***Original Research Article***

**Impact of organic manures in enhancing soil carbon stocks and soil enzyme activities in intensively managed ginger production systems**

**Abstract**

Nutrient management is one of the key determinants of crop production. Variability in nutrient additions through fertilizers and organic manures appears to be an influencing factor on soil fertility status and ginger productivity. In Banavasi area of Uttara Kannada Ginger farmers adopted different nutrient management practices in ginger cultivation were grouped in to Local Farmers-1: High OM and High Fertilizers, Local Farmers-2: Low OM and Moderately High Fertilizers and Migrated Farmers: Very Low OM and Very High Fertilizers district. This study was conducted to assess different magnitudes of organic and inorganic nutrient inputs influence on soil carbon stock and soil enzymes activities. Soils samples were collected at two sampling depths (0-15 cm and 15-30 cm) in three groups of ginger farmer’s fields. 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.

**Key words:** Organic manures, fertilizer, Ginger production, Soil-C stocks, Urease, Phosphatase, Dehydrogenase

**INTRODUCTION:**

Ginger (*Zingiber officinale*) is an important commercial spice crop and also long been used as medicinal plant. Especially, the fresh and dry rhizomes of ginger is widely used in folk medicine for the treatment of colds, sore throats, asthma, joint pain and also to stimulates appetite (Egamberdieva and Jabborova, 2018).As a spice, ginger is one of the most widely used condiment 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 and 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 as spread for medicinal and beverage industries are increasing. (Asfaw and Demissew, 2009). India is the largest producer, consumer and exporter ginger (Srinivasan *et al.* 2019). Our country accounts for almost 30 percent of the total world’s ginger production (Singh *et al.* 2015). In Karnataka, it is grown in an area of 23.09 thousand hectares with annual production of 58.39 thousand metric tonnes (Anon., 2018)

Nutrient management is essential in achieving the best growth and productivity in any crop (Srinivasan *et al.* 2019). 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 fertilizers can deteriorate soil quality in terms of soil physicochemical and biological properties (Lal 2015). Injudicious use of fertilizers can damage the natural ecosystem and cause soil and water pollution (Pathak and Ram 2013).

In this context, Organic manure is a good source of nutrietns which enhances soil productivity, increases the soil organic carbon content, enhances the activities of soil microorganisms and supplies major plant nutrients (Sanchez and Miller 1986). Further, Organic practices increases 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 manures feeds both plants and the soil micro organisms simultaneously and thus, enhances soil health and its quality leading to overall improvement of agroecosystem. Exclusive use of fertilizers 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 on 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 no or little efforts on influence of combined use of organics and inorganics and their influence on soil-C stocks and soil enzymes at 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.

**MATERIALS AND METHODS**

**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 provides optimum conditions for ginger cultivation. In Karnataka, ginger is widely grown in Shivamogga, Chikkamagaluru, Uttara Kannada, Udupi and Mysursu districts. In the Uttara Kannada district, the Ginger farmers are spread over a large area. However, the study was restricted to 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 temperature more than 350 C and 124 warm days ranging 30-350 C and remains below 350 C during rest of the year for about 214 days

**Selection and categorization 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 were collected. It was interesting to note that the rhizome yield varied from as high as 30-35 tonnes ha-1 in high nutrient applied fields to as low as 15-18 tonnes ha-1in 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 fertilizers applied, the farmers were grouped as **Local Farmers-1**: High organic manures and high fertilizers (G1), **Local Farmers-2**: Low organic manures and moderately high fertilizers (G2), **Migrated Farmers**: Very low organic manures and very high fertilizers (G3). and the details are given in Table 1 and presented in Fig.1.

**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 them to get one composite sample and collected soil samples were dried in shade, powdered and then sieved through 2 mm sieve.

