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Unlocking the Secrets of Soil Health: Exploring the Influence of Natural and Synthetic Nutrients on Soil Organic Carbon and Active & Passive Carbon Pool in Vertisols

Vishal Gupta [a*], K.S. Bangar [a], B.B. Parmar [a], Jyoti Bangre [a], Kishan Kumar [b] and Brajesh Yadav [a]

[a] *College of Agriculture, Indore, Madhya Pradesh, India.*
[b] *Rajasthan college of agriculture Udaipur (MPUAT), India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment carried out in this field study was between 2022 and 2023 at the (AICRP) research farm in the outward-bound farm of the College of Agriculture, Indore. Indore is a small city in the western part of Madhya Pradesh, Central India, situated on the Malwa Plateau. An experiment was conducted with three replication by using different combination of N, P levels and crop residues in RBD design. Experiment field was medium to black soil with pH of 7.63 and medium in organic carbon 0.58%. The soil was low in available nitrogen (208.0 kg/ha) medium in available phosphorus (21.0 kg/ha) and high in potassium (585 kg/ha) and divided into gross plot size of 10 x 7.2 m2 and

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**Corresponding author: E-mail: vg999637@gmail.com;*

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a net plot size of 9 x 6.4 m2, respectively. During crop harvest four different depths were used to gather the soil samples: 0–10, 10–20, 20–30, and 30–40 cm. All the collected samples are examined separated for soil organic carbon, active (highly labile, labile SOC), and passive (non-labile, less labile SOC) carbon pools. The finding showed that maximum soil organic carbon (%) was observed with the application of treatment T6 treatment (FYM 6 t ha-1 + N20 P13. Similar trend was found with active (very labile, labile) and passive carbon (less labile, non-labile) pools of soil.

Keywords: Soil organic carbon (SOC); very labile; labile; less labile; non-labile; active and passive carbon pool.

1. INTRODUCTION

The organic input of the soil is critical for protecting its physical properties or fertility because plants need it as a mineral source to successfully implement an agricultural production process. The pages of the report are comprised of the active and inactive carbon stocks in soil, known as the active and passive carbon pools, respectively. Carbon in the active carbon pool, with roots and microbes being the greedy ones, is available for plants and microbial metabolism. Also, it is known and thus linked to recent plant inputs. Given its structure, active carbon is distinguished and is characterized by the ease of its breakdown. On the other hand, the carbon in the passive carbon pool is longer-lasting and thus less likely to break down in the soil. Learning the positions of carbon pools, which include active and passive, is essential to understanding the cycling and storage of carbon in the soil. While passive carbon may be a source of data about the possibility of future carbon storage in the soil, active carbon is most probably a more fluctuating measure of short-term changes in soil carbon dynamics. The present work is undoubtedly aimed at the comprehensive examination of vertical .This has effect on the active and passive carbon stores in organic character and inorganic fertilizers.

