination with $ZnSO_4$ and FYM @5t ha^{-1}.

Key words: *Organic manures, Inorganics, HAC and FAC.*

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INTRODUCTION

Soil is the major reservoir of terrestrial organic carbon in the biosphere, which plays an important role in global carbon cycle. Large scale changes in land use like deforestation and agricultural activities like biomass burning, ploughing, drainage, low input farming have resulted in significant changes in SOC pools[5]. To better understand the mechanism by which C is lost of stabilized in the soil, the SOC pools is separated in to a labile or actively cycling pool, a slow pool and a stable or passive, recalcitrant pool with varying residence times[8]. The total carbon pool constitutes a major global reservoir comprising of SOC pool and SIC pool.

Net change in SOC depends not only on the current management practices but also on the management history of the soil. Long term experiments are the primary source of information to determine the effect of cropping systems, soil management, fertilizer usage and residue utilization on the changes in soil organic carbon[9].

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The long-term fertilizer experiments conducted by the AICRP have shown that the conjunctive use of fertilizers and manures would not only impart sustainance to production and improve soil health but also enhance the efficiency of applied nutrients.

MATERIAL AND METHODS

A long-term field experiment was initiated in *kharif*, 1989 with rice-rice cropping system at APRRI & RARS, Maruteru, West Godavari. The experiment was carried out under field conditions during *kharif* and *rabi* seasons of 2016-2017 and 2017- 2018 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, West Godavari district in the ongoing All India Coordinated Research Project on Long Term Fertilizer Experiment Project. The treatments consisted of control, 100 per cent recommended dose of NPK, 100 per cent recommended dose of NK, 100 per cent recommended dose of PK, 100 per cent recommended dose of NP, 100 per cent recommended dose of NPK+$ZnSO_4$ @ 40 kg/ ha, 100 per cent recommended dose of NPK+$ZnSO_4$ @ 40 kg/ ha + FYM @ 5 t ha^{-1}, 50 per cent recommended dose of NPK, 50 % NPK + 50 % N through green manures, 50 % NPK + 50 % N through FYM, 50 % NPK + 25 % N through green manures + 25 % N through FYM and FYM only @ 10 t/ha. There were twelve treatments laidout in RBD with three replications for both *kharif* and *rabi* seasons in two years of study. Nitrogen was applied through urea in three equal splits ($1/3^{rd}$ basal+$1/3^{rd}$ at tillering+$1/3^{rd}$ at panicle initiation stage). Phosphorus was applied through DAP was used duly taking its N content into account and potassium as muriate of potash (60 % K_2O) and zinc as zinc sulphate ($ZnSO_4.7H_2O$). The entire dose of phosphorus, potassium and zinc were applied as basal. Recommended dose of fertilizer for *kharif* season was 90: 60: 60 N: P_2O_5: K_2O kg ha^{-1} and for *rabi* season it was 180: 90: 60 N: P_2O_5: K_2O kg ha^{-1}. Well decomposed farmyard manure (FYM) manure and *Calotropis* (green leaf manure) were applied two weeks before transplanting. The experiment on rice – rice sequence as detailed above was repeated on a same site during *kharif* 2016-17 and *rabi* 2017-18, respectively. Popular cultivars of *kharif* rice and *rabi* rice, MTU-1061, MTU-1010 respectively, were used for the study. Data was collected on on active carbon pools (MBC, WSC and $KMnO_4$-C) of both *kharif* and *rabi* rice. For determining particulate organic carbon (POC), 10 g soil was dispersed with 30 ml of 5g L^{-1}sodium hexa metaphosphate after shaking for 16 hours and the solution was passed through a 0.053 mm sieve[2]. The humic substances were isolated, extracted by followingTyurin's method as described by Kononova[4].

RESULTS AND DISCUSSION

Particulate Organic Carbon (MBC)

Data pertaining to particulate organic carbon in soil presented in table 1 to 4 revealed a significant effect of inorganic fertilizers, organic manures and their combination on particulate organic carbon in soil at initial and harvesting stages of rice during both the years of study.

At initial stage, the highest particulate organic carbon content (1270, 1273, 1276 and 1279 mg kg^{-1} in *kharif* and *rabi*, 2016-17 and 2017-18, respectively was observed in T_7 which was significantly superior over other treatments except T_{10} (50% NPK + 50 % N through FYM) and the lowest particulate organic carbon (502, 504, 506 and 507 mg kg^{-1}) was observed in control (T_1). Application of the organics (FYM and green manure) significantly improved POC in soil.

