



# Impact of Organic Additives on Soil Organic Carbon and Enzyme Activities in Intensive Ginger Agro-ecosystems

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## Authors' contributions

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

## Article Information

DOI: <https://doi.org/10.9734/ijpss/2025/v37i65515>

## Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://pr.sdiarticle5.com/review-history/136662>

Original Research Article

Received: 25/03/2025

Accepted: 29/05/2025

Published: 12/06/2025

## ABSTRACT

Organic manure is a good source of nutrients, which enhances soil productivity, increases the soil organic carbon content, enhances the activities of soil microorganisms, and supplies major plant nutrients. Nutrient management is one of the key determinants of crop production. Variability in nutrient additions through fertilisers and organic manures appears to be an influencing factor on soil fertility status and ginger productivity. This study was conducted to assess different magnitudes of organic and inorganic nutrient inputs on soil carbon stock and soil enzyme activities. A survey-based study was conducted. The data obtained was subjected to one-way ANOVA using Excel software version of Windows MS Office -2007. In the Banavasi area of Uttara Kannada, Ginger

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**Cite as:** V. J., Poornima, Shivakumar, K. M., Manukumar H. R., Nagaraja M. S., Yogeeshappa H., and Shankar Meti. 2025. "Impact of Organic Additives on Soil Organic Carbon and Enzyme Activities in Intensive Ginger Agro-Ecosystems". *International Journal of Plant & Soil Science* 37 (6):349-60. <https://doi.org/10.9734/ijpss/2025/v37i65515>.

farmers adopted different nutrient management practices in ginger cultivation were grouped into Local Farmers-1: High OM and High Fertilisers, Local Farmers-2: Low OM and Moderately High Fertilisers and Migrated Farmers: Very Low OM and Very High Fertilisers. Soil samples were collected at two sampling depths (0-15 cm and 15-30 cm) in three groups of ginger farmers' fields. The mean rainfall of this region is 2500 mm, with up to 103 rainy days in a year. Annually, this region has 25 hot days with temperatures more than 35° C and 124 warm days ranging 30-35° C and remains below 35° C during the rest of the year for about 214 days. The soil organic carbon content was higher in soils of Local Farmers-1 compared to Local Farmers-2: Low OM and Moderately High Fertilizers and Migrated Farmers: Very Low OM and Very High Fertilizers thus, the study revealed that application of organic manures in intensively managed ginger production systems helps to enhance soil carbon stocks and maintain soil biological activities.

**Keywords:** Organic manures; fertilizer; ginger production; soil-c stocks; urease; phosphatase; dehydrogenase.

## 1. INTRODUCTION

Ginger (*Zingiber officinale*) is an important commercial spice crop and has also long been used as a medicinal plant. It is a perennial herb member of the *Zingiberaceae* family, and its thick tuberous rhizomes are very popular for medicinal uses and as a spice and additive agent for flavouring foods and drinks (Arcusa et al., 2022). Especially, the fresh and dry rhizomes of ginger are widely used in folk medicine for the treatment of colds, sore throats, asthma, joint pain, and also to stimulate appetite (Egamberdieva & Jabborova, 2018). As a spice, ginger is one of the most widely used condiments for various foods and beverages (Jabborova et al., 2021). Further, ginger extracts from both fresh and dried rhizomes are used extensively in the food, beverage, and confectionery industries (Jabborova & Egamberdieva, 2019). In terms of mineral nutrients, the rhizome is rich in calcium, phosphorus and potassium. Ginger cultivation is expanding throughout the world as its demand is spreading for medicinal and beverage industries are increasing. (Asfaw & Demissew, 2009). India is the largest producer, consumer and exporter of ginger (Srinivasan et al. 2019). Our country accounts for almost 30 per cent of the world's total ginger production (Singh et al. 2015). In Karnataka, it is grown in an area of 23.09 thousand hectares with an annual production of 58.39 thousand metric tonnes.

