The Pharma Innovation Journal 2022; 11(6): 294-299

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(6): 294-299

www.thepharmajournal.com
Received: 02-04-2022
Accepted: 22-05-2022

SK Sahoo
Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

DK Bastia
Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

S Tripathy
Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

KC Sahoo
Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

M Ray
Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Corresponding Author:
SK Sahoo
Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Long term effect of organic amendments on soil carbon dynamics and sustainability of organically managed rice-rice cropping sequence in *Inceptisols* of Odisha

SK Sahoo, DK Bastia, S Tripathy, KC Sahoo and M Ray

Abstract
A field experiment was conducted during 2008-2017 at the Organic Block of Central research Station of Odisha University of Agriculture and Technology, Bhubaneswar. Rice-rice cropping sequence was taken up for nine consecutive years with seven organic nutrient management treatment combinations in *Kharif* and summer rice in randomized block design. The soil of the experimental site was sandy loam in texture with pH of 6.0. The values of bulk density and soil organic carbon contents in 0-15, 15-30, 30-45 and 45-60 cm soil depth, respectively, were 1.58, 1.61, 1.64, 1.66 g m^{-3} and 5.2, 4.0, 2.8 and 1.8 g kg^{-1}. Application of organic ammendments recorded significant effect on soil organic carbon status and sustainable yield index. The observed soil organic carbon stock was maximum (83.26 t ha^{-1}) in treatment receiving *Dhanicha* @ 25 kg seed ha^{-1} + FYM (5 t ha^{-1}) + Vermicompost (2 t ha^{-1}) in *Kharif and* FYM (5 t ha^{-1}) + Vermicompost (2 t ha^{-1}) in summer and highest rate of sequestration was also observed in the same treatment (5.55 t ha^{-1} $year^{-1}$). Highest system grain yield of 9.42 t ha^{-1} and Sustainable Yield Index (SYI) of 0.75 was also recorded in the treatment receiving *Dhanicha* @ 25 kg seed ha^{-1} + FYM (5 t ha^{-1}) + Vermicompost (2 t ha^{-1}) in *Kharif* and FYM (5 t ha^{-1}) + Vermicompost (2 t ha^{-1}) in summer (T_5) with B:C of 1.78.

Keywords: Carbon sequestration, soil organic carbon, sustainable yield index & economics

Introduction
Rice (*Oryza sativa* L.), the world's most important food crop, is the staple food for about four billion people i.e., half of the humankind on the planet and is grown over 150 million ha worldwide. In India, rice is grown in 43 million hectare with production of 112 million tons (Mt) of milled rice and average productivity of 2.6 t ha^{-1} (NRRI Research Bulletin No. 22, 2020) [13]. It is a established fact that the use of organic fertilizers improves soil structure, nutrient exchange and maintains soil health, which has raised interests in organic farming in recent times. (Larson & Clapp, 1984; Doran & Parkin, 1994; Sudha & Chandini, 2003) [19, 10, 34].

To offset deterioration of soil structure, different organic amendments such as manure (farmyard manure, green manure), compost, and crop residues (particularly rice straw) are commonly recommended and when applied, they are distributed in different SOC pools (Majumder *et al.*, 2008; Pradhan *et al.*, 2015; Ali *et al.*,2018) [21, 26, 1]. SOC is simultaneously a source and sink for nutrients and plays a vital role in soil fertility maintenance. Optimum management of the soil resource for provision of goods and services requires good management of organic resources, mineral inputs and the SOC pool (Vanlauwe, 2004; Gogoi *et al.*, 2021) [36, 11]. Addition of exogenous OM such as FYM, Vermicompost results in enhancement of OC storage in addition to improvement of many other soil function related to the presence of organic matter (Yadav *et al.*, 2009; Ngo *et al.*, 2012; Dey *et al.*, 2020) [37, 24, 9]. Thus, it becomes imperative to increase SOC density for improvement in quality soil for sustainable crop productivity. The enormous SOC sequestration potential of agriculture can be exploited through proper organic nutrient management options in intensive agriculture systems (Assefa, 2019) [33]. According to Mahanta *et al.* (2013) [20] the sustainable yield index (SYI) of a cropping system continuously increases by repeated addition of bulky organic manures. Keeping all these in view, the present investigation was conducted to estimate SOC sequestration and sustainable yield index of organically grown rice-rice sequence.