Among the inorganic treatments the treatment T_6 (100% RDF %+ $ZnSO_4$) recorded the significantly highest POC (894, 896, 898 and 901 mg kg^{-1} in *kharif* and *rabi*, 2016-17 and 2017-18 respectively over T_4 and T_5 but however it was on par with treatment T_2 (100% NPK) and T_3 (100% NK).

The significantly higher POM content in treatments those received manure plus NPK than N, NP treated plots and unfertilized control was also reported by Yan *et al.*[11]. Liang *et al*.[6] revealed that the application of

FYM significantly increased the POM over treatments receiving inorganic fertilizers and control in both surface and subsurface soils.

At harvest stage of *kharif* rice, among all the treatments the particulate organic carbon in T_7, which received 100% RDF+ $ZnSO_4$ + FYM recorded highest (1274 mg kg^{-1} in 2016 and 1280 mg kg^{-1} in 2017) which was significantly superior over all other treatments but however it was on par with treatments T_{10} (50% NPK+ 50% N through FYM) with 1195 in 2016 and 1201 mg kg^{-1} in 2017 and T_{11} (50% NPK+ 25% N through FYM + 25% N through green manure) in both the years and the lowest particulate organic carbon was observed in control (T_1).

During the *rabi* season (2017 and 2018), the highest particulate organic carbon content was observed in T_7 which was significantly superior over other treatments but however it was on a par with T_{10} (50% NPK+ 50 % N through FYM). The lowest particulate organic carbon was observed in control (T_1) in harvesting stage during the both *rabi* seasons.

Particulate organic matter, an active pool of soil organic matter, mainly consists of partially decomposed plant and animal residues, root fragments, fungal hyphae, spores, faecal pellets, faunal skeleton and seeds[3]. The main source of POC in soil is the difficultly decomposable organic residues having high lingo cellulose index as is found in root biomass, often of recent origin.

The only organic (T_{12}) treatment recorded significantly highest particulate organic carbon and this was significantly superior over other inorganic treatments (T_1, T_3, T_4, T_5, T_8) at initial and harvest stage in *kharif and rabi*, 2016-17 and 2017-18, respectively. However, the treatment T_{12} was on par with treatment T_2 (100 % RDF).

The results of the experiment revealed that the combined application of organics and inorganics recorded the highest POC. The results were coincided with the findings of[7]. This is due to the increased rhizodeposition might enter the particulate fraction of SOC. The POC fraction was significantly elevated by the organic amendments compared to imbalanced fertilization in this study. This elucidates that the organic manuring also contributes to the POC fraction in soil. And hence, significant quantities of C from farmyard manure were retained in soil particulate fractions.

Humic Acid Carbon (HAC)

The data revealed that at initial stage, the humic acid carbon content was significantly influenced by different treatments. The humic acid content varied from 2.1 to 3.1 g C kg^{-1} in (*Kharif*, 2016); 2.2 to 3.4 g C kg^{-1} in (*Rabi*, 2017); 0.24 to 0.37 in (*Kharif*, 2017); 0.24 to 0.38 in (*Rabi*, 2018). The highest HAC was recorded with application of FYM @ 10 t ha^{-1}which was significantly superior over all other treatments but however it was on par with treatment T_7 (100% NPK + $ZnSO_4$ + FYM), T_{10} (50% NPK+ 50% N through FYM) and T_{11} (50% NPK+ 25% N through FYM + 25% N through green manures). The lowest (2.1, 2.2, 2.4 and 0.24 g C kg^{-1}) humic acid carbon content was obtained in control. Similar results were observed in *kharif* and *rabi* season during both the years of study.

At initial stage among the inorganic treatments (T_2, T_3, T_4, T_5, T_6 and T_8), the treatment T_6 (100% RDF +$ZnSO_4$) was recorded significantly highest HAC over T_2, T_3, T_8 but however it was on par with treatments T_4 (100% PK), T_5 (100% NP) during both the years of study in *kharif* and *rabi* seasons.

Among the inorganic treatments, passive fraction of organic carbon was highest under 100% NPK. The addition of root residue consequent to higher biomass might have produced more amount of humus fraction[10].

At harvest stage humic acid carbon was highest (3.5, 3.8, 3.9, 3.9 g C kg^{-1} in *kharif* and *rabi*, 2016-17 and 2017-18, respectively) under FYM-amended plots T_{12} (FYM @ 10t/ha) and lowest (2.2, 2.4, 2.6 and 2.6 g C kg^{-1} in *kharif* and *rabi*, 2016-17 and 2017-18, respectively) under control. Application of organics (FYM and green manure) significantly improved humic acid carbon in soil.

