

**STUDIES ON SOIL ORGANIC CARBON FRACTIONS IN
RELATION TO NUTRIENT MANAGEMENT PRACTICES ON
RICE-WHEAT CROPPING SYSTEM IN A VERTISOL**

M.Sc. (Ag.) Thesis

by

Subhra Siran Dash

**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL
CHEMISTRY
FACULTY OF AGRICULTURE
COLLEGE OF AGRICULTURE
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Thesis

Submitted to the

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by

Subhra Siran Dash

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In

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CERTIFICATE-I

This is to certify that the thesis entitled “**Studies on soil organic carbon fractions in relation to nutrient management practices on rice –wheat cropping system in a Vertisol**” submitted in partial fulfillment of the requirements for the degree of **Master of science in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bona fide research work carried out by **Subhra Siran Dash** under my guidance and supervision. The subject of the thesis has been approved by the student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date:

01/10/2021



Chairman

THESIS APPROVED BY THE STUDENT’S ADVISORY COMMITTEE

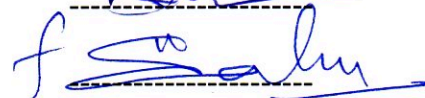
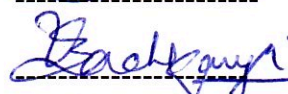
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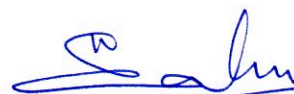
Member (Dr. R.R. Saxena)

HOD (Dr. K. Tedia)



CERTIFICATE-II

This is to certify that the thesis entitled “**Studies on soil organic carbon fractions in relation to nutrient management practices on rice –wheat cropping system in a Vertisol**” submitted by **Subhra Siran Dash** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in the partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the **Department of Soil Science and Agricultural Chemistry** has been approved by the external examiner and Student’s Advisory Committee after oral examination, under the chairmanship of Head of the Department.



Signature of Head of the Department

(Name – Dr. K.K. SAHU.....)

Date: 22/10/2021

Major Advisor



Head of the department



26/10/2021

Faculty Dean

Approved/Not Approved

Director of Instruction



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Subhra Siran Dash

Subhra Siran Dash

(Department of Soil Science &

Agricultural Chemistry, IGKV, Raipur)

Chhattisgarh, 492001

Date: 01/10/2021

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LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTIONS
%	Per cent
@	At the rate of
RDF	Recommended dose of fertilizer
dS/m	Deci Simens per meter
<i>et al</i>	Et alii (and other)
Fig	Figure
VM	Vermicompost
FYM	Farm yard manure
ha ⁻¹	per hectare
<i>i.e.</i> ,	id est (that is)
Kg	Kilogram
Kg/ha	kilogram per hectare
q/ha	quintal per hectare
cm	Centimeter
Mg	Mega gram
m ³	cube meter
t/ha	Tonne per hectare
°C	Degree Celsius
OC	Organic carbon
EC	Electrical conductivity
NS	Non- Significant
SEm±	Standard Error of means

ABSTRACT

- a) Title of the Thesis : "Studies on soil organic carbon fractions in relation to nutrient management practices on rice–wheat cropping system in a *Vertisol*."
- b) Full Name of student : Subhra Siran Dash
- c) Major Subject : Soil Science and Agricultural Chemistry
- d) Name and Designation of major advisor : Dr. V. N. Mishra, Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture IGKV, Raipur (C.G)
- e) Degree to be awarded : Master of Science in Agriculture (Soil Science and Agricultural Chemistry)


Signature of Major Advisor


Signature of Student

Date: 01/10/2021


Signature of Head of Department 26/10/2021

ABSTRACT

The present experiment entitled "Studies on soil organic carbon fractions in relation to nutrient management practices on rice –wheat cropping system in a *Vertisol*." was conducted in the long-term experiment at Instructional cum Research Farm of Indira Gandhi Agricultural University, Raipur (C.G) during *kharif* season, 2020. The treatments were comprised of five treatments viz, T1- Control ($N_0P_0K_0$), T2- General Recommended Dose (100:60:40 N:P₂O₅:K₂O kg/ha), T3- STCR Fertilizer dose to achieve a yield target (YT) of 5 t/ha (98:9:32 N:P₂O₅:K₂O kg/ha), T4 - STCR Fertilizer dose to achieve a YT of 6 t/ha (137:17:46 N:P₂O₅:K₂O kg/ha), T5- STCR Fertilizer dose with

5t/ha FYM application to achieve a YT of 6 t/ha (116:9:37 N:P₂O₅:K₂O kg/ha).The treatments were laid out in randomized block design (RBD) with four replications.

The results showed that soil chemical properties like pH, EC were not significantly affected under different nutrient management practices, macro nutrient availability got enhanced with fertilizer application in long term experiment, highest in application of FYM along with chemical fertilizer. Similarly, soil biological properties like SMBC, SMBN, DHA elevated with nutrient addition by means of fertilizers and organic manure over 13 years of continuous application in comparison to control. The highest of both SMBC and SMBN *i.e* 395.36 and 46.85 mgKg⁻¹, respectively was found in T5. The dehydrogenase activity was significantly increased in T5 (46.28µg TPF/g soil /day) that received the fertilizer application along with FYM for 6 t/ha yield target than all other treatments. The total organic carbon significantly increased in T5 (1.51%) in comparison to control (1.07%). Among the carbon fractions, non-labile carbon fraction (NLCF) contributed the highest value, found in case of T5 (0.55%). The grain and straw yields of rice significantly differed with various fertilizer practices. The grain yield was highest in case of T5 (60.94 q/ha) followed by T4 (58.05 q/ha), T2 (53.62 q/ha), T3(50.93 q/ha), T1(40.09 q/ha). Similar results found with straw yield. Among four carbon fractions, labile carbon fraction (LCF) was significantly correlated to rice grain yield followed by VLCF > LLCF>NLCF. All these were indicative by the R² value of the best fit line regression equation.

