Biological Forum – An International Journal **15(5): 1194-1200(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Effect of Long-term Manuring and Fertilization on Passive pools of Carbon under Sorghum Wheat Sequence Cropping in Vertisols

P.H. Rathod[1*], S.M. Bhoyar[2], S.D. Jadhao[3], P.W. Deshmukh[3], G.S. Lahariya[3] and A.B. Aage[4]

[1]Ph.D. Research Scholar, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra), India.

[2]Professor and Head, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra), India.

[3]Associate Professor, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra), India.

[6]Assistant Professor, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra), India.

(Corresponding author: P.H. Rathod)*

(Received: 11 March 2023; Revised: 16 April 2023; Accepted: 22 April 2023; Published: 20 May 2023)
(Published by Research Trend)

ABSTRACT: The field study, "Appraisal of carbon dynamics and its sequestration under long-term sorghum-wheat cropping sequence in Vertisols", was conducted concurrently with the 32nd and 33rd cycles of the ongoing long-term fertilizer experiment (LTFE) on the sorghum-wheat sequence in 2019–20 and 2020–21 at the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. With twelve treatments spread across four replications, the experiment was carried out using a randomized block design. The results of the current experiment show that the application of solitary FYM observed the highest passive pools of carbon (Humic carbon, Fulvic carbon, and Humin carbon), followed by 100% NPK+ FYM @ 5 t ha^{-1} and 75% NPK+ 25% N through FYM. With the amount of NPK fertilizer increased from 50% to 150%, the passive pools of carbon increased, showing the significance of their primary nutrients in accumulation and becoming, which ultimately led to higher root growth and overall plant development. Thus, it can be said that the application of FYM, either alone or in conjunction with NPK, had a positive impact on the stability of carbon and on the fertility, overall health, and crop productivity of the soil.

Keywords: Humic, Fulvic, Humin carbon, Yield, humification and Vertisols.

INTRODUCTION

In addition to maintaining the physical properties of the soil, soil organic matter is crucial for supplying vital plant nutrients for optimal crop production (Gathala *et al*., 2007). The largest and most significant component of soil organic matter, humus, which comprises humin, humic acid (HA), and fulvic acid (FA), is created when microorganisms break down plant and animal remains. Farmyard manure (FYM) and long-term continuous application of inorganic fertilizers including N, P, K, S, and Mg both significantly enhanced the level of soil organic carbon (SOC), however, the rise in inorganically treated soils was much smaller than that caused by FYM (Santhy *et al*., 2001).

Natural compounds known as humic substances (HS) make up the biggest concentration of recalcitrant organic carbon (OC) in the terrestrial environment. According to studies by Galantini *et al*. (2014); Novotny *et al*. (1999); and Sharanbhoopal *et al*. (2014), management practices can change the quality of HS or its humic acid (HA) and fulvic acid (FA) components. Due to their intricate polymer structure, physical protection provided by thick aggregates, association with metal ions, or association with clays, humic compounds are stabilized in the soil against microbial destruction. However, the creation and degradation of humus can be significantly impacted by a variety of environmental conditions and agricultural practices. Temperature, moisture, tillage, and agricultural systems are key factors among these.

The term "humification" refers to the extraordinarily complex creation and transformation processes that take place in the soil where biotic activity is present, and polycondensation occurs with the help of inorganic-organic catalysts (such as OH ion, Fe, and Mn oxides). A number of humus fractions have been separated and given the names humin, humic acid (HA), fulvic acid (FA), and hematomelaonic acid based on how well they dissolve in specific extractants. These fractions are observed to range from low to high in molecular weight, elemental analysis, functional groups, and overall acidity (Kononova, 1966). Specific (humic compounds) and non-specific (non-humic fractions) substances make up the humus. Both of these types of elements are crucial to the soil ecology. The soil ecosystem depends on both these specific and non-specific components. Non-specific materials have immediate consequences, such as serving as a source of food and energy for microorganisms and a natural fertilizer for soil.

The passive portion of soil organic matter that results from the humification process is composed of stable components that have been present in the soil for hundreds or even thousands of years. This subset consists of humus that is physically shielded by clay-humus complexes. For instance, humin and humic acids. In moist soils, the passive fraction makes up 60 to 80% of the organic matter, and its quality progressively improves or degrades. The passive fraction adds to the soil's colloidal characteristics, specifically its ability to hold water and exchange cations. Smith and Paul (1990) reported findings that were comparable. In soil organic matter (SOM), humic compounds serve as the building blocks of organic carbon and are often classified as humic acid (HA), fulvic acid (FA), and human. As a result, knowing carbon sequestration in terms of HA, FA, and HU is crucial for comprehending the global carbon cycle. Compared to FAs, humic compounds have higher carbon and lower oxygen concentrations. The FA are richer in aromatic and hydrophobic (water-repelling) groups, and they are more hydrophilic (water-loving) and acidic in nature. The molecular weight of FA is only a few hundred to a few thousand times lower than that of HA, which can range from 10,000 to 200,000. Accordingly, FAs are fractions that have undergone less polymerization, whereas HA is compounded with longer chains that have undergone more polymerization.