Materials and Methods

A field experiment was conducted during 2008-2017 at the Organic Block of Central Research Station of Odisha University of Agriculture and Technology, Bhubaneswar located at 20^0 15' N latitude and 85^0 52' E longitude and at an altitude of 25.9 m above mean sea level. The station comes under the East and South Eastern Coastal Plain Agro-climatic Zone of Odisha. The region is characterized by a sub-tropical climate with a hot and humid summer (March-June), hot and wet monsoon (late June-mid October) and a mild and dry winter (Nov.-Feb.). The soil of the experimental site was sandy loam in texture with pH 6.0. The bulk densities were 1.58 and 1.61, 1.64, 1.66 t m^{-3} and soil organic carbon were 5.2, 4.0, 2.8 and 1.8 g kg^{-1} for 0-15, 15-30, 30-45 and 45-60 cm soil depth, respectively at the start of the experiment. *Kharif* rice followed by summer rice was cultivated for nine consecutive years in a fixed site and layout with seven treatment combinations as follows

Table 1: Treatment Details

	Kharif	**Summer**
T_1	*Dhanicha* @ 25 kg seed ha^{-1}	Control
T_2	T_1+FYM 5t ha^{-1} (basal)	FYM 5t ha^{-1} (basal)
T_3	T_1+ Vermicompost 2t ha^{-1} (basal)	Vermicompost 2t ha^{-1} (basal)
T_4	T_1+ Vermicompost 2t ha^{-1} (split) - Basal & 20 DAT	Vermicompost 2t ha^{-1} (split)-Basal & 20 DAT
T_5	T_1+FYM + Vermicompost 2t ha^{-1} (split)- basal & 20 DAT	FYM + Vermicompost 2t ha^{-1} (split)- basal & 20 DAT
T_6	T_1+FYM+ Vermicompost 2t ha^{-1} (basal)	FYM+ Vermicompost 2t ha^{-1} (basal)
T_7	T_1+ + FYM + *Panchagavya*	FYM + *Panchagavya*

The experiment was laid out in a randomized block design with three replications. Rice cv. Lalat (Obs 677/ IR 2071/ Vikram / WI 263) of 120 days duration (125 days in summer) with maximum yield potential of 6.8 t ha^{-1} was cultivated in both the seasons in all nine years. Square planting (25 × 25 cm) of 12 days old seedlings @ one seedling per hill were done in individual beds measuring 12 m in length and 6 m in width. Channels of 30 cm width were opened up all around the brds and water level was maintained only in the channels through out the cropping seasons. Organic management options were adopted as per the treatments along with biodynamic formulation *'Panchagavya'*. The plots were kept moist all along. Vermicompost was applied in split as basal and at 20 DAT. Cono weeder was used thrice at 15 days interval starting from 10 DAT in order to manage weed menace. No major incidence of disease and insect pest was noticed. However, as a prophylactic measure, pot manure (5 kg cow dung + 5 litre urine + 250 g gur + 1.0 kg each of *Azadirachta indica*, *Pongamia pinnata* and *Calotropis gigantia* leaves, fermented for 15 days) was sprayed four times at 15 days interval starting from 15 DAT in both the seasons (Bastia *et al.*, 2013; Kar *et al.*, 2013; Pradhan *et al.*, 2015) [2, 15, 26]. Bulk density was determined for each treatment by using core sampler method (Dastane, 1972) [6]. Soil samples were collected from each plot with a post-hole auger from 0-15, 15-30, 30-45 and 45-60 cm soil depth. SOC stock was calculated from this depths using the following formula:

$$\text{SOC stock} = \sum_{1}^{n} \left(\text{Profile volume} \times \text{Bulk density} \times \text{SOC content} \right)$$

From total SOC stock of 60 cm profile, the SOC sequestration rate was calculated (Kundu *et al.,* 2007) [17] separately for each treatment due to nine years of experimentation with the following formula:

$$\text{SOC sequestration rate} = \frac{\text{Increase in SOC stock due to treatments over the initial stock}}{\text{Number of years of experimentation}}$$

The data so obtained for each observation were analyzed using analysis of variance technique for randomized block design as described by Gomez and Gomez (1984) [12]. The sustainable yield index (SYI) of rice-rice sequence was calculated for the treatments taking into consideration the yield data for the last nine years by using the following formula (Singh *et al.*, 1990) [31]:

$$SYI = \frac{Y_{mean} - \sigma}{Y_{max}}$$

Where Ymean = Mean yield of a treatment over the years; σ = Standard deviation of a treatment over the years, and Ymax = Maximum yield irrespective of treatment and year.

