*Original Research Article*

# Impact of Cropping Systems on Soil Organic Carbon Levels and Enzyme Activity

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## ABSTRACT

Monocropping makes agriculture more susceptible to the adverse effects of climate change. Resilient agriculture systems that can buffer crops against various agricultural vulnerabilities is the need of the hour. In this context, a study was conducted to assess the impact of various rice based cropping systems on soil health.

**Aims:** To study the effect of different rice based cropping systems on soil enzyme activity and organic carbon.

**Study design:** Randomized block design, Replications - 3

**Place and Duration of Study:** Integrated Farming System Research Station (IFSRS) of Kerala Agricultural University located at Karamana, Thiruvananthapuram, during *kharif, rabi* and summer seasons of 2019-2020.

**Methodology:** The experiment consists of eleven cropping systems *(*$T_1$ : rice - fallow - fallow, $T_2$ : rice - rice - fallow, $T_3$ : rice - daincha - cowpea, $T_4$ : (rice + daincha) - rice - green gram, $T_5$ : rice - cassava - amaranthus, $T_6$ : rice - cassava - cowpea, $T_7$ : rice - para grass - fodder cowpea, $T_8$ : rice - fodder cowpea - fodder maize, $T_9$ : rice - okra - culinary melon, $T_{10}$ : rice - okra - yard long bean and $T_{11}$ : rice - rice – amaranthus).

**Results:** Soil organic carbon and enzyme activities were found highest in the cropping system (rice+daincha) – rice – green gram during *kharif*. During *rabi*, soil organic carbon and activity of urease and acid phosphatase were highest in rice- daincha- cowpea while dehydrogenase activity was highest in rice- fodder cowpea – fodder maize. During summer, rice- okra – yard long bean, rice- cassava- amaranthus and rice- cassava – cowpea recorded the highest urease, acid phosphatase and dehydrogenase activity, respectively. The organic carbon was highest for the sequence rice – okra –culinary melon. The soil organic carbon and enzyme activities were least in rice- fallow-fallow cropping sequence during all the three cropping seasons.

**Conclusion:** Brown manuring, use of leguminous crops and cover crops in the crop sequence instead of leaving the land fallow and addition of organic sources of nutrition increase the soil organic carbon and enzymatic activity of microbes. The increase in soil organic carbon and activity of enzymes in soil owing to crop rotation of rice with arable crops relies on the crop species which are cultivated.

*Keywords: enzyme activity, rice based cropping systems, soil health, urease, dehydrogenase, acid phosphatase, organic carbon*

## 1. INTRODUCTION

Rice – based cropping systems form an integral part of agriculture in Kerala. Rice-rice-fallow was identified as the major rice based cropping system in the southern districts of Kerala [1]. However, rice-rice and rice- fallow systems are no longer sustainable for South Asian countries [2]. The decline in sustainability of rice-based cropping systems could be due to the reduction of soil organic matter and bio resources, as well as the lack of adequate crop rotation, which leads to a decline in soil fertility and crop productivity.

Cropping system diversification with the introduction of diverse crop species can maintain soil fertility and productivity; suppress pest attack and disease incidence, and increase yields [4]. Instead of leaving the fields fallow, inclusion of vegetables, pulses, tubers, fodder crops etc. in *rabi* and summer seasons could help sustain the soil health. Inclusion of legumes and other crops in the cropping systems, as per the resource availability, could improve the productivity, profitability and soil fertility [5]. Different crops grown during different seasons under various cropping systems enhanced the soil nutrient status, soil health and sustained crop productivity [6]. Several studies have suggested that incorporation of green manures like *Sesbania* and application of FYM increased organic C in soil [7],[8].

The soil productivity primarily depends on its biological health. The composition and quantity of the microbial biomass with respect to organic carbon, soil nitrogen, and enzyme activities play a crucial role in determining the soil health. Soil microorganisms produce and release different enzymes that break down soil organic matter into smaller compounds [9]. Enzyme activity is a sensitive indicator of changes in soil environment. The changes in enzyme activity could be used to evaluate soil quality [10]. Urease enzyme degrades urea and plays a vital role in the N cycle, generating accessible N for plant growth [11]. Phosphatase enzymes are essential for mineralizing soil organic P into available P for plant uptake [12],[13]. Dehydrogenase enzymes are present in live cells of microbes and are considered a direct indicator of microbial activity of soil. It helps in the biological oxidation of organic matter.