शोध सारांश

- अ) शोध का शीर्षक का नाम : “कन्हार मृदा में चावल-गेहूं फसल प्रणाली पर पोषक तत्व प्रबंधन प्रथाओं में मृदा कार्बनिक अंशों का अध्ययन।”
- ब) विद्यार्थी का पूरा नाम : सुभ्र सिरन दाश
- स) मुख्य विषय : मृदा विज्ञान एवं कृषि रसायन विज्ञान
- द) मुख्य परामर्शक का नाम व पता : डॉ. विद्यानन्द मिश्रा
प्राध्यापक, मृदा विज्ञान एवं कृषि रसायन विभाग,
कृषि महाविद्यालय, रायपुर इ.गां.कृ.वि. (छ.ग.)
- इ) उपाधि का नाम : स्नातकोत्तर (कृषि) मृदा विज्ञान एवं कृषि रसायन

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सारांश

वर्तमान प्रयोग शीर्षक “कन्हार मृदा में चावल – गेहूं फसल प्रणाली पर पोषक तत्व प्रबंधन प्रथाओं में मृदा कार्बनिक कार्बन अंशों का अध्ययन।” इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.) के निर्देशात्मक सह अनुसंधान फार्म में दीर्घकालिक प्रयोग के अंतर्गत खरीफ मौसम 2020 के दौरान आयोजित किया गया था। उपचारों में पांच उपचार शामिल थे, T₁—नियंत्रण (नत्रजन₀ स्फूर₀ पोटाश₀), T₂—सामान्य अनुशंसित मात्रा (100:60:40 नत्रजन, स्फूर, पोटाश कि.ग्रा प्रति हेक्टेयर), T₃—मृदा परीक्षण फसल अनुक्रिया (STCR) उर्वरक मात्रा (98:9:32 नत्रजन, स्फूर, पोटाश कि.ग्रा प्रति हेक्टेयर) 5 टन प्रति हेक्टेयर की उपज लक्ष्य (Yield Target) को प्राप्त करने के लिए, T₄—मृदा परीक्षण फसल अनुक्रिया (STCR) उर्वरक की मात्रा (137:17:46 नत्रजन, स्फूर, पोटाश कि.ग्रा प्रति हेक्टेयर) 6 टन प्रति हेक्टेयर की उपज लक्ष्य प्राप्त करने के लिए, T₅—मृदा परीक्षण फसल अनुक्रिया (STCR) उर्वरक मात्रा (116:9:37 नत्रजन, स्फूर, पोटाश कि.ग्रा. प्रति हेक्टेयर) 5 टन प्रति हेक्टेयर गोबर खाद के साथ 6 टन प्रति हेक्टेयर का उपज प्राप्त करने के लिए। उपचारों को चार प्रतिकृतियों के साथ यादृच्छिक ब्लॉक डिजाइन (RBD) में रखा गया था।

प्रयोग के परिणामों से पता चलता है कि विभिन्न पोषक तत्व प्रबंधन प्रथाओं के तहत मृदा अम्लता (pH), मृदा लवणता (EC) जैसे मिट्टी के रासायनिक गुण महत्वपूर्ण रूप से प्रभावित नहीं हुए थे। दीर्घकालिक प्रयोग में उर्वरक आवेदन के साथ प्रमुख पोषक तत्व उपलब्धता में वृद्धि हुई, जिसमें रासायनिक उर्वरक के साथ गोबर खाद के उपयोग अंतर्गत उच्चतम वृद्धि प्राप्त हुई। इसी तरह मृदा माइक्रोबियल बायोमस

कार्बन (SMBC), मृदा माईक्रोबियल बायोमास नत्रजन (SMBN), डिहाइड्रोजिनेज गतिविधि (DHA) जैसे मृदा जैविक गुणों को उर्वरकों और जैविक खाद के माध्यम से नियंत्रण की तुलना में निरंतर आवेदन के 13 वर्षों में पोषक तत्वों के साथ बढ़ा पाया गया है। मृदा माईक्रोबियल बायोमास कार्बन (SMBC), मृदा माईक्रोबियल बायोमास नत्रजन (SMBN) दोनों सबसे ज्यादा क्रम¹: 395.36 और 46.85 मिली ग्राम प्रति किलो ग्राम (mg/kg) T₅ में पाया गया। डीहाइड्रोजिनेज गतिविधि अन्य सभी उपचारों की तुलना में उपचार T₅(46.28 माइक्रोग्राम टीपीएफ प्रति ग्रा. मिट्टी प्रति दिन) में काफी बढ़ गई थी, जिसमें 6 टन प्रति हे. उपज लक्ष्य के लिए गोबर खाद के साथ उर्वरक उपयोग किया गया था। नियंत्रण T₁(1.07%) की तुलना में T₅(1.51%) में कुल कार्बनिक कार्बन में उल्लेखनीय वृद्धि हुई। मृदा के कार्बन अंशों में, नान लेबाईल कार्बन फ़ैक्टोर (NLCF) ने उच्चतम मान का योगदान दिया, जो कि T₅ (0.55%) के मामले में अत्यधिक पाया गया। धान की अनाज और पुआल की पैदावार विभिन्न उर्वरक प्रथाओं में काफी भिन्न-भिन्न होती है। अनाज की उपज उपचार T₅(60.94 क्विंटल प्रति हेक्टेयर) में सबसे अधिक थी, उसके बाद T₄ (58.05 क्विंटल प्रति हेक्टेयर) T₂ (53.62 क्विंटल प्रति हेक्टेयर), T₃(50.93 क्विंटल प्रति हेक्टेयर), T₁ (14.09 क्विंटल प्रति हेक्टेयर) में पाई गई। इसी तरह के परिणाम भूसे की उपज के साथ भी मिले। प्रयोग में चार कार्बन अंशों में क्रम¹: लेबाईल कार्बन अंश, अधिक लेबाईल कार्बन अंश¹, नान लेबाईल कार्बन अंश¹,लेस लेबाईल कार्बन अंश¹ (LCF>VLCF>LLCF>NLCF) का चावल के दानों की उपज से महत्वपूर्ण संबंध प्राप्त हुआ ये सभी लाइन रिग्रेशन समीकरण के मान (r²) से संकेतित थे।