Results and Discussion

SOC stock and soil organic carbon sequestration rate

Soil profile organic carbon at sampling depths of 0-15, 15-30, 30-45 and 45-60 cm showed significant variation due to organic nutrient management and biodynamic formulation (Table 2). Total initial SOC stock was 33.35 t ha^{-1} during 2008-09. At the end of nine year cycle on 2016-17, maximum SOC stock was found in treatment receiving *Dhanicha* + FYM + Vermicompost (split) in *Kharif* and FYM + Vermicompost (split) in summer (T_5) *i. e*, 83.26 t ha^{-1}, which was at par with those of T_4, T_6 and T_7. Highest rate of sequestration was also recorded in T_5 (5.55 t ha^{-1} $year^{-1}$), which was at par with treatment T_6 and T_7. Lowest soil organic carbon stock and minimum SOC sequestration rate was found in treatment T_1 (62.40 t ha^{-1} and 3.23 t ha^{-1} $year^{-1}$). The increase in organic carbon content in the manurial treatment combinations is attributed to the direct incorporation of organic matter in the soil. Subsequent decomposition of these materials might have resulted in the enhanced organic carbon content of the soil (Singh *et al.*, 2008; Dey *et al.*, 2020; Datta *et al* 2022) [30, 9, 7]. Higher amount of SOC stock in T_5 can be attributed to greater carbon input through organic manures and enhanced crop productivity. Kundu *et al.* 2007; Ali *et al.*, 2018 and Datta *et al.*, 2022 [17, 1, 7] also justified increase in SOC stock in similar trend. Many researchers (Lal, 2004; Mandal *et al.*, 2007; Choudhary *et al.*, 2017) [18, 22] have reported that application of FYM and green manure adds organic carbon in the soil. Kukal *et al.* (2009) [16] and Choudhary *et al.*, (2017) observed a higher SOC sequestration in a rice wheat system due to application of FYM and the cropping system had greater capacity to sequester carbon because of high carbon input through enhanced productivity.

Average of SOC stock in different layers over the initial sock exhibited conspicuous increase. However, the layers 0-15 cm and 15-30 cm which is most amenable to agricultural operations, showed much higher percentage of increase in SOC stock (156.9% and 173% respectively) over the initial values. The percent increase of SOC stock in 30-45 cm and 45-60 cm layers was only 17.6% and 22.0% respectively, over the initial value. This suggests that agriculture has high potential of carbon sequestration and can be a prospective option for mitigation of climate change.

Grain yield and SYI

The average grain yield was found to be the highest for T_5 (4.76 and 4.66 t ha^{-1}) in *Kharif* and summer seasons (Table 3). However, it was at par with T_4, T_6 and T_7 in *Kharif* and T_6 and T_7 in summer season. It was observed that simultaneous application of organic manures (T_5, T_6 and T_7) resulted in higher yield (8.9 t ha^{-1}) than treatments where single manure was applied (T_1, T_2, T_3 and T_4) (7.45 t ha^{-1}). The highest system grain yield of 9.42 t ha^{-1} and SYI of 0.75 was also observed in T_5 which was at par with T_6 and T_7 and were significantly different from rest of the treatments. (Sankarmoorthy *et al.*, (2019) and Ojha *et al.*, (2014) [25] opined that integrated use of use two or three sources of organic nutrients has resulted in higher grain yield of rice. Furthermore, Yadav *et al.*, (2009); Davari and Sharma, (2010); Singh *et al.*, (2011) and Haque *et al.*, (2019) [37, 8, 32, 14] opined that integrated use of organic sources release adequate amount of essential nutrients in different phenophases of the crop which facilitate augmentation of plant growth and development and ultimately resulted in yield. Besides, they encourage the activity of microbes which, in turn, release enzymes and hormones that promote plant growth. Mankotia (2007) [23] and Chanda *et al.*, (2017) [3] reported higher yield of rice due to in situ green manure of *Dhanicha* with application of FYM. Shekara *et al.* (2010) [29] and Sharma *et al.* (2020) [28] suggested that increase in the growth, yield attributes and yield of rice due to addition of various organic manures could be attributed to adequate supply of nutrients, higher uptake and recovery of applied nutrients, which in turn, must have improved synthesis and translocation of metabolites to various reproductive structures of the plant. According to Mahanta *et al.* (2013) [20] the SYI of a cropping system continuously increases by continuous application of FYM and other bulky organic manures.