Nutrient management is essential in achieving the best growth and productivity in any crop (Srinivasan et al. 2019). Nutrient management is essential in achieving the best growth and productivity in ginger, in addition to soil type. Because it is a crop that exhausts nutrients, it needs a sufficient supply during key growth

periods (Prasath et al., 2024; Ravi et al., 2022). A good nutrient management practice not only sustains crop production but also helps to improve soil health and enhance nutrient use efficiency (Dinesh et al. 2012). The productivity of ginger is affected due to poor nutrient management (Dinesh et al., 2012a), as it is a nutrient-exhaustive crop and therefore requires an adequate supply of nutrients at specific stages of its growth (Weiss, 1997). Inappropriate agricultural intensification coupled with reckless use of fertilisers can deteriorate soil quality in terms of soil physicochemical and biological properties (Lal, 2015). Injudicious use of fertilisers can damage the natural ecosystem and cause soil and water pollution (Pathak & Ram, 2013).

Soil structure plays a pivotal role in determining the overall productivity and sustainability of agricultural systems (Ramasamy et al., 2024). In this context, Organic manure is a good source of nutrients which enhances soil productivity, increases the soil organic carbon content, enhances the activities of soil microorganisms and supplies major plant nutrients (Sanchez & Miller, 1986). Further, Organic practices increase the soil carbon content and the overall biological activities (Bai et al. 2019). Even organic wastes from different sources can be used to improve soil fertility and productivity (Palm et al. 2001). The organic manure feeds both plants and the soil microorganisms simultaneously and thus, enhances soil health and its quality, leading to overall improvement of the agroecosystem. Exclusive use of fertilisers can significantly reduce microbial activity (as measured by dehydrogenase, acid phosphatase and other enzymes (Parham et al. 2002; Ning et al. 2017).

The biochemical properties are more sensitive to environmental stress and provide rapid and

accurate estimates of soil quality. These soil biochemical parameters have been considered as potential indicators of soil quality (Nannipieri *et al.* 2002). Application of organic manures helps to improve soil structure, soil moisture retention, and available water content and reduce bulk density. Enhancing SOC through organics is crucial for both sustaining intensive production as well as mitigating greenhouse gases (GHGs). However, there are or no little efforts on the influence of the combined use of organics and inorganics and their influence on soil-C stocks and soil enzymes at the farmer's field. Thus, a survey-based study was carried out to assess the magnitude of organic and inorganic inputs application on soil organic carbon stocks and soil enzyme activities in soils cropped with ginger.

## 2. MATERIALS AND METHODS

### 2.1 General Description of the Study Area

Ginger is widely grown in the Hilly zone of Karnataka, where the soils mostly belong to alfisols and oxisols, having slightly acidic, medium-textured and well-drained soil conditions. Thus, these regions provide optimum conditions for ginger cultivation. In Karnataka, ginger is widely grown in Shivamogga, Chikkamagaluru, Uttara Kannada, Udupi and Mysuru districts. In the Uttara Kannada district, the Ginger farmers are spread over a large area. However, the study was restricted to the Banavasi region of Uttara Kannada district the mean rainfall of this region is 2500 mm, with up to 103 rainy days in a year. Annually, this region has 25 hot days with temperatures more than 35° C and 124 warm days ranging 30-35° C and remains below 35° C during the rest of the year for about 214 days

### 2.2 Selection and Categorisation of Ginger Farmers

An initial survey was carried out in the study areas to identify the farmers involved in ginger cultivation. During the survey, the information on yield and proper nutrient management practices adopted was collected. It was interesting to note that the rhizome yield varied from as high as 30-35 tonnes ha<sup>-1</sup> in high nutrient applied fields to as low as 15-18 tonnes ha<sup>-1</sup> in low nutrient applied plots. Nutrient management appeared to be a key factor in determining the productivity compared to other management practices such as seed material, irrigation schedules and plant

care measures. Thus, based on the organic manures and fertilisers applied, the farmers were grouped as Local Farmers-1: High organic manures and high fertilisers (G<sub>1</sub>), Local Farmers-2: Low organic manures and moderately high fertilizers (G<sub>2</sub>), Migrated Farmers: Very low organic manures and very high fertilizers (G<sub>3</sub>). and the details are given in Table 1.