Studies have reported that enzyme secretion and activities depend on multiple factors like type and species of crop, cropping history, crop rotation, seasons, chemical nature of root exudates, organic matter content, soil depth and agricultural practices. Even though most soil enzymes are produced by soil microorganisms, plant roots also contribute to extracellular enzymes [14],[15]. Organic compounds such as amino acids and sugars released by plant roots simulate activity of microorganisms in the plant rhizosphere [16],[17].Significantly higher activity of enzymes (dehydrogenase, protease, acid phosphatase, alkaline phosphatase and urease) were observed in organic system as against the conventional system in a five year old crop rotation involving sugar beet, spring barley, red clover, winter wheat and oats. [18]. The use of green manure in organic farming system led to an increase in the activity of all enzymes studied in comparison to the intensive system of agriculture. [19]. Legumes had a more beneficial effect on soil enzymes than cereal crops [20]. Studies suggested that use of cover crops increase organic matter accumulation that in turn improve soil biological and enzymatic activitiy [21].

Hence, the present study was conducted to assess the impact of various rice based cropping systems on soil health, in terms of soil organic carbon and enzyme activity.

## 2. MATERIAL AND METHODS

The study was conducted as part of the All India Co-ordinated Research Project on Integrated Farming Systems (ICAR) implemented in the Integrated Farming System Research Station (IFSRS) of Kerala Agricultural University located at Karamana, Thiruvananthapuram, Kerala during *kharif, rabi* and summer seasons of 2019-2020. The experimental site, is located at 8° 28´ 25˝ N latitude and 76° 57´ 32˝ E longitudes and an altitude of 5 m above mean sea level. A warm humid tropical climate existed over the experimental site. The rainfall received during *kharif* (May to September 2019) was 1172.2

mm, while during *rabi* (October 2019 to January 2020) was 519.8 mm, and during summer (February to May 2020) was 622.2 mm. During the *kharif* season, the maximum temperature varied between 27.5°C and 34.5°C, while the minimum temperature varied between 22°C and 29°C. During the *rabi* season, the maximum temperature varied between 26°C and 33.5°C, while the minimum temperature varied between 21°C and 27°C and during the summer season the maximum temperature varied between 31.5°C and 38°C while the minimum temperature varied between 21°C and 29°C. The experiment was laid out in randomized block design with eleven cropping sequences *i.e*., $T_1$ : rice – fallow - fallow, $T_2$ : rice - rice - fallow, $T_3$ : rice – *daincha* - cowpea, $T_4$ : (rice + *daincha*) - rice - green gram, $T_5$ : rice - cassava - amaranthus, $T_6$ : rice - cassava - cowpea, $T_7$ : rice - para grass - fodder cowpea, $T_8$ : rice - fodder cowpea – fodder maize, $T_9$ : rice - okra - culinary melon, $T_{10}$ : rice - okra - yard long bean and $T_{11}$ : rice - rice – amaranthus replicated thrice. The plot size was 6 x 6 m. The recommended agronomic package of practices of the state was followed for raising different crops [22]. In treatment $T_{4,}$ daincha was used for brown manuring. It was raised as an intercrop by sowing seeds @ 20 kg $ha,^{-1}$ two days after transplanting rice. The crop was later incorporated by spraying 2, 4- D @ 1.0 kg $ha^{-1}$ at 50 per cent flowering stage (45 DAS). Well decomposed farmyard manure (FYM) containing 0.5 per cent N, 0.2 per cent $P_2O_5$ and 0.4 per cent $K_2O$ was applied as the source of organic manure. Urea (46 % N), Rajphos (18 % $P_2O_5$) and Muriate of potash (60 % $K_2O$) were used as inorganic source of nitrogen, phosphorus and potassium, respectively. Details of crop, variety and fertilizers and manures applied are presented in Table 1. The soil of the experimental field was isohyperthermic typic tropofluent sandy loam. After each crop season, surface soil samples (0-15 cm) were collected, shade dried, passed through 2mm sieve and analysed for soil physical, chemical and biological parameters. Soil physical and chemical properties of the experimental site are given in Table 2. Urease activity was analysed by the incubation method proposed by Tabatabai and Bremner [23]. Acid phosphatase- and dehydrogenase activity was analyzed by the procedures proposed by Tabatabai and Bremner [24] and Thalmann [25] respectively. Organic carbon was estimated by Walkley and Black’s rapid titration [26]. GRAPES KAU statistical software was used to analyse the data [27].