According to Srilatha *et al*. (2013); Stevenson (1982); Schnitzer and Khan (1972), the relationship between E_4/E_6 ratio and the aromaticity and degree of condensation of a humic substance's chain of aromatic carbons can be utilized as a humification index. According to Chen *et al*. (1977), the E_4/E_6 ratio has been employed as a benchmark parameter for characterizing HA and FA. Humic and fulvic acid are characterized using the ratio of optical densities at 465 and 665 nm large E_4/E_6 ratio results compared to soil-derived HA showed the existence of a large proportion of aliphatic structures, a low aromatic condensation level, and some degree of humification (Senesi *et al*., 2007). HA, however, might be present in a stable form while OM breaks down. Following fertilizer application, the HA had greater aliphatic and phenolic OH group contents (Galantini and Rosell 2006). In this study's manure treatments, the E_4/E_6 ratio increased, indicating that the HA in those treatments was highly aliphatic.

MATERIALS AND METHODS

A. Location, climate, and field experiment

The experiment was superimposed ongoing long-term fertilizer experiment (LTFE) that was started in 1988–1989 at the Central Research Station (CRS) of Dr. Panjabrao Deshmukh Krishi Vidyapeeth in Akola at the Research Farm, Department of Soil Science and Agricultural Chemistry. The experimental field is located 30.78 (m) above mean sea level (MSL) at latitude 22°42' 19.2' North and longitude 77°03' 43.2' East. The long-term fertilizer experiment was launched in 1988–1989 to examine how soil quality, crop productivity, and sustainability changed over time. The current study, "Appraisal of carbon dynamics and its sequestration under long-term sorghum-wheat cropping sequence in Vertisols," was conducted at the Dr. Panjabrao Deshmukh Krishi Vidyapeeth's Research Farm AICRP on Long-Term Fertilizer Experiment in Akola. Akola is located in the subtropical zone between latitudes 22°42'N and 77°02'E. The location is 304.42 meters above mean sea level. The semiarid climate of Akola has three distinct seasons, including a hot and dry summer from March to May. From June to October, there is a warm, humid, and rainy season, and from November to February, there is a pleasant winter. 818.6 mm of precipitation each year on average over the last 33 years. The hottest month, May, has an average maximum temperature of 45.2°C, while December has an average minimum temperature of 8.4°C. In the month of May, the mean evaporation can be as high as 16.8 mm day^{-1} and as low as 4.3 mm day^{-1}in the month of December.

B. Treatment details

The experiment was set up using a randomised block design (RBD), with four replications of each of the twelve treatments. The treatment's specifics are listed below. T_1: 50%NPK, T_2, 100% NPK, T_3, 150% NPK, T_4, 100% NPK (S free), T_5, 100% NPK+ Zn @ 2.5 kg ha^{-1}, T_6, 100% NP, T_7,100% N, T_8, 100% NPK+FYM@ 5 t ha^{-1}, T_9, 100% NPK +S @ 37.5 kg ha^{-1}, T_{10}, FYM @ 10 t ha^{-1}, T_{11}, 75% NPK + 25% N through FYM, T_{12}: control (No manures and fertilizer). Before sowing, FYM was applied on an oven-dry basis. When seeds are sown, N, P, and K are distributed equally. The remaining N was administered to wheat 21 days after sowing and to sorghum 30 days after sowing. Wheat: 120: 60: 60 Kg N, P_2O_5, and K_2O ha^{-1}; are the recommended fertilizer doses. All treatments, with the exception of T_4 and T_9 used the application of N, P_2O_5, and K_2O through urea, SSP, and MOP. By using gypsum, sulphur was applied. Zinc treatment is based on the results of the soil test. Drilling was used to plant the sorghum. As and when necessary, every field operation was completed. Once the crop reached maturity, it was harvested, and the spikelets were trimmed, packaged separately, and kept for sun drying. The yield was measured following threshing based on the presence of moisture. Drilling was used for the sowing of wheat. As and when necessary, every field operation was completed.