### 2.3 Soil Sample Collection

The soil samples were collected from each of the selected ginger fields (15 farmers) at two depths (0-15 cm and 15-30 cm) after the harvest of the crop during January-February 2020. At each location, the samples were collected at 8-10 spots and pooled to get one composite sample, and the collected soil samples were dried in the shade, powdered and then sieved through a 2 mm sieve.

### 2.4 Soil C Stocks Assessment

**Soil organic carbon:** The soil organic carbon was determined by the wet oxidation method (Walkley & Black, 1934). A known weight of 0.2 mm sieved soil sample was treated with an excess volume of standard potassium dichromate solution in 500 ml conical flasks, and 25 ml of concentrated sulphuric acid was added. The soil suspension was kept undisturbed for 30 minutes. The unused potassium dichromate was determined by back titration using standard ferrous ammonium sulphate solution in the presence of ferroin indicator. The soil organic carbon contents were expressed in per cent.

**Soil carbon stock:** Carbon stock for a given soil layer was estimated by multiplying the soil organic carbon content by the corresponding soil bulk density of that particular layer (Batjes, 1996). The total soil carbon stock was estimated by using the formula as given below.

Carbon stock (t ha<sup>-1</sup>) = Volume of soil in ha x Soil BD x SOC

**Soil enzyme analysis:** The stored soil samples were pre-incubated at 25 °C for 2 days, after adjusting the soil moisture content to field capacity, to rejuvenate soil biological activity. These pre-incubated soils were analysed for dehydrogenase, acid phosphatase and urease enzyme activities. The dehydrogenase activity was determined by incubating soil samples at 37 °C with 3 per cent of 2, 3, 5- 5-triphenyl

**Table 1. Categorization of ginger farmers based on the nutrients applications**

Group of Ginger farmers	Organic manures used (t ha <sup>-1</sup> )	Nutrients through fertilizers (kg ha <sup>-1</sup> )		
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
<b>G<sub>1</sub>: Local Farmers -1 (High OM + High Fertilizer)</b>	27.41 ± 2.78	101.52 ± 32.92	75.17 ± 15.44	80.19± 8.02
<b>G<sub>2</sub>: Local Farmers -2 (Low OM + Mod. High Fertilizer)</b>	15.65 ± 2.55	134.45± 21.67	122.76± 21.57	151.65 ± 18.06
<b>G<sub>3</sub>: Migrated Farmers (Very Low OM + Very High Fertilizer)</b>	11.65 ± 1.77	198.80± 9.34	162.22± 8.24	195.25 ±13.87

*NOTE: The recommended dose of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O nutrients for ginger is-100:50:50 kg ha<sup>-1</sup> and 25 t ha<sup>-1</sup> FYM*

tetrazolium chloride (TTC) aqueous solution. The amounts of triphenyl formazon (TPF) formed were extracted with methanol and measured at 485 nm (Casida et al. 1964).

The acid phosphatase activity was determined by the *p*-Nitrophenol Phosphate (*p*-NPP) method (Eivazi & Tabatabai 1977). A known weight of the soil sample (< 2 mm) was incubated with four ml of modified universal buffer (pH 6.5 for any assay of acid phosphatase). One ml of *p*-NPP solution (as substrate) and 0.2 ml of toluene (to suppress further microbial activity). After one hour, the *p*-nitrophenol (*p*-NP) formed in the supernatant was extracted by centrifugation and the intensity of yellow colour was measured at 420 nm.

For the urease enzyme, the soil samples (2mm) were incubated with urea and citrate buffer solution for three hours at 37 °C. The soils were extracted and the amount of ammonia produced was measured colourimetrically by the phenate-NaOCl method (Hofmann, 1963).