CHAPTER - I

INTRODUCTION

The population of India is estimated to touch about 1.4 billion by the year 2025. With total food grain production hovering around 250-275 MT for the last few years, it may become very difficult to achieve a target of 325 MT by 2025 without improvement in soil health. It is therefore, essential to protect the soil health by using balanced fertilization through soil testing with integrated nutrient combination. Balanced fertilization of crops ensures improved quality of produce, maintenance of soil fertility, and conservation of our precious soil and water resources. Balance nutrition should ensure the nutrient in available forms in adequate quantity and in required proportion in the soil to meet the requirement the crops for obtaining the desired levels of yield. It is rarely found that nutrients available in the soil are in adequate amount. The fertilizers recommendations based on quantitative/semi-quantitative approaches do not give expected yield responses. Some nutrients like potassium and micronutrients like Fe Zn, Cu Mn may be present in more than sufficient to meet the crop nutrients requirement whereas, soil N and P may not be present in sufficient and this imbalances need to correct in a balanced manner by external application based on the crop nutrients requirement, soil fertilizer and organic nutrients efficiencies. Therefore, it needs a more comprehensive approach for fertilizer use, incorporating components like soil test, field research and economic evaluation of the results.

The formulation of soil test-based fertilizer equations generated for a particular crop, soil type and climatic condition requires validation for their suitability in similar soil and climatic conditions. If validation is within the $\pm 10\%$ then information is finalized in the form of fertilizer prescription equation for obtaining balanced fertilizer dose with INM component. This information can be tested in a long term with a certain cropping system for changes in soil physical, chemical and biological properties for sustainable soil

and crop productivity. The rice-wheat cropping system is a major cropping system in India, covering approximately 12.3MH, with rice and wheat accounting for roughly 23 and 40 percent of the total cropping area. The state of Chhattisgarh, covering a geographical area of 13.6 MH lies in the tropical belt of eastern region of India. The agro-climate of the state is characterized by transition between hot dry sub-humid to moist sub-humid with dry summers and cool winter. According to soil taxonomy (7th approximation), soils of Chhattisgarh falls under 5 orders and 9 dominating sub-groups. The order *Vertisol* covers 26.4% area of the total land. (WTCER, Bhubaneswar (2006)).

The state of Chhattisgarh is considered as rice bowl of India as most of the cultivated land is planted with rice during *kharif* season and contributes a significant proportion of the country's rice production. Rice is grown on 3.65 MH with a productivity of more than 2.2 t/ha and wheat productivity in the state is poor as compared to the national average. Rice–wheat cropping systems have shown signs of soil nutrient loss and imbalances, poor nutrient usage, a general decline of soil organic matter, and dwindling yields as a result of decades of continuous cropping and the contrasting edaphic needs of the two cereals. Various factors such as biotic and abiotic restrictions, insect and disease outbreaks, growing of local, vulnerable cultivars in adverse and fluctuating climate conditions, conventional sowing techniques, rainfed crop cultivation, and low soil organic carbon coupled with nitrogen content in soil may be responsible for yield stagnation in both crops.

Viewing the diverse role that soil organic carbon performs such as buffering, rebuilding, and delivering plant nutrients; it has both an indirect and direct impact on yield. It serves as a repository for all soil microorganisms those live in the soil and helps to enhance the physical, chemical, and biological properties of the soil.

If the necessary dosage of fertilizer is applied on a regular basis, the rice-wheat cropping system does not reduce SOC levels (Bado *et al.*2010). This type of vivid information, however, is not available in this Chhattisgarh region as elaborately analyzed in the Gangetic plains. Similarly, in different nutrient management systems, decreased production might be linked to decreased SOC fractions. Soil

carbon pools could well be created using management strategies those contribute a lot of bio mass to the soil, little soil disturbance, preserve soil and water, improve soil structure, and boost soil fauna activity. Long-Term Fertilizer Experiments are the finest method for determining this impact of fertilizers and manure on soil sustainability. Long-term fertilizer trials are a great source of knowledge concerning fractionation of soil organic matter.

Keeping this in view, it may be quite worthy to study on the impact of various nutrient practices/sources on soil organic pools in order to maintain soil health and achieve greater and sustainable yields of both crops under such circumstances in the state of Chhattisgarh. With this in mind, the research entitled, **“Studies on soil organic carbon fractions in relation to nutrient management practices on rice –wheat cropping system in a *Vertisol*”** with the following objectives.

1. To assess the soil organic carbon fractions as influenced by long term nutrient management practices.
2. To estimate the soil biological parameter as influenced by long term nutrient practices.
3. To establish the relationship between yield and organic carbon fractions.

CHAPTER- II

REVIEW OF LITERATURE

This chapter examines the results of various researchers' research projects on the topic, “**Studies on soil organic carbon fractions in relation to nutrient management practices on rice –wheat cropping system in a *Vertisol*.**” has been concisely elaborated. The literatures on the aspects have been reviewed under following head:

2.1 The consequences of continuous fertilization and FYM application on chemical parameters of soil

2.2 The consequences of inorganic fertilization and FYM application on oxidizable soil organic carbon fractions, total carbon content & yield.

2.3 The effect of inorganic fertilization and FYM application on biological properties of soil.

2.1 The consequences of continuous fertilization and FYM application on chemical parameters of soil

2.1.1 Soil pH

The soil pH value is the measure of hydrogen or hydroxyl ion activity in the soil solution & it indicates whether the soil is acidic, neutral or alkaline in reaction. It is the most important soil property of soil as it controls the availability of plant nutrients, operation of microbes and the soil's physical state. According to Pothare *et al.* (2007), the cumulative usage of organics and inorganics altered all soil parameters, including pH. The treatment of 100% NPK + 10 t FYM ha⁻¹ yielded the best value. Generally, 100 %NPK+FYM had the best results of all the treatments, whereas control had the worst.

Prasad *et al.* (2010) examined the effect of nutrient delivery from inorganic and organic sources; found that soil pH was slightly higher in treatments that integrated inorganic and organic fertilizers and manures in a rice-wheat cropping sequence. In comparison to treatments using only inorganic fertilizers, continuous application of organic manures with inorganic fertilizers was more successful in lowering soil pH. (Lal Bahadur *et al.* 2012)

Parvathi *et al.* (2013) analyzed that several treatments of integrated nutrient delivery had no significant effect on soil pH. The highest value (7.6) was found in 100 percent NPK + FYM, while the lowest (7.3) was found in 50 percent NPK + FYM. When compared to the original (7.7) value, all treatments showed a modest reduction in soil pH, which was attributed to the acidifying action of acids during organic decomposition.