Alkaline extraction was used to remove humic compounds from soil (Stevenson, 1982). Microorganisms break down plant and animal waste to produce humic chemicals. They are a dark-colored, colloid-sized polymeric material. Fulvic acid, humic acid, and humin are the three components of humic substance. The most popular technique for removing humic material involves treating it with diluted alkalis like NaOH and Na_2CO_3. The insoluble polyvalent cation is transformed by alkali treatment into humates. Before extracting the alkali, the soil is treated with diluted HCI if it is particularly high in Ca^{2+} ions or includes $CaCO_3$ concretions; otherwise, humate is used. A 15 g soil sample was placed in a 250 ml conical flask together with 150 ml of newly produced sodium hydroxide (0.5 M NaOH) at pH 13.0. A mechanical shaker was used to stir the mixture for 24 hours. After centrifuging it for 15 minutes at 2000 rpm, the dark-colored supernatant was collected in a flask. The collected precipitated humin fraction was then filtered, collected, dried, and kept as humin for the remaining analyses. For the remaining fractions, collect the supernatant in a different flask and acidify it to a pH of 1.5 to 2. The fulvic acid supernatant was collected after the acidify flask had been allowed for 24 hours to settle. For 15 minutes, the precipitated humic acid was centrifuged at 2000 rpm. Remove the precipitated, dry it at 105ºC, and store it for analysis while discarding the supernatant. According to Walkley and Black (1934), the fast titration method was used to measure the carbon content of humic acid.

RESULT AND DISCUSSION

A. Grain and Straw yield of wheat

Under 100% NPK+ FYM, the wheat grain yield was significantly higher (30.36 q ha^{-1}); it was followed by 100% NPK+ S and 100% NPK+ Zn. Utilizing FYM, which in addition to providing all necessary nutrients, may enhance the physical, chemical, and biological qualities of soil, maybe the major contributing factor to the highest yield ever obtained. This provided more evidence that the productivity of wheat may be maintained with the combined use of organics and fertilizers. Both Singh *et al*. (2012); Sawarkar *et al.* (2013) reported on similar crop productivity figures. In order to maintain crop yield and soil fertility over the long term, Ram *etal.*, (2016) discovered that long-term integrated use of inorganic fertilizers and organic manure (FYM) was preferable to unilateral use of inorganic fertilizers.

The results demonstrated that increasing the dosage of NPK fertilizer over time improved the grain yield of crops. Application of 150% NPK (T_3), followed by 100% NPK through (SSP) (T_2), and 100% NPK S free (DAP) (T_4), resulted in a noticeably greater yield. The yield results with increased fertilizer use were consistent with those reported by Suresh *et al.* (2017). The addition of sulphur using SSP in (T_2) may have increased the grain and straw yields of wheat in 100% NPK (T_2) over 100% NPK without sulphur treatment (T_4). Mehta *et al*. (2005) reported that the addition of sulphur through fertilizers increased the yield of the wheat crop. The productivity of the grain crop, on the other hand, significantly decreased when the sulphur nutrient (100 percent NPK-S) was not included in the fertilizer dose, resulting in a 20% reduction in grain yield over the recommended amount of fertilizer. The physical health of the soil has significantly improved as a result of increased supplies of the three essential nutrients and the formation of more organic matter through greater roots, stubbles, and leaf litter fall. However, a study on Typic Ustochrepts in Andhra Pradesh's clayey soil (Srilatha *et al.*, 2014) found that 150% NPK produced a higher yield than 100% NPK + FYM.

Therefore, it makes sense that the application of N, P, and K in sufficient amounts would boost agricultural yields. Lower yields of wheat and wheat straw were also observed when sulphur was absent; this could be because DAP was used in place of SSP. Compared to SSP, di-ammonium phosphate has 46% P but no S or Ca. As a result of the ongoing use of high-analysis fertilizers, which has caused a shortfall in secondary and micronutrients and decreased agricultural output, the soil has been mined for sulphur. Nziguheba *et al.* (2009) also noted that larger grain yields of rice were produced in comparison to all nutrient absence plots, despite the fact that maize yield was decreased due to the removal of N, P, K, S, and Zn.

Continuous long-term experiment results showed that, regardless of continuous cereal-cereal intensive cropping system and soil type, depletion of SOM is the principal driver of yield decrease, particularly in plots receiving only N, which worsens soil quality. However, the treatment getting 100% N alone, followed by 100% NP over 100% NPK, was found to have the greatest impact on the grain production of wheat. Depletion of SOC status, active SOC fractions, and related nutrients may be to blame for this. These findings concur with those made by Mahapatra *et al.* (2007). According to Singh *et al.* (2018), the application of chemical fertilizer and FYM together boosted the grain yields of wheat and rice. The combination of NPK, FYM, and Zn increased both crops' grain yields because they improved their fertility status over time, resulting in a sustainable supply of nutrients. It is clear from similar results (Katkar *et al.*, 2011; Srivastava *et al.*, 2015) that the FYM treatment is crucial for the sustained production of sorghum and wheat under rice-wheat and other cropping systems.