2. MATERIALS AND METHODS

Applying the organic and inorganic fertilizers from the latitude 22.70 and longitude 75.90 of the All India Coordinated Research Project (AICRP) for dry land agriculture farm of the College of Agriculture, Indore, from 2022 to 2023, this experiment is presently in motion. The mean annual precipitation is 1212.80 mm.The minimum temperature is 23.08 0C, and the mean average maximum temperature is 32.34 0C. Humidity of the cropping area ranged from an average of 85.58%. For the analysis to be performed, composite duplicate soil samples taken horizon-wise from the depths of 0–10, 10–20, 20–30, and 30–40 cm will be air dried, ground, passed through a 2 mm sieve and finally stored in a plastic container-for routine laboratory tests. The Walkley-Black potassium dichromate heating method described by the authors [1] was used to assess the quantity of soil organic carbon. With 5, 10, and 20 ml of the c.a (36N) H2SO4, the mixing in the pools was done separately, and those were used to estimate SO as reported by Chan et al. [2]. This produced three acid-aqueous solution ratios of 0.5:111, 181, and 222 (beruhiger form: 11, 18, und 22, das entspricht 12, 18, und 24 N's vielleicht von H2SO4).By defining C pools based on the length of oxidation, which is getting more difficult over time, SOC was divided into four parts. Pool I (CVL: Similarly, irreversible non-renewable resources do not emit carbon while the production or transport of products like coal, oil, or natural gas takes place (12 N H2SO4 can oxidize organic carbon). The difference between C oxidizable by 18N and that by 12 N H2SO4 is known as Pool II (CL: Climate change, together with the soil carbon (SAC), could operate in a synergistic way to increase soil carbon input. The difference between C oxidizable by 24 N and that by 18 N H2SO4 is known as Pool III (CLL: The addition of organic matter to the soil has a variety of benefits, including the reduction of soil erosion, the provision of compounds available to plants, and the promotion of agro ecosystems by increasing soil carbon stability (longer residence time of carbon). Pool IV (CNL: Indirect methods: Measurement of labiality of soil carbon (labile C): with the difference between oxidizable C and the SOC (stable organic C). Soil carbon stock (Mg C ha-1) can be calculated as follows: are computed by multiplying carbon content by a thickness (g C kg-1) × BD (Mg m-3) × 0.1.

3. RESULTS AND DISCUSSION

3.1 Soil Organic Carbon (SOC%)

The statistical evaluation of the organic carbon content of the soil was carried out to depths of

(0-10cm, 10-20cm, 20-30cm, and 30-40cm), in comparison with the manures and fertilizers with and without supplementation is depicted in Table 1. Top soil showed more SOC than deep soil, according to the research. Moreover, it demonstrated that, for soil depths for sections of 0 - 10, 10 - 20, 20 - 30, and 30 - 40 cm, correspondently, the SOC content ranged from 0.34 - 0.77%, 0.30 - 0.71%, 0.28 - 0.6 These trends were closely perfectly with an upsurge in the nutrient dose under FYM 6 t ha-1 + N20 P13 (T6), the SOC at 0–10 cm depth was significantly higher—0.77% at 0–10 cm, 0.71 % at 10–20 cm, and 0.62% at 20–30 cm. 0.44% at 30–40 cm depths, which was similar to the treatments for Residues 5 t ha-1 + N20 P13 (T7) and FYM 6 t ha-1 (T8), although T6 outperformed the other treatments by a large margin. The trend remained the same for a given soil depth and all depths. At 0–10, 10– 20, 20– 30, and 30– 40 cm depths, SOM content was highest in the control plot (0.32%, 0.30%, 0.28%, and 0.25%, respectively). The study by Masto et al. [3] revealed a significantly higher soil organic carbon content in the depth of 0-10 cm in the FYM 6 t ha-1 + N2O and P13 treatment combinations than in the control treatments. Similar results were also recorded in the range that accepted only the NPK fertilizer, or the presence of FYM and straw in combination with the NPK fertilizer was noted. One important indicator for assessing soil quality is soil organic carbon. However, increase in soil organic carbon content improves soil nutrient availability, drainage of soluble water maintenance, fills sink wells for supplements, and maintains soil fertility [4]. Geetakumari et al. [5] reported a similar kind of finding,on increase in organic carbon content through the application of organic manure. Meena et al. [6] discovered that the treatment NPK+ FYM 10 t ha1 significantly improved Organic carbon 0.75% due to integrated input use.