The highest gross return of Rs 123436.00 was also recorded in treatment receiving *Dhanicha* @ 25 kg seed ha^{-1}+ FYM @ 5 t ha^{-1} + Vermicompost (split) @ 2 t ha^{-1} in *Kharif* and FYM @ 5 t ha^{-1}+ Vermicompost (split) @ 2 t ha^{-1} in summer (T_5) which was at par with T_6 and T_7. However the B:C ratio of 1.78 witnessed in T_5 was at par with T_4, T_6 and T_7.

A positive linear relationship (R^2 = 0.933 and 0.938 in *Kharif* and summer seasons, respectively) was observed between SOC and grain yield (Fig.1) and for SOC sequestration rate and grain yield (Fig. 2) (R^2 = 0.790 and 0.780 in *Kharif* and summer seasons, respectively). Similar trend was also observed in case of system yield with SOC and SOC sequestration rate (R^2 = 0.937, 0.937, respectively).

The experiment concluded that application of Dhanicha @ 25 kg seed ha^{-1}+ FYM @ 5 t ha^{-1} + Vermicompost (split) @ 2 t ha^{-1} to *Kharif* rice and FYM @ 5 t ha^{-1}+ Vermicompost (split) @ 2 t ha^{-1} to summer rice can increase the grain yield and sustainability of the system. The SOC concentration, SOC stock and SOC sequestration rate also get enhanced due to the same treatment. Moreover, organic agriculture has potential to mitigate climate change through sequestration of carbon into soil.

Table 2: Effect of organic nutrient management on soil organic carbon stock and carbon sequestration rate.

	Soil profile organic carbon (g kg^{-1})				Bulk density (t m^{-3})				Total soil organic carbon stock (t ha^{-1})					SOC sequestration rate (t ha^{-1} $year^{-1}$)
	0-15 cm	15-30 cm	30-45 cm	45-60 cm	0-15 cm	15-30 cm	30-45 cm	45-60 cm	0-15 cm	15-30 cm	30-45 cm	45-60 cm	Total	
Initial Value	5.20	4.00	2.80	1.80	1.58	1.61	1.64	1.66	12.32	9.66	6.89	4.48	33.35	
T_1	11.29	9.86	3.05	2.10	1.55	1.59	1.62	1.64	26.31	23.52	7.41	5.17	62.40	3.23
T_2	12.62	10.35	3.24	2.21	1.51	1.57	1.61	1.63	28.51	24.37	7.82	5.40	66.12	3.64
T_3	12.86	10.62	3.36	2.24	1.49	1.54	1.59	1.62	28.69	24.53	8.01	5.44	66.68	3.70
T_4	13.28	11.35	3.38	2.28	1.48	1.53	1.58	1.60	29.48	26.05	8.01	5.47	69.01	3.96
T_5	17.24	13.46	3.83	2.45	1.47	1.52	1.54	1.56	38.01	30.69	8.82	5.73	83.26	5.55
T_6	16.58	12.86	3.62	2.34	1.48	1.50	1.56	1.57	36.76	28.87	8.45	5.50	79.57	5.14
T_7	15.24	11.76	3.48	2.35	1.48	1.51	1.57	1.58	33.83	26.56	8.17	5.56	74.13	4.53
S.Em(±)	1.15	1.14	1.03	0.71	0.03	0.14	0.02	0.03	1.77	1.18	1.30	0.88	4.65	0.47
CD(0.05)	3.55	3.52	3.49	2.50	0.08	0.45	0.08	0.08	5.44	3.63	4.01	2.70	14.34	1.46