**Table 1. Details of crops, variety and fertilizers and manures applied**

| Crop | Variety | Fertilizers and manures applied |
|---|---|---|
| Rice | Uma | N:P:K - 90:45:45 kg $ha^{-1}$<br>FYM - 5 t $ha^{-1}$ |
| Daincha | Local | - |
| Cowpea | Anaswara | N:P:K - 20:30:10 kg $ha^{-1}$<br>FYM - 20 t $ha^{-1}$ |
| Green gram | CO-8 | N:P:K - 20:30:30 kg $ha^{-1}$<br>FYM - 20 t $ha^{-1}$ |
| Cassava | Vellayani Hraswa | N:P:K - 50:50:100 kg $ha^{-1}$<br>FYM - 12.5 t $ha^{-1}$ |
| Amaranthus | Arun | N:P:K - 100:50:50 kg $ha^{-1}$<br>FYM - 50 t $ha^{-1}$ |
| Para grass | Local | N:P:K - 80:30:30 kg $ha^{-1}$<br>FYM - 40 t $ha^{-1}$ |
| Fodder cowpea | CO-8 | N:P:K - 25:60:30 kg $ha^{-1}$<br>FYM - 10 t $ha^{-1}$ |
| Fodder maize | African Tall | N:P:K - 120:60:40 kg $ha^{-1}$<br>FYM - 10 t $ha^{-1}$ |
| Okra | Salkeerthi | N:P:K - 110:35:70 kg $ha^{-1}$<br>FYM - 20 t $ha^{-1}$ |

| | | |
|---|---|---|
| Culinary melon | KAU Vishal | N:P:K - 70:25:25 kg $ha^{-1}$<br>FYM - 20 t $ha^{-1}$ |
| Yard long bean | Vellayani Jyothika | N:P:K - 20:30:10 kg $ha^{-1}$<br>FYM - 20 t $ha^{-1}$ |

**Table 2. Physical and chemical properties of the soil at the experimental site**

| Mechanical composition of the soil | | | |
|---|---|---|---|
| Sl. No. | Fractions | Content in soil (%) | Methods adopted |
| 1 | Coarse sand | 62 | International pipette method [28] |
| 2 | Silt | 10 | |
| 3 | Clay | 28 | |
| Textural class: | | Sandy clay loam | |

| Chemical properties of the soil | | | | |
|---|---|---|---|---|
| Sl. No. | Parameters | Content | Rating | Method adopted |
| 1 | Soil reaction (pH) | 5.8 | Acidic | 1:2:5 soil solution ratio using pH meter [29] |
| 2 | Electrical conductivity (dS $m^{-1}$) | 0.2 | Normal | Using electrical conductivity meter [30] |
| 3 | Available N (kg $ha^{-1}$) | 288.1 | Medium | Alkaline permanganate method [31] |
| 4 | Available $P_2O_5$ (kg $ha^{-1}$) | 36.8 | Medium | Bray colorimetric method [30] |
| 5 | Available $K_2O$ (kg $ha^{-1}$) | 137.7 | Low | Ammonium acetate method [30] |



## 3. RESULTS AND DISCUSSION

### 3.1 Enzyme activity

The enzyme activity of urease, acid phosphatase and dehydrogenase were considered for this study. All the three enzymes showed significant effect on cropping systems at the end of the crop cycle.