B. Humic acid carbon (HAC)

After the 32^{nd} and 33^{rd} cycles of LTFE, the FYM-modified treatments revealed the highest levels of humic acid-C compared to the inorganically fertilized treatments, according to mean data on humic acid-C. Significantly, the maximum amount of humic acid carbon (52.97%) was achieved using FYM alone @ 10 t ha^{-1}, followed by 100% NPK+ FYM @ 5 t ha^{-1}, and 75% NPK + 25% N using FYM. This was attributed to the ongoing usage of FYM as a direct source of organic matter with high levels of lignin and phenol, which are resistant to degradation and help create passive carbon pools. Similar results have been reported by Bhoye *et al*. (2011) who found that adding 10 t of fully decomposed FYM and 10 t of partially decomposed FYM along with the recommended dose of fertilizer (RDF) improved the amount of humic acid in the soil and that these treatments were significantly better than the other treatments. The suboptimal set of treatments revealed that 50% NPK had the highest humic acid carbon (46.16%), followed by 100% NP, and 100% N alone. The HA-C was raised when NPK fertilizer levels were increased or when P and K were added to the fertilization schedule, but this increase in the HA-C over the ideal level was not statistically significant. Results aligned with According to Manna *et al*. (2013), when compared to the NPK with FYM treatment, the most recalcitrant fractions of C in the unfertilized control, N, NP, and NPK treatments were considerably reduced by 13.4–33.3%.

The elemental carbon recovery was much higher when using alone FYM @ 10 t ha^{-1} over a period of years compared to integrated and chemically fertilised plots, according to the data. When FYM amended treatment was applied at 10 t ha^{-1}, NPK + FYM @ 5 t ha^{-1}, and 75% NPK+ 25% N through FYM over RDF, HA-C values were 12.08%, 7.56%, and 4.35%, respectively. It serves as a direct supply of carbon due to its high lignin concentration, wide C:N ratio, and sluggish rate of breakdown, which requires additional deposition of roots, shoot biomass, root stalk, etc. Organic matter can stay in the soil for a very long time-hundreds to thousands of years-before it decomposes. The higher lignin and polyphenol contents of FYM provided a more resistant carbon complex, which may have increased the SOC living in the passive pool in the T_6 treatment as compared to the T_4 and T_5 treatments, according to Tian *et al.* (1992); Manna *et al.* (2013). Furthermore, a number of studies (Paustian *et al.*, 1992; Stevenson, 1982) demonstrated that materials with higher lignin content (FYM) result in a bigger accumulation per unit of C input than that of low lignin residue amendments.

C. Fulvic acid carbon (FA-C)

After the harvest of the wheat crop, data clearly showed that different progressive nutrient management practices had significant effect on the fulvic acid carbon content of the soil, ranging from 27.78 to 38.23%. It was followed by treatments with 100% NPK + FYM @ 5 t ha^{-1}, 75% NPK+25% N through FYM, and 150% NPK. Significantly, the maximum fulvic acid carbon (38.33%) was obtained with the application of FYM @ 10 t ha^{-1}. In contrast, the control therapy had the lowest FA-C value (26.51). The continual use of FYM as a source of carbon substrates discovered to have a substantial impact on the development of fulvic acid carbon may be the cause of the increase in FA-C. It has a significant impact on the physical, chemical, and biological characteristics of the soil, which promotes the growth of C and the accumulation of organic matter in the soil profile. It causes the recalcitrant percentage of passive pools to build up or become stabilized C-. These outcomes matched those that Singh *et al*. (2017) reported. Under long-term studies in India, Gathala *et al.* (2007) revealed that the combined use of organic manures and inorganic fertilizer produced higher fulvic acid in Vertic Ustopept and Typic Haplusteps, respectively.

From 50% to 150% NPK, or from sub-optimal to super-optimal levels of fertiliser application, the degree of FA-C enhancement increases. The large improvement in FA-C may be attributable to the extra growth and development of above- and below-ground biomass caused by greater doses of NPK incorporation which results in an accumulation of organic matter that contributes to the construction of passive C pool components. Similar findings were reported by Song *et al*., (2014), who noted an increase in HA-C and FA-C compared to the control as a result of the application of N fertilizer and manure. When compared to the RDF, the continuous, long-term unbalanced fertilization exhibited a drop in FA-C. The FA-C value with 100% N alone was significantly the lowest, and it was followed by 50% NPK and 100% NP. Similar findings were reported by Meshram *et al.* (2016), who also found that under nitrogen alone (100% N) and unfertilized treatments, there was a significant decrease in FA-C. This may have happened because crops had removed a lot of nutrients, leaving less crop residue and root biomass to contribute to the soil's organic matter, and there was no external source of organic carbon to provide nourishment.

