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# An appraisal of organic and inorganic carbon contents in post-harvest soils of rice based sequential cropping systems influenced by rice cultivation methods and nutrient management practices

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**Abstract**

Carbon is the primary source in plant nutrient system thus crop growth and yields are basically influenced by soil carbon status. Contraption and contents of soil organic and inorganic carbon play an important role in carbon status. Several studies reported on soil organic carbon (SOC) but not soil inorganic carbon (SIC) "the missing sink" of carbon pool. Also, reports on the impact of cultivation and nutrient management practices under different rice based cropping system for SOC and SIC are very meagre. To investigate these carbon details, field experiments were conducted during September to May in 2021-2022 and 2022 -2023 under rice based sequential cropping system (rice-black gram, rice-maize and rice-groundnut) and evaluate how cultivation methods and integrated nutrient management (INM) practices influences the carbon contents in soils for two years. Experiment designed with two establishment methods (transplanted method (TPR) and direct seeded method (DSR)) and five INM practices (RDF (NPK) only, RDF + poultry manure compost @5 t ha$^{-1}$, RDF + coirpith compost @5 t ha$^{-1}$, RDF+green manure @6.25 t ha$^{-1}$ and RDF+green leaf manure @ 6.25 t ha$^{-1}$). The nutrient treatments were imposed only to rice crop and no manures/ fertilisers applied to sequential crops. INM practice of RDF + green manure @ 6.25 t ha$^{-1}$ imposed under direct seeded rice cultivation method registered higher SOC (8.68 and 8.96g kg$^{-1}$) and total carbon (11.83 and 12.41 g kg$^{-1}$), for season I and season II, respectively and it was statistically on par with RDF+ green leaf manure @ 6.25 t ha$^{-1}$ in rice-groundnut cropping system. Further, we observed that there is no

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significant improvement in soil inorganic carbon content. However, slight changes occur in SIC compared to initial status after rice cultivation but no changes due to cultivation of sequential crops.

**Key words :** Black gram, Maize, Groundnut, Rice, Sequential cropping system, soil organic carbon, soil inorganic carbon.