## 2.5 Statistical Analysis

The data obtained was subjected to one-way ANOVA. using Excel software version of Windows MS Office -2007.

## 3. RESULTS AND DISCUSSION

### 3.1 Soil Carbon Stock

The soil carbon stock of ginger farmers' fields soil samples was estimated by multiplying the SOC content with the corresponding BD based soil mass in the top 30 cm layer of a 1 ha area.

### 3.2 Soil Organic Carbon

The application of organic manures significantly influenced the SOC content, and it ranged from 0.77 to 1.33 per cent. The soil organic carbon content in surface soils was found significantly higher in fields of local farmers-1 ( $1.33 \pm 0.08$  %) compared to local farmers-2 ( $0.82 \pm 0.06$  %) and migrated farmers ( $0.77 \pm 0.10$  %). The soil OC content was found to be substantially lower in sub-surface soils compared to surface soils. The corresponding organic carbon content in sub-surface soils was  $1.08 \pm 0.05$  per cent,  $0.50 \pm 0.07$  per cent and  $0.46 \pm 0.06$  per cent in local farmers- 1, local farmers- 2 and migrated farmers, respectively. However, the carbon content in the soils of local farmer-1 was found

to be significantly higher compared to the other two groups.

The variations in SOC among different ginger growers may be attributed to additions of different levels of organic manure (Niranjana *et al.* 2018). The quality of organic matter is also an important factor in any ecosystem (Dattaraja *et al.* 2018). As its additions determine the soil organic matter content (Grewal *et al.*,1981 and Kaushik *et al.*,1984). The surface soils recorded higher soil organic carbon content compared to sub-surface soils. This was due to the various carbon input distributions in terms of root biomass, root exudates, rhizospheric deposition, followed by slow decomposition due to poor oxygenic conditions for microbial oxidation at deeper soil layers. The results are consistent with the findings of Padbhushan *et al.* (2016) and Mahanta *et al.* (2013). Further, the upper layer remains in dynamic equilibrium with biological and anthropological activities and thus is generally richer in C than the lower layers.

### 3.3 Soil Bulk Density

The bulk densities of surface soils were significantly higher in migrated farmers ( $1.24 \pm 0.07$  Mg m<sup>-3</sup>) compared to soils of local farmers-2 group ( $1.19 \pm 0.03$  Mg m<sup>-3</sup>) and soils of local farmers-1 group ( $1.15 \pm 0.07$  Mg m<sup>-3</sup>). Similarly, the bulk density values in sub surface soils were found to be higher than surface soils with respective values ranging from  $1.29 \pm 0.06$  Mg m<sup>-3</sup>,  $1.24 \pm 0.04$  Mg m<sup>-3</sup> and  $1.22 \pm 0.04$  Mg m<sup>-3</sup> among migrated farmers, local farmers-2 and local farmers-1 respectively (Table 2). The variation in bulk density among three groups of ginger growers could be attributed to the differences in organic manure applications. The organic matter addition improves soil structure, pore size distribution and soil water transmission (Srikanth *et al.*, 2000). The low bulk density values in soils of local farmers-1 may be attributed to better soil structure as a result of higher organic inputs (Sharma *et al.*, 2001). The soil organic carbon content among different groups was in concurrence with these observations. Lower bulk density in surface soils may be due to loosening of soils during ginger harvest by manual hand tools and machines would have reduced soil bulk density (Bhavya *et al.*, 2018). On the otherhand, Higher bulk density in sub-surface soils might be due to compaction as a result of the pressure exerted by the upper layers (Patil & Jagdish, 2004). It may also be due to the fact that the organic matter is mostly

added to the surface layers and only a small portion of it would reach the sub-surface layers (Tejada *et al.*, 2008 and Nagaraja, 1997).