Data show that the FYM amended treatment noted a considerable influenced on FA-C over the chemically fertilized plot. Significantly higher FA-C values of 17.24%, 13.00%, and 5.28% than the RDF of NPK were recorded by (T_{10}), (T_8) and (T_{11}). The development of FA-C was significantly impacted by the continuous application of a single FYM @ 10 t ha^{-1} under a sorghum wheat cropping sequence during a 33-year period. It entails the addition of root and shoots biomass, the recycling of agricultural leftovers as a source of organic matter, the provision of biological habitats for ecosystem functioning and ecosystem maintenance, and the formation of fulvic acid carbon following decomposition. The findings corroborated Bhoye*et al*., (2011) observation that fulvic acid in soil was greatly enhanced by the treatment of 10 t ha^{-1} fully decomposed FYM and 10 t ha^{-1} partially decomposed FYM with RDF.

D. Humin carbon

The information about humin carbon content is shown in Table 2. The findings show that progressive nutrient management practices have an impact on how much humin-C is present in soil. The treatment receiving only FYM @ 10 t ha^{-1}, comparable to 100% NPK together with FYM @ 5 t ha^{-1}, followed by 75% NPK + 25% N through FYM and 150% NPK, acquired the significantly highest humin carbon. The control treatment had the lowest value (6.98%), on the other hand. The humin carbon was significantly affected by the regular, long-term usage of unbalanced fertilization and the removal of nutrients from their fertilization schedule. Additionally, the lowest amount of humin carbon (7.16%) was found to be produced by 100% N alone, followed by 50% NPK and 100% NP. It can be the result of improper fertilizer application.

It generates an environment that is unfavorable for crop development and growth, emphasizing the significance of balanced NPK nutrient fertilization. When compared to RDF fertilizer, long-term manuring and fertilization over a 33-year period had a considerable impact on the accumulation of humin carbon. This is explained by the observation that biological habitats and ecosystem functions, as well as carbon levels, have significantly improved when solitary FYM @ 10 t ha^{-1} has been used as a source of nutrients and C substrates. It will support the preservation of biological variety, hence accelerating the slow mineralization and breakdown of organic matter and enriching refractory passive carbon stores. Humin is the most resistant component of SOC, and it contributes the most compared to the other components. Due to the warmer surface soil temperatures in tropical areas, the concentration of mineralization in the humin fraction increased (Santhy *et al*., 2001).

E. E_4/E_6 ratio of HA and FA

In comparison to treatments using inorganic replacements, the E_4/E_6 ratio of HA and FA showed significant differences. In comparison to treatments getting 100% NPK+FYM and 75% NPK+25% N through FYM, the treatment receiving sole FYM @ 10 t ha^{-1} showed the highest E_4/E_6 ratio (4.31) of humic and (6.52) fulvic acid. 33 years of research have shown that using organic manure (FYM) as a source of nutrients over a long period of time has a significant impact on the physical, chemical, and biological characteristics of soil. The process of root density, root exudates, and rhizospheric biomass aggregation and proliferation as C substrates for enhancing floral and faunal activities will be made easier. The E_4/E_6 ratio has been positively impacted by the continual use of 50% more NPK fertilizer over a 33-year period, which helps to maintain, improve, or resist long-term soil nutrient mining. The E_4/E_6 ratio observed at 150% NPK was higher than the ratios measured at 100% NPK through SSP and 100% NPK S free through (DAP). The E_4/E_6 ratio of HA and FA likewise consistently rises as the level of NPK fertilization increases. This might be because the conditions are right for excessive development and the accumulation of above- and below-ground biomass to raise the level of organic carbon. Fulvic acid was found to have a marginally higher E_4/E_6 ratio than humic acid, according to Satish and Devarajan (2011). A low level of aromatization and the presence of a comparatively high proportion of aliphatic structures in FAs are reflected in ratios of FAs that are considerably wider than those of HAs (Stevenson, 1994).

The highest ratio (4.02) among the treatments for unbalanced fertilization was found with 100% NP, followed by 50% NPK and 100% N alone. When P was added to N, the ratio significantly improved compared to 100% N alone, which is what was discovered to have the lowest ratio (P and K missing treatment). It may be caused by inconsistent cultivation and insufficient nutrient application, which create an unfavorable environment for growth and lead to the accumulation of crop leftovers as a source of OM. Results were consistent with what Sarma and Gogoi (2017) observed, with T_{100} scoring higher than T_{80} and T_{72} scoring significantly lower than both T100 and T_{80}. A larger extraction of aliphatic groups from N-fertilized soils than in control plots is shown by a higher E_4/E_6 ratio, which lowers SOC stability.

Table 1: Effect of long-term manuring and fertilization on grain and straw yield of wheat under sorghum-wheat cropping sequence.