Carbon is the fundamental building block of all life on Earth[23]. It has unique bonding properties that allow it to combine with many other elements. These properties enable the formation of molecules to support life. The role of carbon in living systems is so significant. According to the Inter-government Panel on Climate Change (IPCC), about 22% of global anthropogenic greenhouse gas (GHS) emissions are contributed by agriculture, forestry and other land uses[8]. Cultivation of arable land leads to the sustainable loss of soil organic matter (SOM) and increase emissions of $CO_2$ from soil to the atmosphere, thereby increasing the $CO_2$ concentration in the atmosphere[11]. The growing concern of global warming and climate change impacts on the community have spurred interest in enhancing the sequestration of atmospheric carbon dioxide in terrestrial ecosystems[26]. In agriculture, carbon is an essential factor of soil quality, which regulates nutrient cycling, soil structure, water availability and other important soil properties[5]. Monitoring quality of agricultural soils has become an integral part of farming nowadays. From very long-time scientists were considering soil organic carbon (SOC) as a key attributes of soil fertility and productivity. Its immense potential to influence soil physico-chemical properties made soil C as most important criteria for judging soil health[6]. Soil can sequester carbon from the atmosphere with a proper management. On the basis of global estimates of historic carbon stocks and projections of rising emissions, the usefulness soil as a carbon sink and drawdown solution seems to be essential. Soil is an ideal reservoir for storage of organic C since soil organic C has been depleted due to land misuse and inappropriate management. Many agricultural management practices are emerging to sequestering soil carbon by increasing carbon inputs to the soil and enhancing various soil processes that protect carbon from microbial turnover[17]. Soil carbon includes organic and inorganic carbon. These carbon pools act as sink as well as source of atmospheric carbon. The soil inorganic carbon (SIC) pool plays an important role in the arid and semi-arid regions. The SIC reservoir consists mainly of carbonates and most research has been conducted on SIC as calcium carbonate[31]. The SIC pool consists of primary inorganic carbonates (PIC) or lithogenic inorganic carbonates (LIC), and secondary inorganic carbonates (SeIC) or pedogenic inorganic carbonates (PeIC). Primary carbonates are inherited from parent material of the soil. Secondary carbonates are formed through dissolution of primary carbonates and re-precipitation of weathering products. The reaction of atmospheric carbon dioxide with water and calcium and magnesium in the upper horizons of the soil, leaching into the subsoil and subsequent re-precipitation results in formation of secondary carbonates and in the sequestration of atmospheric $CO_2$. The SIC pool, therefore, plays an important role in the global C cycle. It is also well known that the free form of carbonate affects soil microbial activity, soil pH and the decomposition rate of soil organic matter. Furthermore, the SIC reservoir can be influenced by potential soil acidification through climate changes. The SIC reservoir and its distribution play an important role in the dynamic changes of the atmosphere, the vegetation and the soil. Therefore, an accurate estimate of the SIC contribution to the soil carbon reservoir is required for a precise appreciation of the role of soils in the global ecosystems. The dynamics of the SIC pool are poorly understood although it is normally quite stable[15]. Soil inorganic carbon sequestration on soil dynamics with climate change is less understood than that of SOC sequestration, especially under lowland paddy production systems. There is a strong need to assess the development of secondary carbonates, the leaching scale, and the impact of land use and management on overall SIC dynamics because the paddy soils of the world cannot be omitted when thinking of carbon both above and below ground[27]. To optimize the efficiency of C sequestration in agriculture, cropping systems, such as crop rotation, intercropping, cover cropping, etc., play a critical role by influencing optimum yield, total increased C sequestered with biomass, and persisted in the soil[30]. This could be a better way of carbon addition and it is possible only through following different cropping system instead of mono cropping. $CO_2$ absorb from atmosphere by plants via photosynthesis. Plant material converted to organic matter through microbe mediated biochemical reactions and stored in soil[34]. The amount of carbon that is sequestered in different cropping systems also depends on soil fertility, soil texture and biomass production of the respective cropping system and land use patterns. The legume based cropping system sequestered higher amount of SOC compared to that cereal-cereal cropping system. Any cropping system that produces rich source of organic material will have greater amounts of residue SOC[21]. In agriculture soils carbon addition is a complex process it can be controlled by the environmental factors and farming practices[33]. Understanding the changes in physico-chemical properties of soil under agriculture is essential, because if soil health declines it directly affect the cropping system productivity. And another practice is INM, encompassing organic and inorganic sources based on their availability, and cost-effectiveness and the judicious combination of these two sources have been mutually reinforced. The organic manure combined with inorganic fertilizers enhanced the soil organic carbon content[22]; SOC addition was proved with various studies but not SIC. Further, what are all the possible changes occur in SIC content in cultivated soils due to intrinsic anthropogenic and cultural activities for agricultural production is still unclear. Organic amendments proved their competence in increasing soil fertility and also enhancing SOC and nutrient status. Limited studies reported that organic amendment alone or conjoint application of organic and inorganics sources led to increase in both SOC and SIC in certain crop lands but not in paddy soils. Therefore, the objective of this research is to investigate the impacts of rice cultivation methods and INM practices under rice based sequential cropping systems on the undercurrents of soil organic and inorganic content through promoting SOM accumulation and the associated ecosystem services to support soil quality and to mitigate climate change in a dry tract of southern zone Tamil Nadu.