3.2 Active Soil Organic Carbon Pool

The laboratory data in Table 2 above presented the extremely labile soil organic carbon content of different soil depths (0-10, 10-20, 20-30, and 30-40 cm). The data likewise made par with the effects of the functional application of farmyard manure and fertilizers. In the mentioned treatments, the organic carbon content of extremely labile soils was, according to the rule, more in the surface soils than in those at lower surfaces. Depth ranges from 0 to 10 cm, and measurement results ranged from 3.01 to 1.65 g/kg–1), whereas depth ranges from 20 to 40 cm the measurement results ranged from 2.58 to 0.76/kg–1).The highest values of very labile carbon content were recorded under FYM 6 t ha-1 + N20 P13 (T6) at 0–10 cm soil depth (3.83 g kg–1), 10–20 cm soil depth (3.49 g kg–1), 20–30 cm soil depth (2.75 g kg–1), and at 30–40 cm (2.31 g kg–1), followed by Residues 5 t ha-1 + N20 P13 (T7), FYM 6 t ha-1 (T8), Residues 5 t ha-1 (T9), and N60, P35 (T5). While the T1 treatment had the lowest very labile carbon contents (2.47, 2.16, 1.43, and 1.39 g kg–1 at the varied depths), it was similar to the depths 0-10cm, 10-20cm, 20-30cm, and 30-40cm respectively. The effect of treatment T6 and T7 are at par, i.e., but not significantly different, but significantly different from T1, and the T2, T3, and T4 are at par, i.e. but not significantly different, whereas significantly different from T6. Das et al**.** [7] discovered similar results when study the long team effects of fertilizers and organic source on soil organic carbon fractions in an indo gangentic plains rice and wheat system in northwestern India.

One of the treatments was an unfertilized control with labile soil organic carbon analysis from various soil depths (0-10, 10-20, 20-30, and 30-40 cm). The effect of manures and fertilizers was statistically examined on the mentioned SOC levels and soil depths (Table 2). From the data, we deduce that the labile carbon value grew as the fertilizer level increased. The point of it all is that labile carbon content increased from zero or control fertilizers (T1) to FYM 6t ha-1 + N20P13 (T6), then the residues + N20P13 (T7) treatment. That was identical to earlier results, which also occurred at a lower level. By different soil treatments, 3.21, 2.60, 2.19, and 1.37 g probably generated labile carbon content at 0-10, 10-20, 20-30, and 30-40cm depths within T6 FYM 6t ha-1 + N20P13, the highest value was reported. More significant measurements were obtained as a controlled (T1) sample with various soil depths, and two more (NP treatments) were added. However, there is nothing substantial about treatments T2 and T3, just as they are better than T6 and T7, but they are still far from T2 and T3. However, although T8 and T9 are universally good in comparison with T6 and T7, they are still less than what can be.

This can only be the outcome of an increase in the size of applied fertilizers and manures, not the amount of biomass; there is a correlation between them. FYM 6t ha-1 + N20P13, (T6) treatment routed the carbon atoms to 0–10 cm soil depth with the highest concentration for both very labile and labile carbon (FYM 6t ha-1 + N20, P13,(T6). This may be the result of the long-term accumulation of FYM, which has added much more labile carbon in a relatively short term compared to the long-term contribution of other organic carbon sources. Perhaps the cause of these dynamic carbon pools, which are both labile and very labile and detected at 30-40 cm deep, remains unchanged under the control treatment (T1) is the lessening of the input biomass. The results of Kumari et al**.** [8], who report that treatment with NPK in combination with FYM releases more substantial SOC fractions, tend to support this. According to the measured results, it should be noted that the non-labile carbon pool was a significant factor that led to the finding that the amount of organic carbon in the soil was high (FYM+N20P13).