Sr. No.	Treatments	Pooled Yield (q ha^{-1})	
		Wheat	
		Grain	Straw
T_1	50 % NPK	13.36	23.19
T_2	100 %NPK	20.34	34.24
T_3	150 %NPK	27.02	44.93
T_4	100 % NPK S free	18.89	31.63
T_5	100 %NPK + Zn @ 2.5 kg ha^{-1}	22.60	37.25
T_6	100 % NP	15.78	26.88
T_7	100 % N	6.51	11.35
T_8	100 % NPK+FYM@ 5 t ha^{-1}	30.36	51.17
T_9	100 %NPK +S @ 37.5 kg ha^{-1}	23.55	40.83
T_{10}	FYM @10 t ha^{-1}	12.33	21.85
T_{11}	75 % NPK + 25 % N through FYM	24.02	42.09
T_{12}	Control(No manures and fertilizer)	1.84	3.19
	SE m(±)	0.89	1.70
	CD at 5%	2.61	4.98

Table 2: Effect of long term manuring and fertilization on humic acid carbon, fulvic acid carbon and humin carbon under sorghum-wheat cropping sequence.

Treatments		Rabi wheat 2019-20 and 2020-21								
		HA-C (%)		Mean	FA-C (%)		Mean	H-C (%)		Mean
		2019-20	2020-21		2019-20	2020-21		2019-20	2020-21	
T_1	50 % NPK	46.05	46.16	46.11	30.74	30.85	30.79	7.68	7.73	7.71
T_2	100 %NPK	46.45	46.57	46.51	31.55	31.72	31.63	9.78	9.96	9.87
T_3	150 %NPK	47.64	47.75	47.70	31.58	31.93	31.75	10.13	10.22	10.17
T_4	100 % NPK S free	46.08	46.20	46.14	30.48	30.60	30.54	9.24	9.32	9.28
T_5	100 %NPK + Zn @ 2.5 kg ha^{-1}	47.06	47.21	47.13	31.57	31.72	31.64	9.87	9.95	9.91
T_6	100 % NP	45.61	45.70	45.65	29.25	29.34	29.29	7.71	7.76	7.73
T_7	100 % N	42.60	42.69	42.64	27.74	27.81	27.78	7.11	7.16	7.14
T_8	100 % NPK +FYM @ 5 t ha^{-1}	50.21	50.38	50.29	36.25	36.46	36.36	12.88	13.02	12.95
T_9	100 %NPK +S @ 37.5 kg ha^{-1}	47.16	47.30	47.23	31.02	31.18	31.10	9.79	9.85	9.82
T_{10}	FYM @10 t ha^{-1}	52.83	52.97	52.90	38.14	38.33	38.23	13.33	13.42	13.38
T_{11}	75 % NPK + 25 % N through FYM	48.61	48.69	48.65	33.42	33.49	33.46	12.12	12.18	12.15
T_{12}	Control	41.12	41.18	41.15	26.48	26.51	26.49	6.96	6.98	6.97
	SE m(±)	0.58	0.57	-	0.65	0.60	-	0.32	0.36	-
	CD at 5%	1.67	1.66	-	1.87	1.73	-	0.94	1.05	-

Table 3: Effect of long term manuring and fertilization on E_4/E_6 ratio of humic and fulvic acid under sorghum-wheat cropping sequence.

Treatment		E_4/E_6 ratio					
		Humic acid			Fulvic acid		
		2019-20	2020-21	Mean	2019-20	2020-21	Mean
T_1	50 % NPK	4.00	4.02	4.01	6.22	6.23	6.23
T_2	100 %NPK	4.06	4.08	4.07	6.33	6.35	6.34
T_3	150 %NPK	4.19	4.21	4.20	6.39	6.42	6.41
T_4	100 % NPK S free	4.10	4.11	4.11	6.23	6.25	6.24
T_5	100 %NPK + Zn @ 2.5 kg ha $^{-1}$	4.13	4.15	4.14	6.33	6.34	6.34
T_6	100 % NP	4.06	4.07	4.07	6.23	6.24	6.24
T_7	100 % N	4.01	4.02	4.02	6.11	6.11	6.11
T_8	100 % NPK +FYM@ 5 t ha $^{-1}$	4.24	4.27	4.26	6.46	6.48	6.47
T_9	100 %NPK +S @37.5 kg ha $^{-1}$	4.16	4.18	4.17	6.35	6.37	6.36
T_{10}	FYM @10 t ha $^{-1}$	4.28	4.31	4.30	6.50	6.52	6.51
T_{11}	75 % NPK + 25 % N through FYM	4.25	4.27	4.26	6.41	6.42	6.42
T_{12}	Control	3.93	3.93	3.93	6.12	6.12	6.12
	SE m(±)	0.035	0.039	-	0.023	0.026	-
	CD at 5%	0.102	0.114	-	0.068	0.077	-

CONCLUSIONS

From the present investigation, it can be concluded that, long term use of FYM alone or along with inorganic fertilizers enhanced the passive pools of carbon *viz*., humic acid, fulvic acid, and humin. Therefore, the balanced application of NPK fertilizers with FYM was the best choice for crop production of the wheat crop. Research on spectral characteristics, such as E_4/E_6 ratios, showed that humic acid has narrower ratios than fulvic acid.