### 3.4 Soil Carbon Stock

Soil carbon stock was found highest in Local Farmers-1 and in surface ( $23.17 \pm 1.60 \text{ t ha}^{-1}$ ) and sub surface ( $18.14 \pm 2.03 \text{ t ha}^{-1}$ ) soils respectively) and least was noted in migrated farmers in surface ( $03.62 \pm 1.68 \text{ t ha}^{-1}$ ) and sub surface ( $6.67 \pm 1.70 \text{ t ha}^{-1}$ ) soils respectively. The C stock at 0-15 cm depth was higher in surface soil compared to sub-surface soils. However, the total carbon stock at 0-30 cm soil depth among different ginger grown soils varied significantly in the order Local Farmers-1 ( $41.30 \pm 3.39 \text{ t ha}^{-1}$ ) > Local Farmer-2 ( $23.26 \pm 3.06 \text{ t ha}^{-1}$ ) > Migrated Farmers ( $20.08 \pm 3.21 \text{ t ha}^{-1}$ ). 57. Table 3.

The variation in soil carbon stocks in different soils might be due to the application of organic manure. The organic manure additions contribute to enhanced soil organic carbon contents. Similar results were observed in studies conducted by Roy *et al.* (2007) and Dattaraja *et al.* (2018). However, soil carbon stocks were higher in surface soils compared to sub-surface soils This might be due to the direct relation between the organic carbon and soil carbon stocks, therefore, soil carbon stocks also follow the same trend of organic carbon, it decrease with increasing depth (Balloli *et al.*, 2007).

### 3.5 Soil Enzymatic Activities

Soil enzymatic activities and Biochemical parameters are considered to be very sensitive indicators of both short-term and long-term changes in soil quality.

### 3.6 Urease Enzyme Activity

Urease activities are involved in the hydrolysis of urea in the soil. Among the different groups, urease activity was significantly higher in migrated farmers' fields with an activity of  $132.81 \pm 8.59 \mu\text{g NH}_4^+$  released  $\text{g}^{-1}$  soil  $\text{hr}^{-1}$  in surface and  $90.56 \pm 9.67 \mu\text{g NH}_4^+$  released  $\text{g}^{-1}$  soil  $\text{hr}^{-1}$  sub-surface soils, respectively. Contrastingly, fields of local farmers recorded least with values of  $112.97 \pm 6.26$  and  $83.06 \pm 4.27 \mu\text{g NH}_4^+$  released  $\text{g}^{-1}$  soil  $\text{hr}^{-1}$  in surface and sub-surface soils. Higher urease activity in migrated farmers' fields may be due to high use of fertiliser inputs,

including urea. which promoted the urease activity (Shen *et al.*, 2010). The application of both organic manure and fertilisers appears to be substantial in ginger cultivation, which consequently resulted in high urease activity (Sharan *et al.*, 2020). In addition, Urease enzyme activity was higher in surface soils than sub-surface soils. The higher soil organic carbon content and available-N in ginger cultivated soils studied would further strengthen these observations. Lesser urease activity in sub-surface layers might be due to the fact that application of organic manures and fertilisers is confined to the surface layer (Rao *et al.*, 1989).