T_1- *Dhanicha* @ 25 kg seed ha^{-1} in *Kharif* and control in summer.; T_2- *Dhanicha* @ 25 kg seed ha^{-1} + FYM 5t ha^{-1} (basal) in *Kharif* and FYM 5t ha^{-1} (basal) in summer.; T_3- *Dhanicha* @ 25 kg seed ha^{-1} + Vermicompost 2t ha^{-1} (basal) in *Kharif* and Vermicompost 2 t ha^{-1} (basal) in summer.; T_4 - *Dhanicha* @ 25 kg seed ha^{-1} + Vermicompost 2t ha^{-1} (split) - Basal and 20 DAT in *Kharif* and Vermicompost 2t ha^{-1} (split) in summer.; T_5- *Dhanicha* @ 25 kg seed ha^{-1} + FYM + Vermicompost 2t ha^{-1} (split)- basal and 20 DAT in *Kharif* and FYM + Vermicompost 2t ha^{-1} (split)- basal and 20 DAT in summer. T_6 - *Dhanicha* @ 25 kg seed ha^{-1} + FYM + Vermicompost 2t ha^{-1} (basal) in *Kharif* and FYM + Vermicompost 2t ha^{-1} (basal) in summer.; T_7 - *Dhanicha* @ 25 kg seed ha^{-1} + FYM + *Panchagavya* in *Kharif* and FYM + *Panchagavya* in summer

DAT- Days after transplanting; FYM – Farm yard manure. SOC – Soil organic carbon

Table 3: Effect of organic nutrient management on grain yield, SYI and economics of rice-rice sequence

	Kharif		Summer		System		System		
	Grain yield (t ha^{-1})	SYI	Grain yield (t ha^{-1})	SYI	Grain yield (t ha^{-1})	SYI	Gross return (Rs)	Net return (Rs)	B:C
T_1	3.43	0.49	3.23	0.48	6.67	0.49	87403	26841	1.44
T_2	3.71	0.55	3.59	0.54	7.30	0.56	95629	30387	1.47
T_3	3.92	0.58	3.78	0.54	7.70	0.58	100914	35480	1.54
T_4	4.13	0.66	3.98	0.61	8.11	0.65	106275	40841	1.62
T_5	4.76	0.75	4.66	0.71	9.42	0.75	123436	54194	1.78
T_6	4.44	0.68	4.38	0.66	8.82	0.70	115571	46329	1.67
T_7	4.26	0.65	4.21	0.62	8.47	0.66	110990	45856	1.70
S.Em(±)	0.23	-	0.20		0.37		4838		0.07
CD(0.05)	0.69	-	0.61		1.14		14907		0.22

Paddy sale rate-Rs. 13,100.00 per ton

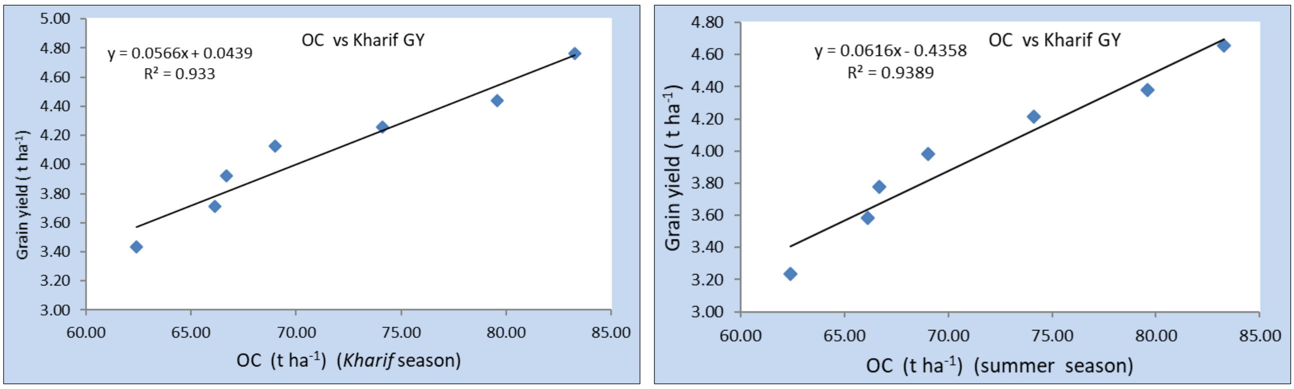

Fig 1: Correlation of organic carbon to grain yield of *Kharif* and summer rice as affected by organic nutrient management