Agarwal *et al.* (2014) concluded with the experiment in a soybean-wheat system found that continual application of nitrogen alone as urea lowered soil pH by 0.8 units over 38 years. They also found that adding FYM (15 t ha⁻¹ yr⁻¹) to the soil helped to regulate the pH and maintain a greater soil organic carbon status.

Jadhao *et al.* (2014) reported that in all treatments of inorganic fertilizer application recorded a rise in soil pH, except when combined with FYM (100 percent NPK + FYM @ 10 t ha⁻¹) which was lowered.

Challa *et al.* (2015) compared and contrasted the influence of continual application of chemical fertilizers and manures on soil pH and found that the application of 150 percent NPK or 100 percent NPK+FYM treatments had no significant effect on soil pH in a long-term experiment.

In a contradictory statement, several studies have found that applying organic manures causes an increase in soil pH. (Patiram and Singh,1993 Hati *et al.* 2008, Mishra *et al.* 2008).

2.1.2 Electrical Conductivity (EC)

The conductivity or more precisely the specific conductance of a soil at a given soil –water ratio is the reciprocal of the specific resistance offered by the solution at 25 °C between the electrodes of 1 sq² cm cross section kept 1cm apart, hence EC of any solution depends on amount of soluble salt present in it.

Study was conducted for assessing the effect of continuous application of inorganic fertilizers with and without integration of FYM on EC of soil and results showed that EC of soil was not affected significantly by different treatments (Sharma and Tripathi, 1992).

Lal Bahadur *et al.* (2012) observed that using organic manures in combination with inorganic fertilizers was more successful at lowering soil EC than using only inorganic fertilizers.

Parvathi *et al.* (2013) reported that several treatments of inorganic fertilizer application with and without FYM integration, no significant change in soil EC was detected. He further stated that owing to continual fertilizer input during the 36th year, there was no significant change in the EC of the soil with depth.

Prajakta *et al.* (2015) when compared to other inorganic fertilizer treatments, found that electrical conductivity of soil was considerably lower (0.290, 0.284 ds m⁻¹) under the NPK + FYM treatment. Under the soybean-wheat system, Norman *et al.* (2016) found that applying inorganic fertilizers and incorporating crop residue changed the EC of soil at the top 10 cm soil depth.

Rahale *et al.* (2018) in a long-term fertility experiment, at the end of the 50th rice crop in rice-rice cropping system found that EC value showed a slight increase among the treatments at the end of the 50th crop, but the values are well below the normal soil. Although EC of the soil increased in different treatments but the actual values did not cross the critical limit of 4.0 dSm⁻¹.

2.1.3 Available Nitrogen, Phosphorus and Potassium status in soil

Manna *et al.* (2005) reported the results on post harvest available N, P and K status from three places namely Ranchi, Barrackpore and Akola under the AICRP on LTFE project. Crop rotations included in the study were: rice–wheat–jute, soybean–wheat and sorghum–wheat system at Barrackpore (Typic Eutrochrept), Ranchi (Typic Haplustert) and Akola (Typic Haplustalf), respectively. Field treatments included unfertilized (control), 100% N, 100% NP, 100% NPK and 100% NPK + FYM. They found out that in all of these soils, the available N held steady in N-, NP-, and NPK-treated plots. In NP-, NPK-, and NPK + FYM-treated plots, available K and available P got elevated.

Mandal *et al.* (2008) in their 19 years LTFE experimental trial with a rice–wheat cropping system on an *Inceptisol* with the following treatments: (i) control (ii) inorganic NPK fertilizer, (iii) NPK + FYM, (iv) NPK + PS, (v) NPK + GM, and (vi) a fallow where no crop was grown since the initiation of the experiment agreed upon that application of INM was significantly higher soil NPK content over control and only chemical fertilizers.

Dadhich *et al.* (2011) conducted an experiment in Udaipur to investigate the direct and indirect effects of fertilizer P, FYM, and bio fertilizers on soybean, as well as their residual influence on following wheat. After wheat harvest, FYM treatment enhanced organic carbon, CEC, accessible N, P, and K content while lowering soil bulk density.

Raghuwanshi *et al.* (2016) conducted a field experiment in the year 2012-13 under AICRP on LTFE, studied the effect on dry matter yields in a *Vertisol* under soyabean – wheat cropping system with 9 treatments i.e. 50%, 100%, 150% NPK , 100% NPK+Zn, 100%NP, 100% N, 100% NPK+FYM, 100% NPK-S and control. Their final remark was that application of FYM with recommended application of fertilizers enhanced primary and secondary nutrients content at different growth stages.

Patel *et al.* (2018) in the 41st year study, from LTFE scheme with soyabean – wheat cropping system since 1972 revealed that the level of N, P, K, S rose significantly with the integrated application of fertilizers and FYM over control and other treatments. Similarly, tandem use of FYM @ 5 t ha⁻¹ with 100% NPK improved the available N, P, K, S, Zn & Fe over the initial value of soil (Meshram *et al.* 2019).

Jadhao *et al.* (2019) in a LTFE project with a view to investigate the effect of INM on soil fertility, crop productivity and sustainability under sorghum- wheat cropping sequence, found that conjoint use of organics and fertilizers improved the available N (317 kg ha⁻¹), P (19.98 kg ha⁻¹) and K (473.2 kg ha⁻¹).

Xiaoguang *et al.* (2020) studied the effect of long-term fertilizer application on crop yield and soil property in maize-wheat system observed that available P and K got enhanced by 97.4% and 68.5% by the mixed application of manure and N fertilizer over chemical fertilizer in de-salinized soil.

2.2 The consequences of inorganic fertilization and FYM application on oxidizable soil organic carbon fractions, total carbon and yield.