Acknowledgment. The author of present study are thankful to the Professor and Head, department of Soil Science and Agricultural chemistry; Associate Dean, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and In charge Long Term Fertilizer Experiment, for providing guidance and necessary facilities for successful completion of present study.
Conflicts of Interest. None.

REFERENCES

Bhoye, K. P., W. P. Badole, Shete, P. G. and Baviskar, V. S. (2011). Influence of partially and fully decomposed FYM on humic, fulvic acid, microbial count in soil and yield of sorghum. *Green Farming*, *2*, 309-311.

Chen, Y., Senesi, N. and Schnitzer, M. (1977). Information provided on humic substances by E_4/E_6 ratios. *Soil Sci. Soc. of Am. J.*, *41*, 352–358.

Galantini, J. and Rosell, R. (2006). Long-term fertilization effects on soil organic matter quality and dynamics under different production systems in semiarid Pampean soils. *Soil and Tillage Res.*, *87*, 72-79.

Galantini, J. A., Duval, M. E., Iglesias, J. O. and Kruger, H. (2014). Continuous wheat in semiarid regions: Long-term effects on stock and quality of soil organic carbon. *Soil Science*, *179*, 284–292.

Gathala, M. K., Kanthaliya, P. C.,Verma, A. and Chahar, M. S. (2007). Effect of integrated nutrient management on soil properties and humus fractions in the long-term fertilizer experiments. *J. Indian Soc. Soil Sci.*, *55*, 360-363.

Katkar, R. N., Sonune, B. A. and Kadu, P. R. (2011). Long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum (*Sorghum bicolor*)– wheat (*Triticum aestivum*) system in Vertisol. *Indian J. of Agri. Sci*., *81* (8), 734–739.

Kononova, M. M. (1966). Soil organic matter. Its nature, its role in the formation and soil fertility. Pub. Izd. Akad Newk, USSR, Moscow.

Mahapatara, P., Singh, R. P., Singh, B. P., Mishra, B. and Sarkar, A. K. (2007). Long-term effect of fertilizer, organic manure, and amendments on soil health, crop productivity and sustainability. *Soil Sci. and Agricultural Chemistry, Technical Bulletin*, *4*, 1–75.

Manna, M. C., Jha, P., Lakaria, B. and Rao, S. A. (2013). Soil Organic Matter under different bago-climatic regions of India. Scientific bulletin. IISS. Bhopal, 1-87.

Mehta, Y. K., Shaktawat, M. S. and Singhi, S. M. (2005). Influence of sulphur, phosphorus and FYM on yield attributes and yield of maize (*Zea maize*) in Southern Rajasthan condition. *Indian J. Agronomy*, *50* (3), 203-205.

Meshram, N. A., Ismail Syed and Patil, V. D. (2016). Long-Term Effect of Organic Manuring and Inorganic Fertilization on Humus Fractionation, Microbial Community and Enzymes Assay in Vertisol. *J. Pure and App. Micro*., *10*(1), 139-150.

Novotny, E. H., Blum,W. E. H., Gerzabek, M. H. and Mangrich. A. S. (1999). Soil management system effects on size fractionated humic substances. Geoderma, *92*, 87–109.

Nziguheba, G., Tossah, B. K., Diels, J., Franke, A. C., Aihou, K., Iwuafor, E. N. O., Nwoke, C. and Merckx. R. (2009). Assessment of nutrient deficiencies in maize in nutrient omission trials and long-term field experiments in the West African Savanna. *Plant and Soil*, *314* (1–2), 143–157.

Paustian,K, Parton W. J. and Persson, J. (1992). Modeling soil organic matter in organic-amended and nitrogen-fertilized long-term plots. *Soil Sci. Soc. Am. J*., *56*, 476–488.

Ram, S., Singh, V. and Sirari, P. (2016). Effects of 41 years of application of inorganic fertilizers and farm yard manure on crop yields, soil quality, and sustainable yield index under a rice-wheat system on Mollisols of North India. *Commun. Soil Sci. Plant Anal.*, *47*(2), 179-193.

Santhy, P., Muthvel, P. and Selvi, D. (2001). Status and Impact of Organic Matter Fractions on yield, uptake and available nutrients in a long term fertilizer experiment. *J. Indian Soc. Soil Sci.*, *49*(2), 281-285.

Sarma, B. and Gogoi, N. (2017). Nitrogen Management for sustainable soil organic carbon increase in inceptisols under wheat cultivation. *Commun. Soil Sci. and Plant Analysis*, *48*(12), 1428-1437.