Field experiments were conducted during Late samba season (September to January) for rice followed by maize, black gram and groundnut cropping system on Navarai season (January to May) of 2021-2022 and 2022- 2023 at Sadurvedamangalam village, Sivaganga district, Tamil Nadu to assess the influence of certain Integrated Nutrient Management (INM) practices on certain promising rice-based cropping systems *viz.,* rice- maize, rice - black gram and rice - groundnut. A post-harvest soil sample of all the cropping system was collected (at a depth of 0-30 cm) air dried, processed and tested for physico-chemical properties. The soil was subject to mechanical analysis and classified as sandy clay loam in texture as per the analytical reports pH 7.4, electrical conductivity 0.39 dS $m^{-1}$ and organic carbon of (0.36%), soil inorganic carbon (0.11%) and total carbon (0.47%). The experiment was carried out in a factorial randomized block design (FRBD) and replicated thrice with ten treatments. The treatments were Factor A-Two establishment methods ($A_1$-Direct Seeded Rice (DSR) and $A_2$-Transplanted Rice (TPR)) and Factor B-Five INM practices ($B_1$- RDF-Recommended Dose of Fertilizer (120:40:40 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$) alone, $B_2$- RDF + Poultry manure compost @ 5 t $ha^{-1}$, $B_3$- RDF+ Composed coir pith @ 5 t $ha^{-1}$, $B_4$- RDF+ Green manure (Daincha) @ 6.25 t $ha^{-1}$, and $B_5$- RDF + Green leaf manure @ 6.25 t $ha^{-1}$). After harvesting of economic part groundnut and black gram stubbles incorporate in soil; maize stubbles cut close to the ground and used for fodder purpose. The post-harvest soil samples were analysed for organic carbon, inorganic carbon and microbial population. Soil organic carbon content was estimated by using Walkley and Black method the formula used to calculate SOC (%) was =10 x (B-T) x 100 x 0.003 x 100/ B x weight of soil (g); where B = Volume (ml) of ferrous ammonium sulphate solution consumed for blank titration and T = Volume (ml) ferrous ammonium sulphate solution consumed for titration of soil sample. Soil inorganic carbon was calculated by using the formula given as SIC (%) was CaCO3 % = (B-T) X 0.05 x 100/Weight of soil (g)[24]; B = Volume (ml) of NaOH required in blank determination, T = Volume (ml) of NaOH required in soil sample determination. And total carbon was calculated by the sum of SOC + SIC. The experimental data were statistically analysed as suggested by Gomez and Gomez, (1976). And significance of the difference between the means of the treatments, critical difference (CD) was calculated at the 5% probability level.

*Carbon content under different sequential cropping systems :*

The post-harvest soil of rice, rice - black gram, rice - maize and rice - groundnut varied among the treatments and cropping system and the organic carbon and total carbon differences are statistically significant; inorganic carbon statistically non-significant. The carbon status of different cropping system presented in table-2, 3, 4. Among the cropping system, rice-groundnut cropping system recorded

Table-1. Basic soil characteristics

| Properties | Estimates |
|---|---|
| Course sand (%) | 35.3 |
| Fine sand (%) | 21.1 |
| Silt (%) | 15.4 |
| Clay (%) | 27.4 |
| Textural class | Sandy clay loam |
| Bulk density (gcc$^{-1}$) | 1.76 |
| Particle density(gcc$^{-1}$) | 2.49 |
| Soil reaction (pH) (Jackson, 1973) | 7.4 |
| Electrical conductivity (dSm$^{-1}$) (Jackson, 1973) | 0.39 |
| Organic carbon gkg$^{-1}$ (Walkley and Black, 1934) | 0.28 |
| Soil inorganic carbon g kg$^{-1}$ | 3.00 |
| Available nitrogen (kg ha$^{-1}$) (Subbiah and Asija, 1956) | 203.6 (Low) |
| Available Phosphorus (kg ha$^{-1}$) (Olsen *et al.*, 1954) | 16.4 (Medium) |
| Available potassium (kg ha$^{-1}$) (Jackson, 1973) | 284.4 (High) |