During *kharif* 2016, at harvesting stage, among all the treatments the highest humic acid carbon was observed in T_{12} (FYM only @ 10 t ha^{-1}) (3.5 g C kg^{-1}) which was significantly superior over all other treatments except T_{10}. In *kharif*, 2017 the treatment T_{12} (3.8 g C kg^{-1}) was significantly superior over remaining treatments but however it was on par with treatments T_9 and T_{10}.

At harvesting satge, during *rabi* season (2017, 2018), among all twelve treatments the highest humic acid carbon (3.8, 3.9 g C kg^{-1}) was produced in T_{12}, which received FYM only 10 t ha^{-1} and it was significantly superior over other treatments but however it was on par with T_7, T_9, T_{10} and T_{11} during both the years of study.

Application of organic manures such as farmyard manure and green manures increased the availability of macro and micro nutrient, and promoted the activity of micro-organism. The long term effect of fertilization on fractions of organic matter (FA and HA) showed positive significant relationship with grain and fodder yield of rice.

The results of the experiment revealed that the organic treated plot recorded the highest humic acid carbon. This is due to decomposition of added residues contribute organic products such as lignin derived phenolic units, carbohydrates or amino compounds which yield the building blocks or substrate for humus formation. The addition of organic amendments over a decade resulted in the higher organic carbon content, improved crop growth when compared to unfertilized control. The plots which received FYM @ 10t ha^{-1} recorded the highest organic carbon content. This might be due to consistent higher yields obtained in this treatment since inception. The relative increase in organic carbon due to FYM addition could be attributed largely to increased return of organic materials and direct addition of organic matter through FYM along with recommended dose of NPK.

Fulvic Acid Carbon (FAC)

At initial stage, the fulvic acid carbon content was varied significantly between the treatments under study. It was ranged from 0.8 to 2.1g C kg^{-1}in *kharif*, 2016; 0.9 to 2.4 in *rabi*, 2017; 1.0 to 2.7g C kg^{-1} in *kharif*, 2017 and 1.2 to 2.8 in *rabi*, 2018 seasons.

The highest fulvic acid carbon content was recorded in the treatment T_{12} (FYM @10t ha^{-1}) with 2.1, 2.4, 2.7, 2.8 g C kg^{-1} in *kharif* and *rabi*, 2016-17 and 2017-18 respectively and lowest fulvic acid carbon content 0.8, 0.9, 1.0 and 1.2 g C kg^{-1} in *kharif* and *rabi*, 2016-17 and 2017-18 respectively was observed in (T_1) control treatment.

Among the twelve treatments the significantly highest fulvic acid carbon content was observed in T_{12}, which received only FYM 10t ha^{-1} and it was significantly superior over all other treatments except T_9 (50% NPK+ 50 % N through green manures and T_{10} (50% NPK+ 50% N through FYM) in the year *kharif*, 2016. The treatment T_{12} (FYM only 10 t/ha) was significantly superior over all other treatments in *kharif*, 2017 at initial stage.

Among all the treatments the highest fulvic acid carbon content was observed in T_{12}, which received only FYM 10t/ha and it was significantly superior over all other treatments except T_{10} (50% NPK+ 50% N through FYM) in both the years of *rabi* season.

At initial stage, among the inorganic treatments the treatment T_6 (100% RDF + $ZnSO_4$) recorded the highest FAC and significantly superior over all other inorganic treatments but however it was on par with treatment T_2 (100% RDF) in both the years of *kharif* and *rabi* season.

At harvesting stage during *kharif* season the highest (2.4 g C kg^{-1}in 2016 and 2.9 g C kg^{-1}in 2017) fulvic acid carbon was recorded by the treatment T_{12} (FYM only 10t/ha) and it was significantly superior over all other treatments but however it was on par with treatments T_7 (100% RDF + $ZnSO_4$+ FYM @ 5t/ha) with 2.3 g C kg^{-1}in *kharif*, 16, 2.8 g C kg^{-1}in *kharif*, 17 and T_{10} (50% NPK+ 50% N through FYM) with 2.0 g C kg^{-1}in *kharif*, 16 and 2.5 g C kg^{-1}in *kharif*, 17 and the lowest fulvic acid carbon of 0.9 and 1.2 g C $kg^{-1}$was produced with treatment T_1 (control).

At harvesting stage the highest (2.7 g C kg^{-1}in 2017 and 3.1 g C kg^{-1}in 2018) fulvic acid carbon was recorded by the treatment T_{12} (FYM @10 t/ha) and it was significantly superior over all other treatments except T_9 (50% NPK + 50% N through green manure), T_{10} (50% NPK + 50% N through FYM) and T_{11} (50% NPK + 25% N through GM+ 25% N through FYM) during both the years of study. Lowest fulvic acid carbon of 1.1 g C $kg^{-1}$and 1.4 g C kg^{-1} were produced with treatment T_1 (control) in *rabi* season in both the years.