Satisha, G. C. and Devarajan, L. (2011). Composition and characterization of humic substances extracted from effluent-based pressmud composts. *Agropedology, 21*(1), 8-17.

Sawarkar, S. D., Khamparia, N. K. Thakur, R., Dewda, M. S. and Singh, M. (2013). Effect of long-term application of inorganic fertilizers and organic manures on yield, potassium uptake and profile distribution of potassium fractions in Vertisol under Soybean- wheat cropping system. *J. Indian Soc. Soil Sci*., *61*(2), 94-98.

Schnitzer, M. and Khan, S. U. (1972). Humic Substances in the Environment. Marcel – Dekker, New York.

Senesi, N., Plaza, C., Brunetti, G. and Polo, A. (2007). A comparative survey of recent results on humic-like fractions in organic amendments and effects on native soil humic substances. *Soil Biology and Biochemistry*, *39*, 1244-1262.

Sharanbhoopal, R., Nagaraja, M. S., Punith Raj, T. S., Police Patil, A. S. and Dhumgond, P. (2014). Elemental analysis, E_4/ E_6 ratio, and total acidity of soil humic and fulvic acids from different land use systems. *Annals of Plant and Soil Research, 16*, 89–92.

Singh, D. K., Pandey, P., Nanda G. and Gupta, S. (2018). Long-term effects of inorganic fertilizer and farmyard manure application on productivity, sustainability and profitability of rice-wheat system in Mollisols. *Archi. of Agro. and Soil Sci., 65*(2), 139-151.

Singh, D., Sharma, R. P., Sankhyan, N. K. and Meena, S. C. (2017). Influence of long-term application of chemical fertilizers and soil amendments on physicochemical soil quality indicators and crop yield under maize wheat cropping system in an acid alfisol. *J. of Pharma. Phyto*., *6*, 198–204.

Singh, Y. V. and Dhar, D. W. (2012). Changes in soil organic carbon and microbialpopulation under organically managed rice (*Oryza sativa*) wheat (*Triticum aestivum*) crop rotation. *J. Indian Soc. Soil Sci*., *79,* 94-100.

Smith, J. L. and Paul, E. A. (1990). The significance of soil microbial biomass estimations. In Soil biology, ed. J.M. Bollagand G. Stotzuy., *6*, 357, New York. Marcel Dekker.

Song, X., Liu, S., Liu, Q., Zhang, W. and Hu, C. (2014). Carbon sequestration in soil humic substances under long-term fertilization in a wheat-maize system from North China. *J. of Integrative Agric*., *13*(3), 562–569.

Srilatha, M., Sharma, S. H. K. Devi, Uma, M. and Rakha, K. B. (2014). Grain yield and soil nutrient status of rice-rice cropping system as influenced by nutrient management under long-term fertilizer experimentation. *J. of Progressive Agri.*, *5*(1), 85-89.

Srilatha, M., Rao, P. C., Sharma, S. H. K. and Rekha, K. B. (2013). Influence of long-term fertilizer application on soil phosphatase enzyme activity and nutrient availability in rice – rice cropping system. *J. of Rice Res*., *6*(2), 45-52.

Srivastava, P. K., Maruthi Sankar, G. R., Vijaya, K. P., Singh, S. P., Rani, N., Singh, A. and Agarwal, V. K. (2015). Effects of organic and inorganic fertilizers on soil and plant nutrients and yields of pearl millet and wheat under semi-arid Inceptisols in India. *Commun. Soil Sci. and Plant Analysis*, *46,* 2595-2614.

Stevenson, F. J. (1982). Humus chemistry: Genesis, composition, reactions. New York, USA: Wiley.

Stevenson, F. J. (1994). Humus Chemistry, Genesis, Composition, Reactions. Second edition. John Wiley and Sons. New York 196.

Suresh, M, Jayasree, G., Srilatha, M., Reddy, S. N. and Reddy, G. K. (2017). Effect of Long Term Fertilizers and Organic Manures on Soil Quality and Sustainability Yield Index in Rice - Rice Cropping System. *Intr. J. Pure App. Biosci*., *5*(4), 1760-1769.

Tian, G., Kang, B. T. and Brussaard, T. (1992). Biological effects of plant residues with contrasting chemical compositions under humid tropical conditions – decomposition and nutrient release. *Soil Biol. Biochem*., *24,* 1051–1060.

Walkley, A. J. and Black, I. A. (1934). Estimation of soil organic carbon by the chromic acid titration method. Soil Science, *37,* 29-38.

How to cite this article: P.H. Rathod, S.M. Bhoyar, S.D. Jadhao, P.W. Deshmukh, G.S. Lahariya and A.B. Aage (2023). Effect of Long-term Manuring and Fertilization on Passive pools of Carbon under Sorghum Wheat Sequence Cropping in Vertisols. *Biological Forum – An International Journal, 15*(5): 1194-1200.