higher organic carbon and total carbon content of8.81 and 9.13g kg$^{-1}$ and 11.96 and 12.59g kg$^{-1}$ for season I and season II respectively and lower inorganic carbon content of 3.15 and 3.46 g kg$^{-1}$ for season I and season II respectively, compare to black gram it was found to be non-significant. Followed by rice-black gram cropping system recorded organic carbon and total carbon content of 7.85 and 8.42 g kg$^{-1}$ and 11.02 and 11.97 g kg$^{-1}$ for season I and season II, respectively and inorganic carbon content ranged from 3.17 and 3.60 g kg$^{-1}$ for season I and season II, respectively it was non-significant, but higher than rice-groundnut cropping system. Rice-maize cropping system recorded organic, inorganic and total carbon content of 6.83 and 7.27, 3.16 and 3.51 and 9.99 and 10.78 g kg$^{-1}$ for season I and season II respectively. And post-harvest soil of rice recorded lower organic, inorganic and total carbon content of 5.57 and 5.83, 3.14 and 3.32 and 8.71 and 9.15 g kg$^{-1}$for season I and season II, respectively. Among the INM practices green manure recorded higher organic carbon, inorganic carbon and total carbon content of 8.68 and 8.96, 3.15 and 3.46 and 11.83 and 12.41 g kg$^{-1}$for season I and season II, respectively, it was on par with green leaf manure; organic carbon, inorganic carbon and total carbon content of green leaf manure treatment 8.66 and 8.90, 3.15 and 3.46 and 11.80 and 12.34 g kg$^{-1}$ forseason I and season II, respectively. And the lowerorganic carbon, inorganic carbon and total carbon content of 4.34 and 4.45, 3.12 and 3.29 and 7.46 and 7.74 g kg$^{-1}$ forseason I and season II, respectively recorded in RDF (NPK) alone treatment. Compare to three sequential cropping system rice-groundnut recorded 7.95 and 4.51% higher total carbon than rice-black gram and 16.40 and 14.18 % higher total carbon than rice-maize cropping system. According to the soil organic carbon content status, DSR superior over conventional rice transplanting method; green manure (daincha) and green leaf manure (neem) surpasses the other two organic sources (poultry manure compost and coir pith compost); and rice –ground nut cropping system showed better carbon accumulation than rice –black and rice maize cropping sequences in sandy clay loam soil. But SIC neither influenced by rice cultivation methods nor INM practices.

*Soil carbon accrual in rice grown soil :*

Puddling with direct seeding improved the SOC which may be due to the high incorporation of rice straw into the soil as a result of reduction in soil disturbance and reduced conversion rate of soil carbon-based matter leading to higher SOC by plowing[2]. Generally intensive puddling can lead to decline in SOC destroying soil structure, exposing soil aggregates and aggravating soil carbon-based matter putrefaction[32]. They found that the C storage is higher with manure application than with plant residues[1]. The role of the soil microbial communities on biogeochemical processes is influenced by the addition of different organic and inorganic fertilizers in soils. The addition of organic manure increases the growth and activity of soil microbes which revealed a strong relationship between the microbial functioning and the biomass C increase and thus the C content increased more than the initial C content in the soil[28].