**Soil C stocks assessment**

**Soil organic carbon**

The soil organic carbon was determined by wet oxidation method (Walkley and 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 with 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-1) = Volume of soil in ha x Soil BD x SOC

**Soil enzyme analysis**

The stored soil samples were pre-incubated at 25oC for 2 days, after adjusting the soil moisture content to field capacity, to rejuvenate soil biological activity. These pre-incubated soils were analyzed for dehydrogenase, acid phosphatase and urease enzyme activities. The dehydrogenase activity was determined by incubating soil samples at 37oC with 3 percent of 2, 3, 5- triphenyl 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 phosphatise activity was determined by the *p-*Nitrophenol Phosphate (*p*-NPP) method (Eivazi and 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 urease enzyme, the soil samples (2mm) were incubated with urea and citrate buffer solution for three hours at 37 ºC. The soils were extracted and the amount of ammonia produced was measured colorimetrically by phenate-NaOCl method (Hofmann 1963).

**Statistical analysis**

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

**RESULTS AND DISCUSSION**

**Soil carbon stock**

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

**Soil organic carbon**

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

The variations in SOC among different ginger growers may be attributed to additions of different levels of organic manures (Niranjana *et al.* 2018). The quality of organic matter is also an important factor in any ecosystem (Dattaraja *et al.* 2018). As its addition 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. Which 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 in 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.

**Soil bulk density**

The bulk densities of surface soils was significantly higher in migrated farmers (1.24 ± 0.07 Mg m-3) compared to soils of local farmers-2 group (1.19 ± 0.03 Mg m-3) and soils of local farmers-1 group (1.15 ± 0.07 Mg m-3). Similarly, the bulk density values in sub surface soils were found to be higher than surface soils with respective values ranging from 1.29 ± 0.06 Mg m-3, 1.24 ± 0.04 Mg m-3 and 1.22 ± 0.04 Mg m-3 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 transmissions (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 were 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 and Jagdish, 2004). It may also be due to 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).

**Soil carbon stock**

Soil carbon stock was found highest in Local Farmers-1 and in surface (23.17 ± 1.60 t ha-1) and sub surface (18.14 ± 2.03 t ha-1) soils respectively) and least was noted in migrated farmers in surface (03.62 ± 1.68 ) t ha-1and sub surface (6.67 ± 1.70 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 ± 3.39 t ha-1 ) > Local Farmer-2 (23.26 ± 3.06 t ha-1 ) > Migrated Farmers (20.08 ± 3.21 t ha-1 ). 57. Table 3.

The variation in soil carbon stocks in different soils might be due to application of organic manures. The organic manure additions contributing 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 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).

**Soil enzymatic activities**

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

**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 ± 8.59 µg NH4+ released g-1 soil hr-1 in surface and 90.56 ± 9.67 µg NH4 + released g-1 soil hr-1 sub surface soils respectively. Contrastingly, fields of local farmers-1recorded least with values of 112.97 ± 6.26 and 83.06 ± 4.27 µg NH4 + released g-1 soil hr-1 in surface and sub surface soils. Higher urease activity in migrated farmers fields may be due to high use of fertilizer inputs including urea. which promoted the urease activity (Shen *et al.,* 2010). Application of both organic manure and fertilizers appear 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 fertilizers being confined to the surface layer (Rao *et al.,* 1989).

**Dehydrogenase activity:**

Dehydrogenase enzyme is used as an index of soil biological activity and is expressed in µg TPF g-1 of soil day-1Its activity was found to be significantly higher in ginger soils of local farmers-1 (15.21 ± 2.92 µg TPF g-1 of soil day-1 and 9.30 ± 0.40 µg TPF g-1 of soil day-1 in surface and sub surface soils respectively) while least was noticed in soils of migrated farmers (9.12 ± 2.81 and 6.73 ± 1.73 µg TPF g-1 of soil day-1 in surface and sub surface soils respectively). The dehydrogenase activity was found higher in surface soils than sub surface soils. Higher dehydrogenase activity in plots of local farmers-1may be due to high application of organic manures. 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 highest fertilizer inputs might be due to the reason that mineral fertilization 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).

**Acid phosphatase enzyme activity**

The phosphatase activity in soils of ginger different growers are presented table 4 The activity was found significantly higher in local farmers-1 (22.38 ± 2.23 µg PNP g-1 of soil hr-1 and 11.45 ± 1.70 µg PNP g-1 of soil hr-1 in surface and sub surface soils respectively) while least activity was found in migrated farmers (15.45 ± 3.91 µg PNP g-1 of soil hr-1 and 8.83 ± 0.49 µg PNP g-1 of soil 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)

**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 increase in organic manure applications. Thus, the addition of organic manure plays a crucial role in maintaining soil health and soil biological properties.