Ding *et al.* (2012) studied in China to identify the changes in different Soil Organic Carbon (SOC) pools (total, labile, and recalcitrant) and they included five fertilizer treatments i.e. unfertilized control, only chemical fertilizer, organic manure @ 7.5 t ha⁻¹ with chemical fertilizer, organic manure @ 15 t ha⁻¹ with chemical fertilizer; and organic manure @ 22.5 t ha⁻¹ with chemical fertilizer. they reported that the applying graded rates of manure, significantly increased total SOC, labile C pools, and recalcitrant C pools. The increasing levels of organic manure application enhanced C storage (in the top 20 cm), suggesting that chemical fertilizer addition had minimal impact on C-sequestration, rather organic manure does have that edge.

In comparison to inorganic fertilization alone, continuous application of organic manures in association with inorganic fertilizers resulted in a greater organic carbon content. Higher biomass addition to soil from crop left overs might explain the rise in

organic carbon content in treatments with both organic and inorganic inputs. The use of solely inorganic fertilizers resulted in a decrease in the organic carbon content of the soil in both control and treatment groups (Nayak *et al.* 2012)

Sharma *et al.* (2016) carried out a study to find the integrated effect of nutrient management on rice -wheat cropping system initiated in the year 1991 at CSK Himachal Pradesh, Palampur. They reported that the yield after 21st cycle (2011-2012), the treatment which consisted of 50% NPK & 50% green manure produced maximum rice grain and straw yields (7.37 & 6.21 t/ha, respectively) which were 16.8 and 14.8% superior over 100% NPK alone.

Rahale *et al.* (2018) worked in a long-term fertilizer experiment initiated in the year 1992 to see how inorganic, organic, agrochemicals, and biofertilizers affected the productivity of a rice-rice system in relation to changes in soil fertility. During the five years (2012-2017), their observations uncovered that the treatment receiving continuous application of NPK at 125:50:50 kg/ha in Kharif and 150:60:60 kg/ha in Rabi seasons, as well as green manure at 6.25 t/ha in Kharif and 12.5 t/ha of FYM in Rabi, and gypsum at 500 kg ha⁻¹ in both Kharif and Rabi seasons, showed greater organic carbon concentration than in the other treatments.

Singh *et al.* (2018) assessed the productivity, sustainability and profitability of the rice-wheat system using data from a long-term fertilizer experiment conducted at Pantnagar, Uttarakhand, India, started in 1984. In a randomized block design, eight treatments (application of N, NP, PK, NK, NPK, NPK + Zn, NPK + FYM, and control) were examined. The findings indicated that after 31 crop cycles, none of the treatments, excluding NPK + FYM, were able to boost soil organic carbon content over the original level, also rice and wheat both produced the best and most sustainable crop yields in case of NPK + FYM. Different treatments had a considerable impact on soil organic carbon (SOC) following the wheat crop in 2015 (after 31 years). Except for NPK + FYM (1.38), which was much higher than all other treatments along with NPK + Zn

(1.07) and NP, none of the treatments were able to sustain soil organic carbon relative to the starting level (1.20).

Majhi *et al.* (2019) reported from a 9-year-old long-term fertilizer experiment at Bhubaneswar, India with seven treatments (control, application of 100% NPK, 150% NPK, 100% NPK + Zn, 100% NPK + FYM, 100% NPK + Zn + B, and 100% NPK + Zn+S) “carried out in randomized block design with four replications” with rice-wheat and rice-rice systems resulted that the rise in soil microbial biomass carbon (SMBC) is related to increase in light carbon fraction under 100% NPK + FYM. They further suggested that continuous use of 100% NPK with 10 t FYM ha⁻¹ can perform better productivity and yield sustainability for dry season rice cultivated in acidic *Inceptisols*. Greater microbial activity resulting from the addition of mineralizable organic matter in the form of crop residues and root exudates might explain the higher proportion of various carbon components in the top 10 cm.

Anantha *et al.* (2020) studied a LTFE under a 24-year-old double rice (*Oryza sativa* L.) cropping system with different management strategies in a hot, sub-humid region of India in an *inceptisol*. They opined that varied management practices and organics sources added to soil would change the carbon allocation into numerous pools. TOC and its pools of varying oxidizabilities (very labile, labile, less labile, and non-labile pools), as well as other fractions were investigated. Their findings suggested that the quantities of the four pools of carbon were as follows: NLCF>VLCF>LCF>LLCF accounting for around 40.5, 37.2, 14.9, and 7.3 percent of Total Organic Carbon, respectively, on average and across management approaches. A larger quantity of C was preserved in passive pools (NLCF and LLCF) when nutrient management strategies were balanced and integrated. Carbon derived from microbial biomass, carbon derived from organic carbon in particles, active carbon and oxidizable organic carbon in soils under a 24-year-old double rice cropping system with different management practices in decreasing order, NPK+FYM + GM had the highest TOC

value, followed by NPK+FYM > NPK+ GM > NPK. However, as compared to the control, there was minimal difference in TOC with 100 percent N.

Mandal *et al.* (2020) made an effort to explore the carbon sequestration capability and labile pool of soil organic carbon (SOC) in flooded tropical rice under long-term fertilizer experiment initiated in 2005–06 in the central farm of Odisha University of Agriculture and Technology (OUAT) under AICRP using rice as a test crop in post kharif-2014. The treatments consisted of no fertilization, 100% N, 100% NP, 100% NPK, 150% NPK and 100% NPK+FYM. The outcomes confirmed that over the years caused a 14% decrease in SOC in unfertilized control over uncultivated soil. The carbon sequestration potential (1.77 Mg ha^{-1}) was highest in 100%NPK +FYM treatment. The greater accumulation of microbial biomass C (SMBC), water and extractable carbon (WEO-C), potassium permanganate oxidizable C (KMnO₄-C) was recorded in 100%NPK + FYM. Results reflected that 100% NPK+ FYM are adequate for maintaining SOC stock and this practice should be helpful in maintaining the sustainability of rice-rice cropping system. Among the labile pools, microbial biomass carbon (SMBC) and KMnO₄-C responded very well to fertilizer management practices. The significant relationships found among the C pools in the soil suggest that they are in a dynamic equilibrium.