The data showed that the content of humic acid was higher than fulvic acid in all the treatments in all the four seasons. Fulvic acids, although primarily considered to be humic acid precursors, may be humic acid degradation products. It is probable that fulvic acid can be adsorbed onto clay, but the size of their molecules suggest that the force of attraction would be less than those for larger humic acid constituents[1].

At both stages (initial, harvest) in both the seasons (*Kharif*, *Rabi*) in both the years (2016-17, 2017-18), the labile carbon (SMBC, $KMnO_4$-C, WSC and less labile carbon (POC) were highest in T_7 (100 % RDF + $ZnSO_4$ +FYM) followed by T_{10} (50 % NPK + 50 % N through FYM) where as non-labile carbon (HAC and FAC) fraction was highest in T_{12} (FYM @ 10 t ha^{-1}) followed by T_{10}. The experimental results revealed that the treatments receiving organic manures (FYM) had recorded the more accumulation of non-labile carbon fractions like HA & FA were more than the labile carbon like SMBC, WSC & $KMnO_4$-C.

Table 1. Effect of long-term use of inorganic fertilizers, organic manures and their combination on soil POC, HAC and FAC under rice (*Kharif*, 2016)

Treatments		Particulate Organic carbon (mg kg^{-1})		Humic acid carbon (g C kg^{-1})		Fulvic acid carbon (g C kg^{-1})	
		Initial	Harvest	Initial	Harvest	Initial	Harvest
T_1	Control	502	504	2.1	2.2	0.8	0.9
T_2	100 % RDF	876	880	2.7	2.9	1.1	1.3
T_3	100% NK	720	723	2.4	2.7	1.0	1.2
T_4	100% PK	694	696	2.6	2.8	1.0	1.3
T_5	100% NP	712	714	2.5	2.7	0.9	1.0
T_6	100 % RDF + $ZnSO_4$ @ 40 kg/ha	894	897	2.7	3.0	1.2	1.4
T_7	100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	1270	1274	3.0	3.4	1.9	2.3
T_8	50% NPK	690	693	2.3	2.6	0.9	1.0
T_9	50% NPK + 50 % N through Green Manures	1011	1014	2.8	3.1	1.6	1.9
T_{10}	50% NPK + 50 % N through FYM	1191	1195	3.0	3.3	1.8	2.0
T_{11}	50% NPK + 25 % N through GM + 25 % N through FYM	1090	1094	2.9	3.2	1.6	1.8
T_{12}	FYM only @ 10 t/ha	1002	1005	3.1	3.5	2.1	2.4
SEm ±		60.69	62.39	0.06	0.11	0.03	0.14
CD @ 0.05		178	183	0.2	0.3	0.1	0.4
CV (%)		11.8	12.2	6.98	6.76	7.54	7.84

Table 2. Effect of long-term use of inorganic fertilizers, organic manures and their combination on soil POC, HAC and FAC under rice (*Rabi*, 2017)

Treatments		Particulate Organic carbon (mg kg^{-1})		Humic acid carbon (g C kg^{-1})		Fulvic acid carbon (g C kg^{-1})	
		Initial	Harvest	Initial	Harvest	Initial	Harvest
T_1	Control	504	507	2.2	2.4	0.9	1.1
T_2	100 % RDF	878	882	2.9	3.2	1.2	1.4
T_3	100% NK	722	725	2.6	2.9	1.1	1.4
T_4	100% PK	695	698	2.7	3.0	1.3	1.5
T_5	100% NP	714	717	2.7	2.9	1.0	1.3
T_6	100 % RDF + $ZnSO_4$ @ 40 kg/ha	896	899	3.0	3.3	1.4	1.6
T_7	100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	1273	1276	3.3	3.6	2.3	2.6
T_8	50% NPK	692	695	2.4	2.6	1.0	1.3
T_9	50% NPK + 50 % N through Green Manures	1013	1018	3.1	3.3	1.9	2.2
T_{10}	50% NPK + 50 % N through FYM	1194	1198	3.2	3.5	2.0	2.3
T_{11}	50% NPK + 25 % N through GM + 25 % N through FYM	1094	1098	3.2	3.4	1.8	2.1
T_{12}	FYM only @ 10 t/ha	1004	1009	3.4	3.8	2.4	2.7
SEm ±		61.37	63.75	0.13	0.06	0.10	0.20
CD @ 0.05		180	187	0.4	0.2	0.3	0.6
CV (%)		12.0	10.1	7.65	6.95	8.14	7.65