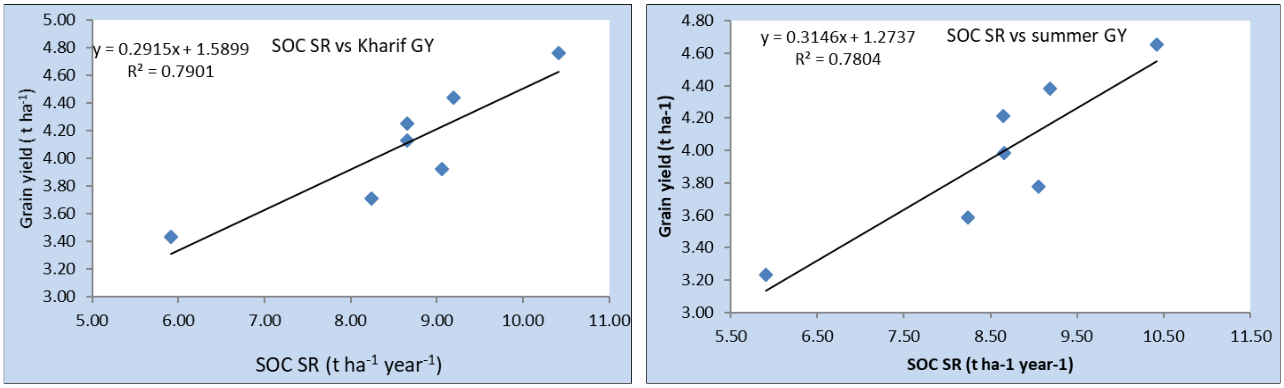

Fig 2: Correlation of carbon sequestration rate (t ha^{-1} year^{-1}) to grain yield of *Kharif* and summer rice as affected by organic nutrient management

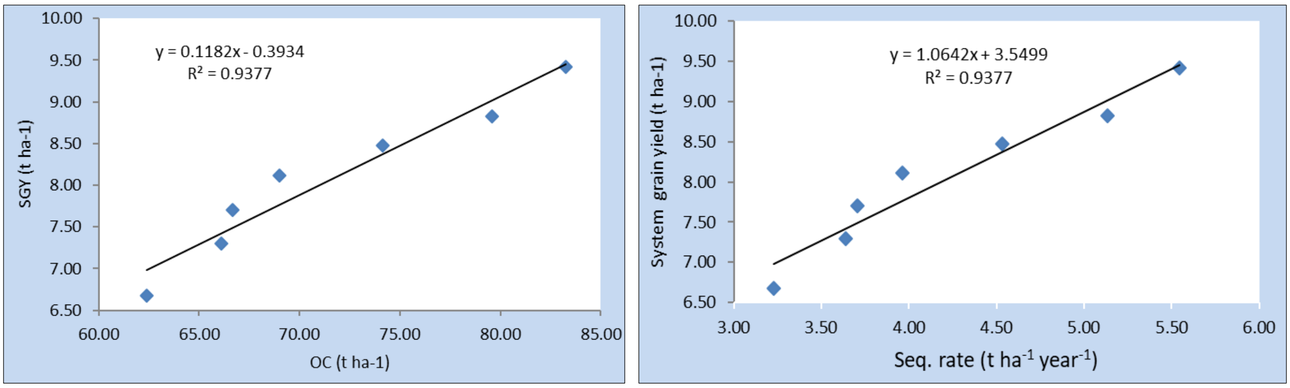

Fig 3: Correlation of organic carbon & sequestration rate to system grain yield as affected by organic nutrient management