*Soil carbon accrual in groundnut grown after rice :*

Compare to other cropping system rice-groundnut recorded higher amount carbon accumulation than rice-black gram and rice-maize cropping system. The amount of C to be stored in soil varies based on the total quantity and quality of residues being added in the soil. The quality of residues had an imperative role in the direction of maintaining or increasing soil C in agroecosystem[4]. This suitably explains the reasons of dissimilarities in accumulation among different crop rotations. The incorporation of surface litter and aboveground biomass of groundnut into the soil caused considerable variation in SOC. Apart from producing a large amount of aboveground plant biomass, the increase in belowground plant biomass, *i.e.*, plant roots, also has a greater significance in C sequestration[9]. They also advocated that the soil under legume-based system have a tendency to be more preservative of residue C inputs, mostly from roots and their exudates than that of soils from monoculture. Inclusion of legumes in rotation has the potential of guaranteeing the in-situ availability of N which in turn plays a vital role in generating higher biomass C. It also promotes the release of C via root exudation into the rhizospheric zone[7]. The BNF by the root nodules of legumes is responsible for a vigorous plant growth which in turn assimilated more $CO_2$ from the atmosphere through the process of photosynthesis. The assimilated C in plants returns to the soil upon their incorporation and subsequent decomposition because of microbial activities. The N provided by the legumes enhances the N utilization efficiency and produces more root biomass and thus, leads to C inputs in soil[14]. Among the INM green manure accumulate more carbon than other nutrients. In green manuring, accumulated standing biomass is directly incorporated into the soil system; green manuring with annual legumes may add dry matter. Legume-based green manuring contributes to GHGs emission reduction in two ways, first, by converting plant C into SOC and, second, by reducing the requirement of nitrogenous fertilizers consequently in lowering of $N_2O$ emissions[16]. Because groundnut have high rhizospheric deposition[13] and root biomass in total C inputs in soil so the carbon accumulation also high.

*Carbon accrual in maize grown soil :*

The lower carbon status recorded in

Table-2. Carbon status of post-harvest soil of rice

| Parameters | Season I | | | | | | Season II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Organic carbon (g kg$^{-1}$) | | Inorganic carbon (g kg$^{-1}$) | | Total carbon (g kg$^{-1}$) | | Organic carbon (g kg$^{-1}$) | | Inorganic carbon (g kg$^{-1}$) | | Total carbon (g kg$^{-1}$) | |
| Treatments | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ |
| $B_1$ | 4.4 | 4.27 | 3.12 | 3.12 | 7.52 | 7.39 | 4.53 | 4.37 | 3.29 | 3.29 | 7.82 | 7.66 |
| $B_2$ | 5.18 | 4.96 | 3.13 | 3.13 | 8.31 | 8.09 | 5.42 | 5.25 | 3.30 | 3.30 | 8.72 | 8.55 |
| $B_3$ | 4.78 | 4.55 | 3.13 | 3.12 | 7.91 | 7.67 | 5.02 | 4.78 | 3.30 | 3.29 | 8.32 | 8.07 |
| $B_4$ | 5.57 | 5.37 | 3.14 | 3.14 | 8.71 | 8.51 | 5.83 | 5.64 | 3.32 | 3.31 | 9.15 | 8.95 |
| $B_5$ | 5.54 | 5.35 | 3.14 | 3.14 | 8.68 | 8.49 | 5.81 | 5.61 | 3.32 | 3.31 | 9.13 | 8.92 |

| | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S.Ed. | 0.02 | 0.02 | 0.03 | 0.01 | 0.02 | 0.02 | 0.02 | 0.04 | 0.05 | 0.02 | 0.03 | 0.04 | 0.01 | 0.02 | 0.02 | 0.03 | 0.04 | 0.06 |
| CD(P=0.05) | 0.04 | 0.05 | 0.07 | NS | NS | NS | 0.05 | 0.07 | 0.10 | 0.04 | 0.06 | 0.09 | NS | NS | NS | 0.05 | 0.08 | 0.12 |

*NS- Non significant

Table-3. Carbon status of post-harvest soil of rice-maize cropping system

| Parameters | Season I | | | | | | Season II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Organic carbon (g kg$^{-1}$) | | Inorganic carbon (g kg$^{-1}$) | | Total carbon (g kg$^{-1}$) | | Organic carbon (g kg$^{-1}$) | | Inorganic carbon (g kg$^{-1}$) | | Total carbon (g kg$^{-1}$) | |
| Treatments | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ |
| $B_1$ | 5.80 | 5.59 | 3.13 | 3.13 | 8.93 | 8.72 | 6.05 | 5.81 | 3.47 | 3.47 | 9.52 | 9.28 |
| $B_2$ | 6.49 | 6.31 | 3.15 | 3.15 | 9.64 | 9.46 | 6.87 | 6.6 | 3.49 | 3.49 | 10.36 | 10.09 |
| $B_3$ | 6.1 | 5.95 | 3.14 | 3.14 | 9.24 | 9.09 | 6.46 | 6.21 | 3.48 | 3.48 | 9.94 | 9.69 |
| $B_4$ | 6.83 | 6.63 | 3.16 | 3.16 | 9.99 | 9.79 | 7.27 | 7.02 | 3.51 | 3.50 | 10.78 | 10.52 |
| $B_5$ | 6.79 | 6.62 | 3.16 | 3.15 | 9.95 | 9.77 | 7.24 | 7.01 | 3.51 | 3.50 | 10.75 | 10.51 |

| | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S.Ed. | 0.02 | 0.04 | 0.05 | 0.01 | 0.02 | 0.03 | 0.02 | 0.04 | 0.06 | 0.03 | 0.04 | 0.06 | 0.02 | 0.03 | 0.04 | 0.03 | 0.05 | 0.07 |
| CD(P=0.05) | 0.05 | 0.08 | 0.11 | NS | NS | NS | 0.05 | 0.08 | 0.12 | 0.06 | 0.09 | 0.13 | NS | NS | NS | 0.06 | 0.10 | 0.14 |

*NS- Non significant

Table-4. Carbon status of post-harvest soil of rice-black gram cropping system

| Para-meters | Season I | | | | | | | | | Season II | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Organic carbon ($g\ kg^{-1}$) | | | Inorganic carbon ($g\ kg^{-1}$) | | | Total carbon ($g\ kg^{-1}$) | | | Organic carbon ($g\ kg^{-1}$) | | | Inorganic carbon ($g\ kg^{-1}$) | | | Total carbon ($g\ kg^{-1}$) | | |
| Treatments | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | |
| $B_1$ | 6.53 | 6.27 | | 3.15 | 3.15 | | 9.68 | 9.42 | | 6.97 | 6.72 | | 3.55 | 3.55 | | 10.57 | 10.32 | |
| $B_2$ | 7.39 | 7.15 | | 3.16 | 3.16 | | 10.55 | 10.31 | | 7.91 | 7.68 | | 3.57 | 3.57 | | 11.48 | 11.25 | |
| $B_3$ | 6.96 | 6.72 | | 3.15 | 3.15 | | 10.11 | 9.87 | | 7.46 | 7.21 | | 3.56 | 3.56 | | 11.04 | 10.8 | |
| $B_4$ | 7.85 | 7.59 | | 3.17 | 3.17 | | 11.02 | 10.76 | | 8.42 | 8.16 | | 3.60 | 3.59 | | 11.97 | 11.72 | |
| $B_5$ | 7.83 | 7.58 | | 3.17 | 3.16 | | 11.00 | 10.74 | | 8.39 | 8.14 | | 3.60 | 3.58 | | 11.94 | 11.7 | |
| | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B |
| S.Ed. | 0.03 | 0.05 | 0.07 | 0.01 | 0.02 | 0.03 | 0.04 | 0.06 | 0.08 | 0.04 | 0.06 | 0.08 | 0.02 | 0.03 | 0.04 | 0.04 | 0.07 | 0.10 |
| CD(P=0.05) | 0.07 | 0.10 | 0.15 | NS | NS | NS | 0.08 | 0.12 | 0.18 | 0.08 | 0.12 | 0.17 | NS | NS | NS | 0.09 | 0.14 | 0.20 |