Pant *et al.* (2020) found that to understand and sustain the health and productivity of soil in the Himalayan region, a thorough examination of soil organic carbon (SOC) and SOC pools as modified by long-term fertilizer usage in a stable crop cycle was required near Uttarakhand, India. The dynamics of SOC pools, viz total soil organic carbon (TOC) and its various components were studied over 42 years in a rice-wheat cropping system exposed to diverse fertilizer management tactics. The soil at the test location was an *Aquic Hapludoll*, with a poorly drained silty clay loam (1–1.5 m deep) above loamy to sandy layers. Over a 42-year period, applying 100 % NPK+ FYM was the most successful management strategy for increasing organic C in soil depths ranging from 0 to 60 cm in the rice-wheat sequence. At all four soil levels, the

combination of this integrated input application (100 % NPK + 15 t ha⁻¹ FYM) considerably increased total organic carbon, microbial biomass carbon (MBC), particulate organic carbon (POC), KMnO₄ oxidizable C, Humic C, Fulvic C, water-soluble carbon, and hot water extractable carbohydrates. Carbon fractions acquired in different amount was more pronounced at 0–15 cm depth than within subsurface region. Treatment NPK with FYM witnessed 158% and 144% increased concentration of TOC at all depths after the harvest of rice & wheat, respectively. As a result, 100 percent NPK + 15 t ha⁻¹ FYM was discovered to be the most promising therapy for retaining various carbon fractions. in rice-wheat cropping system.

2.3 The effect of inorganic fertilization and FYM application on biological properties of soil.

The microbial population plays a key function in the environment since microorganisms are engaged in nearly 90% of soil activities. Because the size, activity, and structure of the soil microbial population are so essential in controlling soil activities such as organic matter decomposition and nutrient cycling, a better knowledge of the mechanisms that affect their size, activity, and structure is crucial. (Masto *et al.* 2006).

Katkar *et al.* (2011) when compared to 150 % NPK without organics found that adding NPK+FYM @ 10 t/ha enhanced soil microbial biomass carbon (SMBC) and dehydrogenase activity by 8.8% and 9.0%, respectively.

Wanjari *et al.* (2013) reported that according to research, nutrition management has an impact on enzymatic activity. The greater microbial population on balanced nutrient application at Akola is supported by the evolution of CO₂-C with corresponding presence of soil microbial biomass carbon (SMBC) in bigger quantities. CO₂-C and SMBC evolution is occurring in lockstep with the population of these species. The discovery of a higher level of dehydrogenase activity (DHA) confirms the findings, as DHA activity provides an overall measure of soil biological health. Microbial biomass

carbon was found to be greater in the FYM modified treatment at Barrackpore. It implies that fertilizer application is beneficial. Similarly, fertilizer use has no negative impact on biological health at Bhubaneswar. Over and above NPK, amending soil with lime and FYM boosted the microbial population in these soils, as demonstrated by increased SMBC and SMBN.

Geisseler *et al.* (2014) opined that SOC and MBC are key indices of soil health and both have risen as a result of inorganic fertilizer usage.

Patra *et al.* (2020) concluded from an experiment conducted at Assam Agricultural University, Jorhat. DHA (dehydrogenase activity) in soil increased significantly after harvesting of rice where enriched compost was applied @ 1 and 2 t ha⁻¹, respectively. The increase in DHA of soil was 97.9% in treatment 25% NP + 100% K + enriched compost @ 2 t ha⁻¹ and 85.2% in 50% NP + 100% K + enriched compost @ 1 t ha⁻¹ treated plot over control in the surface layer. Similar results were also reported by Bhattacharyya, Chakrabarti, and Chakraborty (2005) who reported that the incorporation of organic manure maximized the DHA because decomposition of added material gave the impetus to both intra and extracellular enzymes to multiply and simultaneously increasing microbial activity in the soil.

CHAPTER-III

MATERIALS AND METHODS

The current study entitled “**Studies on soil organic carbon fractions in relation to nutrient management practices on rice –wheat cropping system in a Vertisol.**” was conducted during *kharif* season, 2020. This chapter briefly describes the details of the experiment, including the meteorological conditions, the materials utilized, and the procedures employed throughout the experimentation.

3.1-Experimental site

The experimental field was selected from the long-term studies running under AICRP on STCR since *kharif* 2007 in *Vertisol* with rice-wheat cropping system at the Instructional farm, Department of Soil Science and Agriculture Chemistry, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The current study was taken for *kharif* 2020 with rice crop to evaluate the different carbon fraction and biological properties.

3.2 Geographical situation

Raipur is geographically located in the heart of Chhattisgarh, between 21⁰ 16'N latitude and 81⁰ 60'E longitude, at a mean sea level of 289.56 meter. The Research Farm is located on NH 6 in Raipur's eastern corner between 20⁰ 4' North Latitude and 81⁰ 39' East Longitude, at an elevation of 293 meter above mean sea level.

3.3 Climatic condition

The region has a sub-humid climate and receives 1200-1400 mm of rainfall per year, with roughly 88 percent of it falling during the rainy season (June to September). The warmest month is May, while the coolest month is December.

During the rainy season, the rainfall pattern varies greatly from year to year. During the summer, the temperature often reaches 43.8 degrees Celsius. The weekly averages of meteorological observations during the span of investigation recorded at Agrometeorological observatory, Indira Gandhi Krishi Vishwavidyalaya, Raipur are presented in appendix A and depicted through Fig no :3.1

3.4 Soil characteristics

Kanhar is the local name for the experimental soil. It's a hyperthermic montmorillonitic fine montmorillonite. The Arang II series of *Udic chromustert* is found in the *Vertisol* order. Due to the existence of lime concentrations, it is generally deep, with more than 44.8 percent clay content, dark brown to black in colour, and neutral to alkaline in reactivity. Table 3.1 gives the fertilizer prescription equations derived for rice in *Vertisol* during previous season which were taken for fertilizer doses based on soil testing in different targeted yield treatments. Table 3.2 gives the fertilizer doses for different targeted yield-based treatments based on the soil test levels of different treatment plots.