3.3 Passive Soil Organic Carbon Pool

The tabulation in Table 3 extradites the acidic soil organic carbon at various depths; the sites contain unfertilized and fertilized farmlands. In addition, deeper soil layers had less recalcitrant organic carbon, a concept related to soil structure that describes organic material resistant to degradation. The treatments with the most carbon measured (0.85 g kg-1) had a depth of 0-10 in soils belonging to control treatments (T1). That value steadily fell to treatment (T6) for 6 t ha-1+ N20P13 (0.67 g kg-1) at 0–10 cm depth, then different from the residues 5 t ha-1 (T9) 0.82 g kg-1 at 0–10 cm depth and FYM 6 t ha-1 (T8 The treatments of both N60P35 and (T5) 0.74 g kg were not much different from those of N40P26 (T4) 0.45 g kg at 0-10 cm and 10-20 cm soil depth, respectively. Comparable outcomes were

Table 1. Effect of manures and fertilizer treatments on vertisols' soil organic carbon (%) at different depths

Treatments	Soil organiccarbon(%)			
	0-10cm	**10-20cm**	**20-30cm**	**30-40Cm**
T1-Control	0.32	0.30	0.28	0.25
T2-N20P13	0.36	0.34	0.32	0.31
T3-N30P20	0.40	0.39	0.37	0.35
T4-N40P26	0.42	0.41	0.40	0.38
T5-N60P35	0.51	0.50	0.48	0.42
T6-FYM6tha^{-1}+T2	0.77	0.71	0.62	0.44
T7-Residues5tha^{-1}+T2	0.72	0.67	0.53	0.46
T8-FYM6tha^{-1}	0.67	0.59	0.49	0.42
T9–Residues5tha^{-1}	0.64	0.56	0.43	0.37
SEm±	0.01	0.01	0.01	0.01
CDat5%	0.03	0.03	0.03	0.03

Table 2. Effect of manures and fertilizer treatments on active soil organic carbon (g kg^{-1})of vertisols at different depths

Treatment	Active soil organic carbon pools(gkg-1)							
	Very labile SOC				Labile SOC			
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	0-10 cm	10-20 cm	20-30 cm	30-40 cm
T1-Control	2.47	2.16	1.43	1.39	1.46	1.11	0.92	0.50
T2-N20P13	2.76	2.48	1.46	1.40	1.54	1.28	1.09	0.54
T3-N30P20	2.79	2.68	1.58	1.45	1.57	1.47	1.15	0.52
T4-N40P26	2.90	2.85	1.68	1.55	1.64	1.54	1.12	0.85
T5-N60P35	3.06	2.89	1.73	1.61	1.89	1.62	1.17	0.90
T6-FYM6tha^{-1}+T2	3.83	3.49	2.75	2.31	3.21	2.60	2.19	1.37
T7-Residues5 tha^{-1}+T2	3.36	2.91	2.21	1.90	2.75	2.05	1.36	1.11
T8-FYM6tha^{-1}	3.11	2.81	2.12	1.67	1.91	1.82	1.28	0.97
T9Residues5tha^{-1}	2.84	2.42	2.06	1.57	1.90	1.71	1.27	0.93
SEm±	0.14	0.13	0.13	0.13	0.04	0.03	0.02	0.03
CDat5%	0.40	0.38	0.38	0.39	0.12	0.09	0.07	0.08

Table 3. Effect of manures and fertilizer treatments on passive soil organic carbon ($g\ kg^{-1}$) of vertisols at different depths

Treatment	Passive soil organic carbon pools (gkg^{-1})							
	Non labile SOC				Less Labile SOC			
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	0-10 cm	10-20 cm	20-30 cm	30-40 Cm
T1-Control	0.85	0.70	0.62	0.55	0.85	0.70	0.62	0.55
T2-N20P13	0.80	0.65	0.56	0.51	0.80	0.65	0.56	0.51
T3-N30P20	0.78	0.66	0.56	0.48	0.78	0.66	0.56	0.48
T4-N40P26	0.76	0.64	0.55	0.45	0.76	0.64	0.55	0.45
T5-N60P35	0.75	0.62	0.46	0.43	0.75	0.62	0.46	0.43
T6-FYM6tha^{-1}+T2	0.67	0.63	0.45	0.38	0.67	0.63	0.45	0.38
T7-Residues 5tha^{-1}+T2	0.72	0.53	0.44	0.43	0.72	0.53	0.44	0.43
T8-FYM6tha^{-1}	0.79	0.54	0.50	0.45	0.79	0.54	0.50	0.45
T9-Residues 5tha^{-1}	0.82	0.54	0.53	0.48	0.82	0.54	0.53	0.48
SEm±	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.03
CDat5%	0.09	0.05	0.08	0.09	0.09	0.05	0.08	0.09