### 3.7 Dehydrogenase Activity

Dehydrogenase enzyme is used as an index of soil biological activity and is expressed in  $\mu\text{g TPF g}^{-1}$  of soil  $\text{day}^{-1}$ . Its activity was found to be significantly higher in ginger soils of local farmers ( $15.21 \pm 2.92 \mu\text{g TPF g}^{-1}$  of soil  $\text{day}^{-1}$  and  $9.30 \pm 0.40 \mu\text{g TPF g}^{-1}$  of soil  $\text{day}^{-1}$  in surface and sub surface soils, respectively) while the least was noticed in soils of migrated farmers ( $9.12 \pm 2.81$  and  $6.73 \pm 1.73 \mu\text{g TPF g}^{-1}$  of soil  $\text{day}^{-1}$  in surface and sub surface soils, respectively). The dehydrogenase activity was found to be higher in surface soils than sub-surface soils. Higher dehydrogenase activity in plots of local farmers may be due to high application of organic manure. Thus, the addition of organic manures enhances overall biological activity and is generally measured in terms of dehydrogenase (Martens *et al.*, 1992). Whereas, the enzymatic activity is low in migrated farmers who applied the highest fertiliser inputs might be due to the reason that mineral fertilisation had weaker effects on dehydrogenase activity as compared to organic manuring (Shen *et al.*, 2010). The organic manure additions, soil organic carbon contents and dehydrogenase activities are in concurrence with the above observations. Decreased enzymatic activity in the sub-surface layer with low soil organic matter may be attributed to an increase in soil depth, and lower organic matter content further strengthens the role of soil organic matter. Similar reports are made by several authors (Nagaraja, 1997; Shivakumar, 2010; Sharan *et al.*, 2020; and Dinesh *et al.*, 2010).

### 3.8 Acid Phosphatase Enzyme Activity

The phosphatase activity in soils of ginger different growers are presented Table 4 The

**Table 2. Soil organic carbon and Bulk density in soils of different groups of ginger fields**

Groups of ginger farmers	Soil organic carbon (%)		Bulk density (Mg m <sup>-3</sup> )	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
<b>G<sub>1</sub>: Local Farmers -1 (High OM + High Fertilizers)</b>	1.33 ± 0.08 <sup>a</sup>	1.08 ± 0.05 <sup>a</sup>	1.15 ± 0.07 <sup>b</sup>	1.22 ± 0.04 <sup>b</sup>
<b>G<sub>2</sub>: Local Farmers -2 (Low OM + Mod. High Fertilizers)</b>	0.82 ± 0.06 <sup>b</sup>	0.50 ± 0.07 <sup>b</sup>	1.19 ± 0.03 <sup>b</sup>	1.24 ± 0.04 <sup>b</sup>
<b>G<sub>3</sub>: Migrated Farmers (Very Low OM + Very High Fertilizers)</b>	0.77 ± 0.10 <sup>b</sup>	0.46 ± 0.06 <sup>b</sup>	1.24 ± 0.07 <sup>a</sup>	1.29 ± 0.06 <sup>a</sup>
<b>S. Em. ±</b>	0.02	0.03	0.019	0.016
<b>CD (p=0.05)</b>	0.07	0.09	0.05	0.04

*Note: The extent of significant differences among 3 groups for each parameter is indicated by using alphabets*

**Table 3. Soil carbon stock in soils of different groups of ginger farmer fields**

Groups of ginger farmers	Carbon stock (t ha <sup>-1</sup> )		Total carbon stock (t ha <sup>-1</sup> )
	0-15 cm	15-30 cm	0-30 cm
<b>G<sub>1</sub>: Local Farmers -1 (High OM + High Fertilizers)</b>	23.17 ± 1.60 <sup>a</sup>	18.14 ± 2.03 <sup>a</sup>	41.30 ± 3.39 <sup>a</sup>
<b>G<sub>2</sub>: Local Farmers -2 (Low OM + Mod. High Fertilizers)</b>	14.84 ± 1.32 <sup>b</sup>	8.42 ± 2.01 <sup>a</sup>	23.26 ± 3.06 <sup>b</sup>
<b>G<sub>3</sub>: Migrated Farmers (Very Low OM + Very High Fertilizers)</b>	13.62 ± 1.68 <sup>b</sup>	6.67 ± 1.70 <sup>b</sup>	20.28 ± 3.21 <sup>c</sup>
<b>S. Em. ±</b>	0.48	0.60	1.02
<b>CD (p=0.05)</b>	1.42	1.77	2.97

*Note: The extent of significant differences among 3 groups for each parameter is indicated by using alphabets*