**3.1.1 Urease**

The results pertaining to the effect of different cropping systems on urease activity during *kharif*, *rabi* and summer seasons are given in Table 3. Soil urease activity was significantly influenced by different cropping sequences during all the three seasons. (Rice + daincha) – rice – green gram showed the highest activity after *kharif* (89.43 mg $g^{-1}$ $h^{-1}$). In *rabi*, rice – daincha- cowpea (88.36 mg $g^{-1}$ $h^{-1}$) showed the highest activity which was on par with rice - fodder cowpea –fodder maize (88.30 mg $g^{-1}$ $h^{-1}$). The fast decomposition of daincha releases organic matter that act as a source of carbon and energy for the growth and multiplication of microorganisms, thus enhancing soil enzyme activities [32],[33]. Rice – okra - yard long bean (91.07 mg $g^{-1}$ $h^{-1}$) showed significantly higher urease activity in summer. Yard long bean add a huge amount of crop residue into the soil increasing the overall carbon received by microorganisms present in soil. This in turn could increase the activity of urease enzyme [34] [35]. Lowest activity was observed in rice - fallow - fallow after *kharif* (78.98 mg $g^{-1}$ $h^{-1}$), *rabi* (77.35 mg $g^{-1}$ $h^{-1}$) and summer seasons (76.52 mg $g^{-1}$ $h^{-1}$).

**Table 3. Influence of cropping sequence on soil urease activity after each season, mg of urea hydrolysed $g^{-1}$ soil $h^{-1}$**

| Cropping sequence | *Virippu* | *Mundakan* | Summer |
|---|---|---|---|
| $T_1$: Rice - fallow - fallow | 78.98d | 77.35g | 76.52e |
| $T_2$: Rice - rice - fallow | 82.18c | 82.82f | 81.58d |
| $T_3$: Rice - daincha - cowpea | 85.93b | 88.36bc | 86.80bc |
| $T_4$: (Rice + daincha) – rice –green gram | 89.43a | 86.32ab | 90.13ab |
| $T_5$: Rice – cassava – amaranthus | 82.76c | 83.27ef | 81.74d |
| $T_6$: Rice – cassava – cowpea | 84.60b | 85.71cd | 86.41bc |
| $T_7$: Rice – para grass – fodder cowpea | 82.82c | 83.40def | 84.02cd |
| $T_8$: Rice – fodder cowpea – fodder maize | 84.95b | 88.30def | 85.74c |
| $T_9$: Rice - okra - culinary melon | 85.68b | 85.21cde | 87.69abc |
| $T_{10}$: Rice - okra - yard long bean | 88.91a | 83.37a | 91.07a |
| $T_{11}$: Rice - rice - amaranthus | 85.09b | 84.31cdef | 84.3cd |
| SEm(±) | 0.590 | 0.799 | 1.272 |
| CD (0.05) | 1.75 | 2.356 | 3.754 |

**3.1.2 Acid phosphatase**

The acid phosphatase activity differed significantly among the cropping systems in all the three seasons (Table 4). The acid phosphatase activity was highest in the cropping sequence (rice + daincha)- rice- green gram after *kharif* (29.03 µg $g^{-1}$ $h^{-1}$). After *rabi*, rice – daincha- cowpea (28.90 µg $g^{-1}$ $h^{-1}$) showed highest activity of acid phosphatase. The acid phosphatase activity was highest in rice – cassava - amaranthus (31.16 µg $g^{-1}$ $h^{-1}$) which was on par with rice- okra - yard long bean (30.45 µg $g^{-1}$ $h^{-1}$) after summer season. High amount of FYM application in amaranthus might have produced organic acids during decomposition of FYM which might have resulted in enhanced soil microbial activity. Similar results were reported by Reddy and Reddy (2012) [36]; Bhavani *et al*., (2017) [37]. Different plant species grown during *kharif*, *rabi* and summer produce different root exudates and secretions in the rhizosphere, which acts as a substrate for soil microorganisms. Yard long bean being a legume was found to exude higher amount of acid phosphatases by the plant roots. [38,39,40]. The variation in nutrient requirements of crops and the quantity and quality of litter they produce might have also influenced acid phosphatase activity.