seen at lower depths of 10, 20, 20, 30, and 40 cm. The control group (T1) exhibited a moreexcellent value of 0.70, 0.62, and 0.55 gkg-1, while FYM 6 t ha-1+ N20 P13 (T6) had a lower value of 0.67, 0.45, and 0.38 g kg-1. Treatments T6, T7, and T8 are at par, meaning they differ from T1 but not considerably, and treatments T3, T4, and T5 are at par, meaning they differ from T6 and T1 but not significantly. The results of Parmar et al**.** [9], who report that treatment with NPK in combination with FYM releases more substantial SOC fractions, tend to support this.

Table 3 visually demonstrates the non-labile quantity of carbon left within soil organic after fertilizing and applying different depths of manure and fertilizer, as well as the control case, which is the plot without fertilizer application. The carbonaceous fraction fractional values ranges from 4.86 to 8.74 g kg-1(0-10 cm depth), 4.32 to 6.68 g kg-1 (10-20 cm depth), 3.97 to 6.47 g kg-1(20-30 cm depth), and 3.46 to 5 Application of 6 t ha-1 FYM + N20 P13 (T6) demonstrated significantly higher levels relative to the controls for example soil .depths at 0- 10 cm had 8.74 g kg-1, in 10-20 cm there was 6.68 g kg-1, 20-30 cm had 6.47 g kg. [T1]control group giving the lowest amount of non-labile carbon (4.86; 4.32; 3.97; 3.46 g kg-1) at the available soil depths (0-10 cm; 10-20 cm; 20-30 cm; and 30-40 cm). The order is T1 (or control. The comparisons T6=T7 and T2=T4 indicate that treatments T1, T7, and T4 are alike but not much so, whereas treatments T2 and T4 are alike and not too different from T1. Majumder et al., [10] also found similar contributions of passive soil organic carbon pool to total organic carbon under NPK with FYM treatments

Passive soil carbon has been recognized as such carbon pools located in less labile and non-labile soil organic carbon pools. The C that is least likely to change into CO2 was detected at a 0–10 cm depth by applying organic material from 6 t ha-1 + N20 P13 (T6). Studies of the consequences of different fertilizers as well as manure and their effects on the environment in the long run. There are two kinds of SOC by looking at their degradation rate and turnover: the one that is more irreversible and resistant to degradation is active carbon soil organic carbon is called passive. It is made of organic materials that have been stabilized chemically or physically enough, resulting in more chemically and biologically stable material. Thus, microbial degradation or mineralization decreases. Bendi et al. [11] also found similar outcomes. It was established that a passive fraction of carbon meant more organic carbon when rice and wheat-grown systems were compared.

4. CONCLUSION

The study revealed significant variations in soil organic carbon content across different treatments and depths. The control treatment (T1) exhibited the lowest soil organic carbon levels, particularly at 30–40 cm depth, whereas treatment T6 (FYM 6 t ha-1 + N20 P13) demonstrated notable improvements, especially at 0–10 cm depth. The presence of FYM and nutrient supplementation significantly enhanced soil organic carbon content, with treatment T6 showing the highest values. Additionally, the labile carbon content was notably higher in treatment T6 compared to the control treatment (T1), indicating the effectiveness of FYM and nutrient supplementation in enhancing soil carbon dynamics. These finding sunder score the importance of appropriate soil management practices, such as FYM application and nutrient supplementation, in promoting soil carbon sequestration and improving soil fertility. Further research is acceptable to explore the long-term effects of these treatments on soil carbon dynamics and overall soil health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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