**Table 4. Soil enzymatic activities under different ginger fields**

Groups of ginger farmers	Urease ( $\mu\text{g NH}_4^+$ released $\text{g}^{-1}$ soil $\text{hr}^{-1}$ )		Dehydrogenase ( $\mu\text{g TPF g}^{-1}$ of soil $\text{day}^{-1}$ )		Acid phosphatase ( $\mu\text{g PNP g}^{-1}$ of soil $\text{hr}^{-1}$ )	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
<b>G<sub>1</sub>: Local Farmers -1 (High OM + High Fertilizers)</b>	112.97 $\pm$ 6.26 <sup>b</sup>	83.06 $\pm$ 4.27 <sup>a</sup>	15.21 $\pm$ 2.92 <sup>a</sup>	9.30 $\pm$ 0.40 <sup>a</sup>	22.38 $\pm$ 2.23 <sup>a</sup>	11.45 $\pm$ 1.70 <sup>a</sup>
<b>G<sub>2</sub>: Local Farmers -2 (Low OM + Mod. High Fertilizers)</b>	129.83 $\pm$ 9.53 <sup>a</sup>	85.49 $\pm$ 6.68 <sup>a</sup>	11.29 $\pm$ 2.01 <sup>b</sup>	6.90 $\pm$ 1.78 <sup>b</sup>	17.52 $\pm$ 3.08 <sup>b</sup>	9.34 $\pm$ 0.53 <sup>b</sup>
<b>G<sub>3</sub>: Migrated Farmers (Very Low OM + Very High Fertilizers)</b>	132.81 $\pm$ 8.59 <sup>a</sup>	90.56 $\pm$ 9.67 <sup>a</sup>	9.12 $\pm$ 2.81 <sup>b</sup>	6.73 $\pm$ 1.73 <sup>b</sup>	15.45 $\pm$ 3.91 <sup>b</sup>	8.83 $\pm$ 0.49 <sup>b</sup>
<b>S. Em. <math>\pm</math></b>	2.60	2.28	0.82	0.46	0.99	0.33
<b>CD (p=0.05)</b>	7.61	NS	2.41	1.34	2.91	0.98

*Note: The extent of significant differences among 3 groups for each parameter is indicated by using alphabets*

activity was found significantly higher in local farmers-1 ( $22.38 \pm 2.23 \mu\text{g PNP g}^{-1}$  of soil  $\text{hr}^{-1}$  and  $11.45 \pm 1.70 \mu\text{g PNP g}^{-1}$  of soil  $\text{hr}^{-1}$  in surface and sub surface soils respectively) while least activity was found in migrated farmers ( $15.45 \pm 3.91 \mu\text{g PNP g}^{-1}$  of soil  $\text{hr}^{-1}$  and  $8.83 \pm 0.49 \mu\text{g PNP g}^{-1}$  of soil  $\text{hr}^{-1}$ ). However, phosphatase activity was higher in surface soils compared to sub-surface soils. Higher enzymatic activity in local farmer-1 fields could be due to the fact that the phosphatase activity is generally higher in organically amended soils. The phosphatase activity and organic carbon were positively correlated in the present study also suggesting that that organic matter significantly increases the phosphatase activity in soil and the results are in accordance with that of Dick (1994) and Tabatabai (1984). Least activity was noticed in soils of migrated farmers which could be attributed to marked suppression in phosphatase activity due to P fertilization (Wang et al., 2008). However, the decrease in enzymatic activity in sub-surface soils may be attributed to lower organic matter content (Dinesh et al., 2010).

#### 4. CONCLUSION

It was observed from the present study that the soils of the group-1 ginger growing farmers with high organic manure additions recorded higher soil carbon stock compared to low organic manure added ginger fields belonging to group-2 and group-3 farmers. In terms of biological activity, the activity of dehydrogenase, and acid phosphatase enzymes increased with an increase in organic manure applications. Thus, the addition of organic manure plays a crucial role in maintaining soil health and soil biological properties.

#### ACKNOWLEDGEMENT

The authors acknowledge the Dept. of Soil Science, College of Horticulture Sirsi Uttara Kannada for providing the facilities to conduct this research

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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