**Table 4. Influence of cropping sequence on soil acid phosphatase activity after each season, µg of p- nitro phenol released $g^{-1}$ soil $h^{-1}$**

| Cropping sequence | *Virippu* | *Mundakan* | Summer |
|---|---|---|---|
| $T_1$: Rice - fallow - fallow | 22.22d | 21.58g | 22.46bc |
| $T_2$: Rice - rice - fallow | 25.81b | 25.20d | 26.87ab |
| $T_3$: Rice - daincha - cowpea | 22.52cd | 28.90f | 20.86c |
| $T_4$: (Rice + daincha) - rice -green gram | 29.03cd | 22.13fg | 22.78bc |
| $T_5$: Rice - cassava - amaranthus | 28.71a | 22.26a | 31.16a |
| $T_6$: Rice - cassava - cowpea | 23.48c | 23.68e | 22.14c |
| $T_7$: Rice - para grass - fodder cowpea | 23.08cd | 23.34e | 24.06bc |
| $T_8$: Rice - fodder cowpea - fodder maize | 23.43c | 25.95c | 23.29bc |
| $T_9$: Rice - okra - culinary melon | 28.50a | 27.35b | 29.24a |
| $T_{10}$: Rice - okra - yard long bean | 22.66a | 27.35a | 30.45a |
| $T_{11}$: Rice - rice - amaranthus | 26.55b | 28.73b | 29.56a |
| SEm(±) | 0.368 | 0.211 | 1.533 |
| CD (0.05) | 1.086 | 0.621 | 4.524 |

**3.1.3 Dehydrogenase**

The influence of cropping systems on dehydrogenase activity is presented in Table 5. The dehydrogenase activity differed significantly among the cropping systems in all the three seasons. The highest activity was observed in (rice +daincha) – rice – greengram after *kharif* (28.11 µg $g^{-1}$ $h^{-1}$). Rice -fodder cowpea-fodder maize (29.87 µg $g^{-1}$ $h^{-1}$) and rice – cassava - cowpea (34.51 µg $g^{-1}$) recorded the highest activity after *rabi* and summer season, respectively. The lowest activity was found in the cropping sequence rice - fallow - fallow after *kharif* (24.29 µg $g^{-1}$ $h^{-1}$), *rabi* (23.06 µg $g^{-1}$ $h^{-1}$) and summer seasons (2.43 µg $g^{-1}$ $h^{-1}$). Increasing the cropping intensity of cropping systems by reducing the fallow period increases the biomass production and residue incorporation. This actually increases the soil organic carbon, stimulating soil microflora resulting in enhanced enzyme activities as reflected from the present study. This in turn increases carbon sequestration that could stimulate soil enzyme activity by microbes. Also the increased activity of dehydrogenase in all other treatments except rice – fallow – fallow might be due to the formation of humic acids that enhanced the activity of microorganisms due to the organic and inorganic nutrients applied to the crops. Similar results on dehydrogenase activity were reported by Bajpai *et al*., 2006) [41].

**Table 5. Influence of cropping sequence on dehydrogenase activity after each season, µg of TPF released $g^{-1}$ soil 24 $h^{-1}$**

| Cropping sequence | *Virippu* | *Mundakan* | Summer |
|---|---|---|---|
| $T_1$: Rice - fallow - fallow | 24.29d | 23.06g | 22.43d |
| $T_2$: Rice - rice - fallow | 24.44d | 23.25g | 23.85cd |
| $T_3$: Rice - daincha - cowpea | 25.00d | 28.70g | 23.52cd |
| $T_4$: (Rice + daincha) - rice -green gram | 28.11ab | 25.59ef | 26.31bcd |
| $T_5$: Rice - cassava - amaranthus | 26.57bc | 27.11c | 27.33bc |
| $T_6$: Rice - cassava - cowpea | 27.52ab | 26.57cd | 34.51a |
| $T_7$: Rice - para grass - fodder cowpea | 25.46cd | 24.84f | 25.74cd |
| $T_8$: Rice - fodder cowpea - fodder maize | 24.72d | 29.87de | 25.98cd |
| $T_9$: Rice - okra - culinary melon | 26.78a | 23.45b | 30.63ab |
| $T_{10}$: Rice - okra - yard long bean | 27.57a | 25.75a | 30.75ab |
| $T_{11}$: Rice - rice - amaranthus | 25.42cd | 24.99ef | 25.67cd |
| SEm(±) | 0.408 | 0.28 | 1.521 |
| CD (0.05) | 1.203 | 0.826 | 4.488 |