DISCLAIMER (ARTIFICIAL INTELLIGENCE):

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

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Group of Ginger farmers** | **Organic manures used**  **(t ha-1)** | **Nutrients through fertilizers (kg ha-1)** | | |
| **N** | **P2O5** | **K2O** |
| G1: Local Farmers -1(High OM + High Fertilizer) | 27.41 ± 2.78 | 101.52 ± 32.92 | 75.17 ± 15.44 | 80.19± 8.02 |
| G2: Local Farmers -2(Low OM + Mod. High Fertilizer) | 15.65 ± 2.55 | 134.45± 21.67 | 122.76± 21.57 | 151.65 ± 18.06 |
| G3: Migrated Farmers(Very Low OM + Very High Fertilizer) | 11.65 ± 1.77 | 198.80± 9.34 | 162.22± 8.24 | 195.25 ±13.87 |

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**NOTE**: The recommended dose of N, P2O5, K2O nutrients for ginger is-100:50:50 kg ha-1 and 25 t ha-1 FYM

**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-3** | |
| **0-15 cm** | **15-30 cm** | **0-15 cm** | **15-30 cm** |
| G1: Local Farmers -1(High OM + High Fertilizers) | 1.33 ± 0.08a | 1.08 ± 0.05a | 1.15 ± 0.07b | 1.22 ± 0.04b |
| G2: Local Farmers -2(Low OM + Mod. High Fertilizers) | 0.82 ± 0.06b | 0.50 ± 0.07b | 1.19 ± 0.03b | 1.24 ± 0.04b |
| G3: Migrated Farmers(Very Low OM + Very High Fertilizers) | 0.77 ± 0.10b | 0.46 ± 0.06b | 1.24 ± 0.07a | 1.29 ± 0.06a |
| **S. Em. ±** | 0.02 | 0.03 | 0.019 | 0.016 |
| **CD (p=0.05)** | 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-1)** | | **Total carbon stock**  **(t ha-1)** |
| **0-15 cm** | **15-30 cm** | **0-30 cm** |
| G1: Local Farmers -1(High OM + High Fertilizers) | 23.17 ± 1.60a | 18.14 ± 2.03a | 41.30 ± 3.39a |
| G2: Local Farmers -2(Low OM + Mod. High Fertilizers) | 14.84 ± 1.32b | 8.42 ± 2.01a | 23.26 ± 3.06b |
| G3: Migrated Farmers(Very Low OM + Very High Fertilizers) | 13.62 ± 1.68b | 6.67 ± 1.70b | 20.28 ± 3.21c |
| **S. Em. ±** | 0.48 | 0.60 | 1.02 |
| **CD (p=0.05)** | 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**  **(µg NH4+ released g-1 soil hr-1)** | | **Dehydrogenase**  **(µg TPF g-1 of soil day-1)** | | **Acid phosphatase**  **(µg PNP g-1 of soil hr-1)** | |
| **0-15 cm** | **15-30 cm** | **0-15 cm** | **15-30 cm** | **0-15 cm** | **15-30 cm** |
| G1: Local Farmers -1(High OM + High Fertilizers) | 112.97 ± 6.26b | 83.06 ± 4.27a | 15.21 ± 2.92a | 9.30 ± 0.40a | 22.38 ± 2.23a | 11.45 ± 1.70a |
| G2: Local Farmers -2(Low OM + Mod. High Fertilizers) | 129.83 ± 9.53a | 85.49 ± 6.68a | 11.29 ± 2.01b | 6.90 ± 1.78b | 17.52 ± 3.08b | 9.34 ± 0.53b |
| G3: Migrated Farmers(Very Low OM + Very High Fertilizers) | 132.81 ± 8.59a | 90.56 ± 9.67a | 9.12 ± 2.81b | 6.73 ± 1.73b | 15.45 ± 3.91b | 8.83 ± 0.49b |
| **S. Em. ±** | 2.60 | 2.28 | 0.82 | 0.46 | 0.99 | 0.33 |
| **CD (p=0.05)** | 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

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