Table3. Effect of long-term use of inorganic fertilizers, organic manures and their combination on soil POC, HAC and FAC under rice (*Kharif*, 2017)

Treatments		Particulate Organic carbon (mg kg^{-1})		Humic acid carbon (g C kg^{-1})		Fulvic acid carbon (g C kg^{-1})	
		Initial	Harvest	Initial	Harvest	Initial	Harvest
T_1	Control	506	509	2.4	2.6	1.0	1.3
T_2	100 % RDF	881	885	3.1	3.4	1.3	1.6
T_3	100% NK	724	727	2.8	3.0	1.4	1.7
T_4	100% PK	698	701	2.9	3.2	1.4	1.7
T_5	100% NP	716	719	2.8	3.1	1.2	1.5
T_6	100 % RDF + $ZnSO_4$ @ 40 kg/ha	898	901	3.1	3.5	1.5	1.8
T_7	100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	1276	1280	3.5	3.7	2.6	2.8
T_8	50% NPK	694	697	2.5	2.7	1.3	1.5
T_9	50% NPK + 50 % N through Green Manures	1018	1021	3.2	3.6	2.2	2.4
T_{10}	50% NPK + 50 % N through FYM	1197	1201	3.4	3.6	2.3	2.5
T_{11}	50% NPK + 25 % N through GM + 25 % N through FYM	1097	1102	3.3	3.5	2.0	2.3
T_{12}	FYM only @ 10 t/ha	1008	1013	3.7	3.9	2.7	2.9
SEm ±		59.66	64.44	0.14	0.10	0.17	0.08
CD @ 0.05		175	189	0.4	0.3	0.5	0.2
CV (%)		11.6	12.6	7.68	7.13	7.35	8.95

Table4. Effect of long-term use of inorganic fertilizers, organic manures and their combination on soil POC, HAC and FAC under rice (*Rabi,* 2018)

Treatments		Particulate Organic carbon (mg kg^{-1})		Humic acid carbon (g C kg^{-1})		Fulvic acid carbon (g C kg^{-1})	
		Initial	Harvest	Initial	Harvest	Initial	Harvest
T_1	Control	507	510	2.4	2.6	1.2	1.4
T_2	100 % RDF	884	887	3.3	3.4	1.6	2.0
T_3	100% NK	727	730	2.9	3.1	1.6	2.1
T_4	100% PK	701	704	3.1	3.2	1.6	2.0
T_5	100% NP	718	721	3.0	3.3	1.5	1.9
T_6	100 % RDF + $ZnSO_4$ @ 40 kg/ha	901	904	3.3	3.4	1.8	2.1
T_7	100 % RDF + $ZnSO_4$ @ 40 kg/ha + FYM @ 5t/ha	1279	1283	3.6	3.8	2.8	3.0
T_8	50% NPK	697	701	2.6	2.8	1.4	1.6
T_9	50% NPK + 50 % N through Green Manures	1020	1025	3.4	3.5	2.3	2.6
T_{10}	50% NPK + 50 % N through FYM	1201	1206	3.5	3.7	2.4	2.7
T_{11}	50% NPK + 25 % N through GM + 25 % N through FYM	1101	1106	3.4	3.6	2.3	2.5
T_{12}	FYM only @ 10 t/ha	1012	1017	3.8	3.9	2.8	3.1
SEm ±		64.78	66.48	0.17	0.15	0.14	0.21
CD @ 0.05		190	195	0.5	0.4	0.4	0.6
CV (%)		10.8	12.3	7.95	6.52	8.25	7.95

CONCLUSIONS

The labile carbon ($KMnO_4$- extractable carbon, MBC, WSC), less labile carbon (POC) and non labile carbon (HAC+FAC) had contributed to soil organic carbon under different treatments in 0-15 cm soil (surface). The HAC and FAC (passive pools) were observed higher with FYM @ 10t ha^{-1} which was significantly superior over other treatments. 100 % RDF along with $ZnSO_4$ @ 40 kg ha^{-1} and 100 % RDF were not significantly varying in the above carbon pools.

Proportion of non labile carbon (humic and fulvic acid carbon) was higher in case of only organics and also conjoint use of NPK and organic sources compared to control and inorganics only. Whenever, crops are grown continuously for several years in the same piece of land with application of inorganic fertilizers alone, the physical, chemical and biological activity of soils will be affected. Hence integrated use of organic and inorganic fertilizers is the best practice not only for improving the soil fertility and yields of crops but also to buildup the carbon status.

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