References

1. Ali G, Rao PC, Rani YA. Effect of in-situ incorporation of green manures on soil organic carbon, pH, Bulk Density and economics involved in its incorporation. Int. J Curr. Microbiol. App. Sci. 2018;**7**(09):62-67.
2. Bastia DK, Tripathy S, Barik T, Kar CS, Raha S, Tripathy A. Yield and soil organic carbon sequestration under organic nutrient management in rice-rice system. J

Crop Weed. 2013;9:52-55.
3. Chanda SC, Sarwar AKMG. Status of dhaincha incorporated soil after rice harvest in (boro) rice–dhaincha–rice (t. aman) cropping pattern. Agronomic research in Moldavia, 2017. ISSN 0379-5837.
4. Chaudhary S, Dheri GS, Brar BS. Long-term effects of NPK fertilizers and organic manures on carbon stabilization and management index under rice-wheat, 2017.
5. Cooperband L. Building Soil Organic Matter with Organic Amendments. University of Wisconsin, Madison, Center for Integrated Agricultural systems. pp. 1-13. Cropping system. Soil Tillage Res. 2002;166:59-66.
6. Dastane NG. Practical Manual for Water Use Research in Agriculture. Navbharat Prakashan, Pune, Maharastra, 1972, 120pp.
7. Datta A, Choudhury M, Sharma PC, Jat HS, Jat ML, Kar S. Stability of humic acid carbon under conservation agriculture practices. Soil & Tillage Research. Elsevier B.V. 2022;216:105240.
8. Davari MR, Sharma SN. Effect of different combinations of organic materials and biofertilizers on productivity, grain quality and economics in organic farming of basmati rice (*Oryza sativa*). Indian J Agron. 2010;55:290-94.
9. Dey A, Dwibedi BS, Bhattacharyya R, Datta SP, Meena MC, Jat RK, Gupta RK, Jat. Effect of conservation agriculture on soil organic and inorganic carbon sequestration and lability: A study from a rice-wheat cropping system on a calcarious soil of the eastern Indo-Gangetic plains. Soil Use Manage. 2020;36:429-438.
10. Doran JW, Parkin TB. Defining and assessing soil quality. In J.W. Doran (Eds.) Defining soil quality for a sustainable environment. SSSA Special Publication No:35, Madison, WI, 1994, 3-21pp.
11. Gogoi B, Borah N, Baishya A, Dutta S, Nath DJ, Das R, *et al*. Yield trends, soil carbon fractions and sequestration in a rice-rice system of North-East India: Effect of 32 years of INM practices. Field Crops Research. Elsevier B.V. 2021;272:08289.
12. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. A Willey Inter Science Publication, New York, 1984, 76-83pp.
13. Pathak H, Tripathi R, Jambhulkar NN, Bisen JP, Panda BB. Eco-regional Rice Farming for Enhancing Productivity, Profitability and Sustainability. NRRI Research Bulletin No. 22, ICAR-National Rice Research Institute, Cuttack 753006, Odisha, India, 2020.
14. Haque MM, Biswas JC, Akter M, Maniruzaman M, Kabir MS. Carbon Budget and Aggregate Stability of Paddy Soil under Continuous Organic Amendment, Communications in Soil Science and Plant Analysis. 2019;50(15):1829-1837.
15. Kar Ch S, Bastia DK, Tripathy S. System productivity and soil health in relation to microbial population in organic rice-rice sequence. J Crop Weed. 2013;9:102-08.
16. Kukal SS, Rasool R, Benbi DK. Soil organic carbon sequestration in relation to organic and inorganic fertilization in rice–wheat and maize–wheat systems. Soil Till. Res. 2009;102:87-92.
17. Kundu S, Bhattacharyya R, Prakash V, Ghosh BN, Gupta HS. Carbon sequestration and relationship between carbon addition and storage under rainfed soyabean-wheat rotation in a sandy loam soil of the Indian Himalayas. Soil Till. Res. 2007;92:87-95.
18. Lal R. Soil carbon sequestration to mitigate climate change. Geoderma. 2004;123:1-22.
19. Larson WE, Clapp CE. Effects of organic matter on soil physical properties. In properties. In Organic Matter and Rice. Philippines. International Rice Research Institute, 1984. Retrieved from http//pdf.usaidgov/pdf_docs/PNAAR182.pdf.