### 3.2. Organic Carbon

Soil organic carbon content under different cropping systems during the *virippu*, *mundakan* and summer seasons is presented in Table 6. Perusal of data revealed that the soil organic C showed significant variation among different cropping systems in *virippu*, *mundakan* and summer seasons. In *virippu*, significantly higher organic C was observed in (rice + daincha) - rice -green gram (1.88 %). In *mundakan*, highest value of organic C was obtained in rice – daincha – cowpea (1.71%) which was on par with rice – fodder cowpea – fodder maize (1.64%). In summer, significantly higher organic C was observed in rice – okra –culinary melon (1.94 %). Residual effect of root and shoot biomass returned to soil and regular application of FYM along with recommended inorganic fertilizer may be the reason for high soil organic carbon in these treatments. [42],[43]. Rice- fallow- fallow showed the least soil organic C in all the three seasons. A significant improvement in soil organic C was observed at the end of each cropping cycle.

**Table 6. Influence of cropping system on organic carbon after each season (%)**

| Cropping sequence | *Virippu* | *Mundakan* | Summer |
|---|---|---|---|
| $T_1$: Rice - fallow - fallow | 1.43c | 1.29e | 1.36c |
| $T_2$: Rice - rice - fallow | 1.44c | 1.41de | 1.40c |
| $T_3$: Rice - daincha - cowpea | 1.46bc | 1.71a | 1.56bc |

| | | | |
|---|---|---|---|
| $T_4$: (Rice + daincha) - rice -green gram | 1.88a | 1.45cd | 1.50bc |
| $T_5$: Rice - cassava - amaranthus | 1.45bc | 1.49cd | 1.51bc |
| $T_6$: Rice - cassava - cowpea | 1.51bc | 1.52bcd | 1.58bc |
| $T_7$: Rice - para grass - fodder cowpea | 1.53b | 1.43cd | 1.73ab |
| $T_8$: Rice - fodder cowpea - fodder maize | 1.54b | 1.64ab | 1.69ab |
| $T_9$: Rice - okra - culinary melon | 1.48bc | 1.55bc | 1.94a |
| $T_{10}$: Rice - okra - yard long bean | 1.52bc | 1.51cd | 1.68ab |
| $T_{11}$: Rice - rice - amaranthus | 1.51bc | 1.43cd | 1.51bc |
| SEm (±) | 0.032 | 0.042 | 0.089 |
| CD (0.05) | 0.095 | 0.123 | 0.262 |

### 3.3 Correlation studies

Correlation of organic carbon with enzyme activities at the end of crop cycle is presented in Table 7. A positive correlation was observed between organic carbon and urease, acid phosphatase and dehydrogenase. The positive correlation of enzyme activities with organic carbon may be due to enhanced organic matter decomposition and nutrient cycling by soil enzymes and micro flora [44].

**Table 7. Correlation of organic carbon with enzyme activities at the end of crop cycle.**

| | Organic Carbon |
|---|---|
| Acid phosphatase | 0.226 |
| Urease | 0.559 |
| Dehydrogenase | 0.528 |

## 4. CONCLUSION

From the findings, it can be concluded that brown manuring with daincha, use of leguminous crops or cover crops in the crop sequence instead of leaving the land fallow and addition of organic sources of nutrition like FYM could increase the soil organic carbon and enzymatic activity of microbes. Microorganisms that produce different enzymes prefer certain environment in the root zone, and the plant species play an important role. The increase in SOC in the soil owing to crop rotation of rice with arable crops relies on the crop species which are cultivated due to the quality and quantity of their residue added.

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