Table3.1: Targeted yield equation used

Crop	Soil	Targeted yield equation	Range of YT (Qt/ha)
Rice (MTU 1010)	<i>Vertisol</i>	$FN = 4.05T - 0.57SN - 0.78 ON$ $FP = 1.46 T - 3.09 SP - 0.31 OP$ $FK = 1.61 T - 0.10 SK - 0.14 OK$	40-60

Table3.2: Treatment wise doses of fertilizers applied in the experiment.

Treatments	Initial soil status			Fertilizer dose applied		
	Av. N	Av. P	Av. K	FN	FP	FK
Control	169.1	6.70	427.67	0	0	0
GRD	170.3	23.2	488.21	100	60	40
YT 5t /ha	183.4	20.8	490	98	9	32
YT 6t/ ha	185.8	23	504	137	17	46
YT 6t/ha with F YM 5t/ha	195.5	24	545	116	9	37

GRD= General recommended dose (kg/ha for N, P₂O₅, K₂O), FN= Fertilizer nitrogen (kg/ha); FP= Fertilizer phosphorus (kg/ha); FK= Fertilizer potassium (kg/ha); T= Targeted yield (q/ha); ON= Organic nitrogen, OP= Organic Phosphorus and OK= Organic Potassium through FYM, FYM= Farm yard manure (tones). STCR= Soil Test Crop Response,

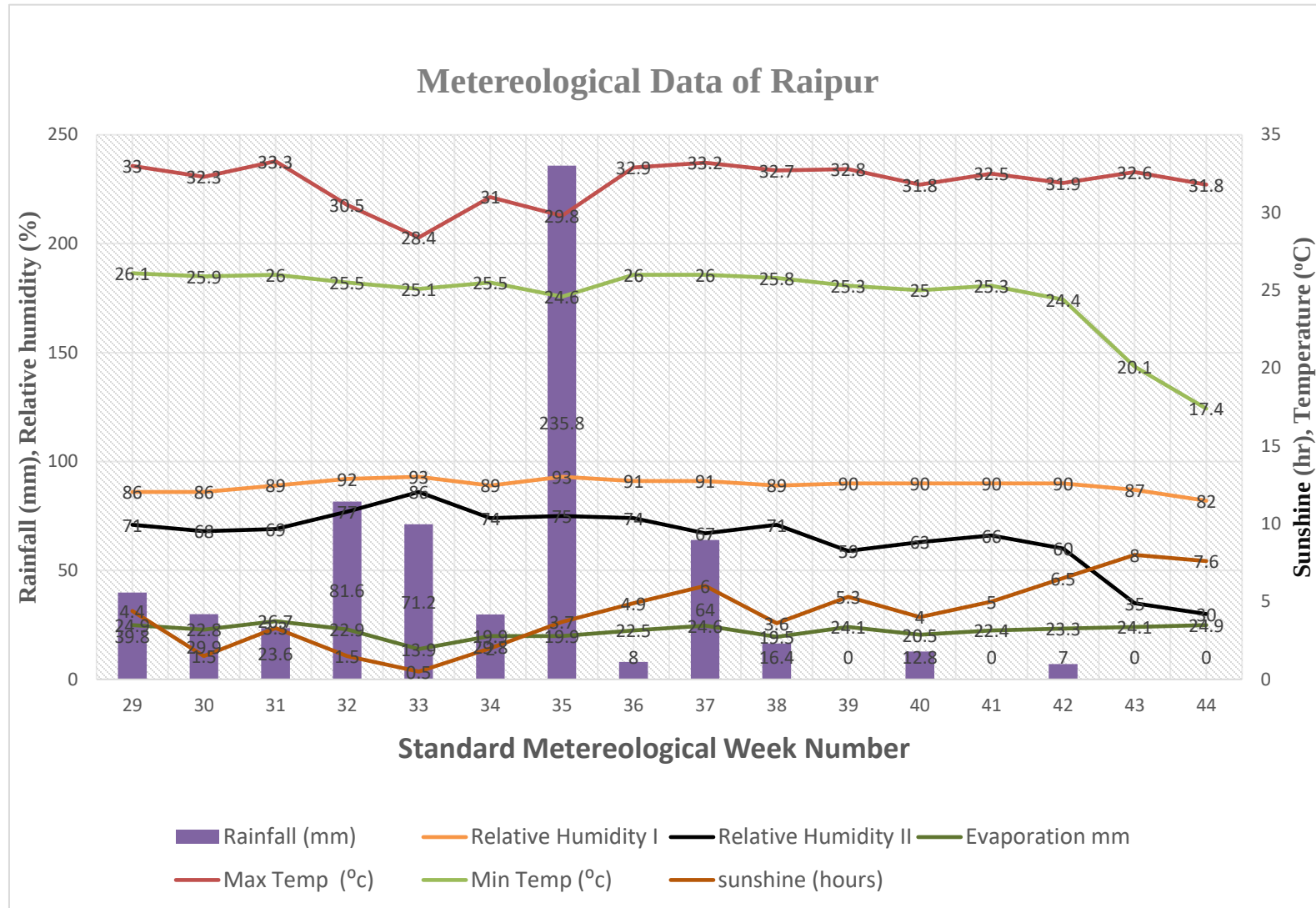


Fig 1 Meteorological data during the crop growth period (weekly) in *Kharif* 2020

Table 3.3 – Properties of the Soil

Particulars		Values	Status/ Remark
I. Physical properties			
1	Sand (%)	26.4	-
2	Silt (%)	28.8	-
3	Clay (%)	44.8	-
4	Soil textural class	Clay	<i>Vertisol</i>
5	Bulk density (Mg m^{-3})	1.35	-
II. Chemical properties			
1	pH (1:2.5)	7.88	Alkaline
2	EC (dSm^{-1} at 25°C)	0.20	Non-saline
3	Organic carbon (%)	0.47	Medium
4	Average Available N (kg ha^{-1})	217.3	Low
5	Average Available P_2O_5 (kg ha^{-1})	19.3	Medium
6	Average Available K_2O (kg ha^{-1})	498.0	High
7	Average Available Fe (mg kg^{-1})	27.54	Sufficient
8	Average Available Zn (mg kg^{-1})	11.57	Sufficient
9	Average Available Cu (mg kg^{-1})	2.57	Sufficient
10	Average Available Mn (mg kg^{-1})	3.25	Sufficient