20. Mahanta D, Bhattacharya R, Gopinath KA, Tuti MD, Jeevanandan K, Chandrashekhara C, *et al*. Influence of farm yard manure application and mineral fertilization on yield sustainability, carbon sequestration potential and soil property of garden pea- frenchbean cropping system in the Indian Himalayas. Scientia Hort. 2013;164:414-27.
21. Majumder B, Mandal B, Bandyopadhyay PK, Gangopadhyay A, Mani PK, Kundu AL, *et al*. Organic amendments influence soil organic carbon pools and rice–wheat productivity. Soil Sci. Soc. Amer. J. 2008;72:775-85.
22. Mandal B, Majumder B, Bandyopadhyay PK, Hazra GC, Gangopadhyay A, Samantaray RN, *et al*. The potential of cropping systems and soil amendments for carbon sequestration in soils under long-term experiments in subtropical India. Glo. Change Biol. 2007;13:357-69.
23. Mankotia BS. Effect of fertilizer application with farm yard manure and in-situ green manures in standing rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. Indian J Agril Sci. 2007;77:512-14.
24. Ngo PT, Rumpel C, Doan TT, Jouquet P. The effect of earthworms on carbon storage and soil organic matter composition in tropical soil amended with compost and vermicompost. Soil Bio. Biochem. 201250:214-20.
25. Ojha RB, Babu R, Shah SC, Pande KR, Dhakal DD. Residual Effect of Farm Yard Manure on Soil Properties in Spring Season, Chitwan, Nepal. International Journal of Scientific Research in Agricultural Sciences. 2014;1(8):165-171.
26. Pradhan S, Bastia DK, Tripathy S. Soil organic carbon health and yield sustainability under organically managed rice-rice sequence Journal Crop and Weed. 2015;11(1):108-112.
27. Sankaramoorthy A, Rangasamy V. Impacts of Different Sources of Organic Manures on Soil Physico-Chemical Properties, Nutrient Balance and Yield of Rice-Greengram Cropping Sequence under Organic Farming International Journal of Agriculture & Environmental Science. 2019;6:65.
28. Sharma S, Singh P, Kumar S. Responses of Soil Carbon Pools, Enzymatic Activity, and Crop Yields to Nitrogen and Straw Incorporation in a Rice-Wheat Cropping System in North-Western India. Front. Sustain. Food Syst. 2020;4:532704.
29. Shekara BG, Sharnappa, Krishnamurthy N. Effect of irrigation schedules on growth and yield of aerobic rice under varied levels of FYM in Cauvery Command area. Indian J Agron. 2010;55:35-39.
30. Singh F, Kumar R, Pal S. Integrated nutrient management in rice-wheat cropping system for sustainable productivity. J Indian Soc. Soil Sci. 2008;56:205-08.
31. Singh RP, Das SK, Bhaskara Rao UM, Narayana RM. Sustainability index under different management. Annual

Report. CRIDA, Hyderabad, India, 1990, 106pp.

32. Singh YV, Dhar DW, Agarwal B. Influence of organic nutrient management on Basmati rice (*Oryza sativa*)-wheat (*Triticum aestivum*)- greengram (*Vigna radiata*) cropping system. Indian J Agron. 2011;56:169-75.
33. Sisay Assefa. The Principal Role of Organic Fertilizer on Soil Properties and Agricultural Productivity -A Review. Agri Res& Tech: Open Access J. 2019;22(2):556192.
34. Sudha B, Chandini S. Vermicompost - potential organic manure for rice. Intensive Agriculture, 2003, 23-29pp.
35. Sudha B, Chandini S. Effect of integrated nutrient management on rice yield and soil nutrient status in Karamana, Kerala. Oryza. 2005;42(3):225-226.
36. Vanlauwe B. Integrated soil fertility management research at TSBF: the framework, the principles, and their application. In: Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa (Bationo, A. Ed.),. Academy science publishers, Nairobi, Kenya. 2004, 124-29.
37. Yadav DS, Kumar V, Yadav V. Effect of organic farming on productivity, soil health and economics of rice-wheat system. Indian J Agron. 2009;54:267-71.