*NS- Non significant

Table-5. Carbon status of post-harvest soil of rice-groundnut cropping system

| Para-meters | Season I | | | | | | | | | Season II | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Organic carbon ($g\ kg^{-1}$) | | | Inorganic carbon ($g\ kg^{-1}$) | | | Total carbon ($g\ kg^{-1}$) | | | Organic carbon ($g\ kg^{-1}$) | | | Inorganic carbon ($g\ kg^{-1}$) | | | Total carbon ($g\ kg^{-1}$) | | |
| Treatments | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | | $A_1$ | $A_2$ | |
| $B_1$ | 7.08 | 6.75 | | 3.13 | 3.13 | | 10.21 | 9.88 | | 7.19 | 6.87 | | 3.39 | 3.38 | | 10.58 | 10.25 | |
| $B_2$ | 8.24 | 7.95 | | 3.14 | 3.14 | | 11.38 | 11.09 | | 8.41 | 8.09 | | 3.43 | 3.42 | | 11.84 | 11.51 | |
| $B_3$ | 7.64 | 7.35 | | 3.13 | 3.13 | | 10.77 | 10.48 | | 7.76 | 7.47 | | 3.41 | 3.40 | | 11.17 | 10.87 | |
| $B_4$ | 8.81 | 8.54 | | 3.15 | 3.15 | | 11.96 | 11.69 | | 9.13 | 8.78 | | 3.46 | 3.45 | | 12.59 | 12.23 | |
| $B_5$ | 8.79 | 8.51 | | 3.15 | 3.14 | | 11.94 | 11.65 | | 9.07 | 8.72 | | 3.45 | 3.44 | | 12.52 | 12.16 | |
| | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B | A | B | A×B |
| S.Ed. | 0.05 | 0.07 | 0.10 | 0.02 | 0.03 | 0.04 | 0.05 | 0.08 | 0.12 | 0.05 | 0.09 | 0.12 | 0.02 | 0.04 | 0.05 | 0.06 | 0.10 | 0.14 |
| CD(P=0.05) | 0.10 | 0.16 | 0.22 | NS | NS | NS | 0.11 | 0.17 | 0.24 | 0.11 | 0.18 | 0.25 | NS | NS | NS | 0.13 | 020 | 0.28 |

*NS- Non significant

rice-maize cropping system. Compare to other cropping systems maize produced more biomass, but only root portion retain in the soil and added less carbon to the soil. And maize is a high nutrient consuming crop, didn't fix N and leaching of nutrients also high thus maize accumulate less carbon compare to other cropping system.

*Soil carbon accrual in black gram grown after rice :*

Black gram also legume but, crop species have a vital role in retaining amount and quality of SOC reserves apart from the diversity of crop residue. Decreased root biomass production by legumes produced the negative effect of SOC. That's why followed by groundnut black gram increase carbon status of soil. The carbon accumulation and the amount of organic C being added into the soil strata by the leguminous crop greatly vary with the selection of appropriate legume. The growth habit, canopy structure, quantity and quality of residues left on the soil surface, root physiology and pattern, number of leaves being produced, climatic stimuli, soil aggregation, existing cropping system and agronomic interventions during the crop cycle improve SOC pool[10]. Black gram also add biomass to the soil to increase but compare to groundnut quantity of added biomass is less. Through roots, dry leaves and stovers of legume crops organic matter added to soil which help to improve the organic carbon percentage, carbon sequestration capacity[19] reduce carbon release from the soil[20].

After the keen estimation of soil organic and inorganic contents from the postharvest soils of rice, rice-black gram, rice-maize, and rice –groundnut sequential cropping system we conclude that rice establishment methods have significant effect on rice but no influence on sequential /residual crops concern with carbon accruals but INM practices. Application of green or green leaf manure leaves the soil with more health (significantly improved carbon status) compare to poultry manure and coir pith compost when conjointly applied with inorganic fertilizers to rice corp. Further, based on the results, soil organic carbon status was significantly enhanced by INM practices compared to inorganic fertilizer alone supplement to rice crop. However, rice –groundnut cropping sequence have profoundly increased the soil organic carbon content compare to rice-black gram and rice – maize cropping systems. Also, we found that there were no significant changes or enhancement in soil inorganic carbon content in all the cropping system *i.e.*, SIC was not influenced by cultivation methods and INM practices.

*Declaration of competing interest :*

The authors declared that they no conflicts of interest to this work. We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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