Table 3.4 Experimental Details

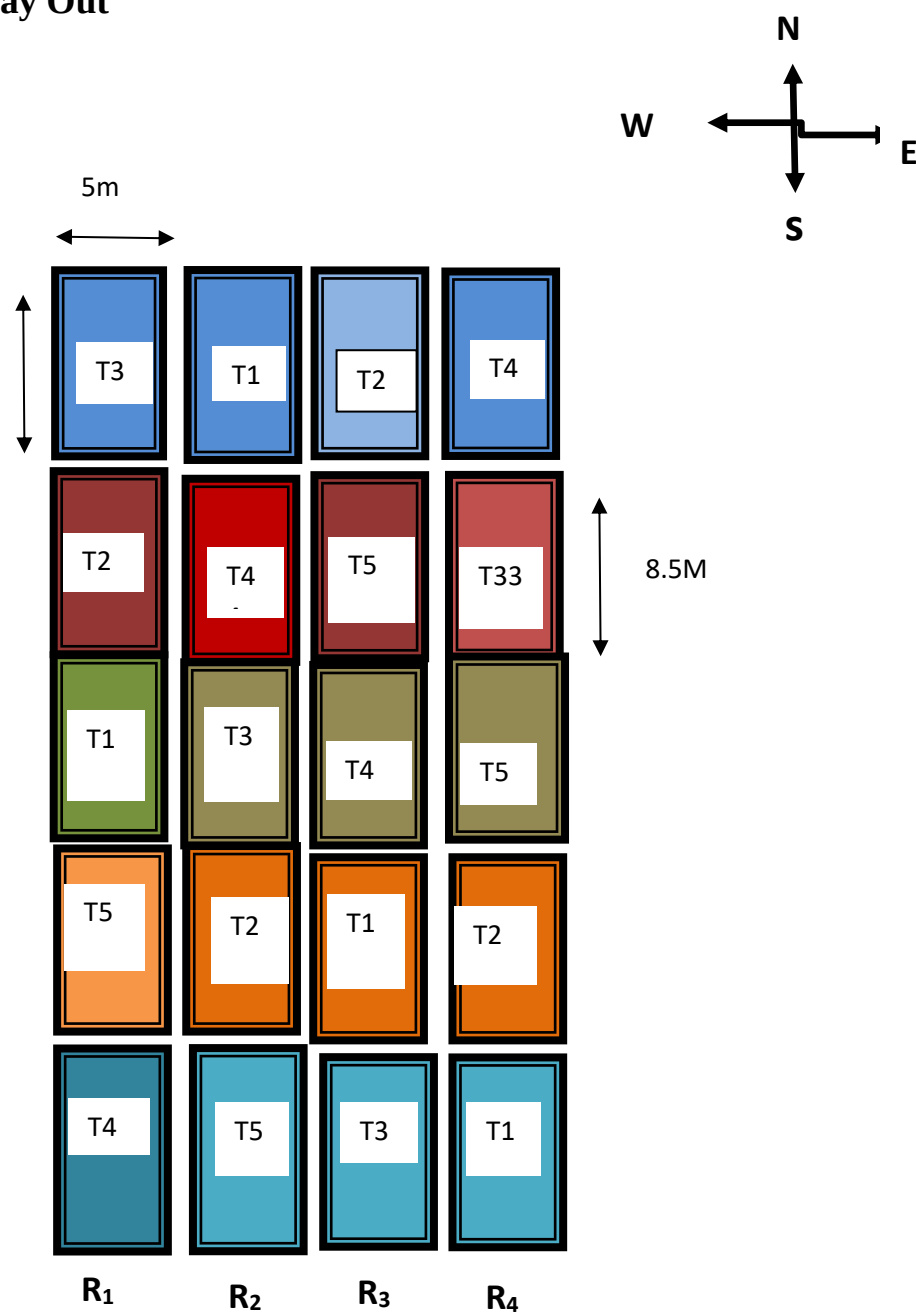
Location	Research farm, I.G.K.V, Raipur (C.G)
Soil Type	<i>Vertisol</i>
Year of Start	2007-08
Year of Study	2020
Season	Kharif 2020
Crop	Rice (<i>Oryza sativa</i>)
Variety	MTU-1010
Plot Size	42.5 m²
Spacing	Row ×Plant (5m ×8.5m)
Treatments	5
Replications	4
Design	RBD
Nursery date of Rice	18/ 06/2020
Transplanting date	23/07/2020

Table 3.5: Treatment details

S. No	Treatments Symbol	Treatments brief	Treatments detail
1	T1	Control (0-0-0)	Control (N ₀ P ₀ K ₀)
2	T2	GRD (100:60:40)	General Recommended Dose (100:60:40 kg of N P ₂ O ₅ :K ₂ O/ha)
3	T3	STCR dose for YT 5 t/ha	STCR Fertilizer dose to achieve a Yield Target of 5 t/ha (98:9:32 kg of N, P ₂ O ₅ and K ₂ O/ha)
4	T4	STCR dose for YT 6 t/ha	STCR Fertilizer dose to achieve a Yield Target of 6 t/ha (137:17:46kg of N, P ₂ O ₅ , K ₂ O/ha)
5	T5	STCR dose for YT 6t/ha (with 5t FYM)	STCR Fertilizer dose with 5t/ha FYM application to achieve a Yield Target of 6 t /ha (116:9:37 kg of N, P ₂ O ₅ and K ₂ O/ha)

Where, GRD=General Recommended Dose (kg/ha for N, P₂O₅, K₂O), STCR= Soil Test Crop Response, YT= Yield Target (q/ha), FYM= Farm Yard Manure (t)

3.5 Lay Out



3.6 Soil sample collection, processing and analysis

The soil samples were collected from the surface (0–15cm) after harvesting of rice (2020) from all plots. The collected soil samples were used to analyze different parameters of soil quality. From the collected soil sample some parts were air-dried, crushed and passes through 2 mm sieve. Another part of the moist soil was kept in the refrigerator to determine the biological parameters.

The processes soil sample analyzed for various physical, chemical and biological parameters.

3.7 Soil chemical parameters

3.7.1 Soil pH: Soil pH was analyzed by glass electrode pH meter in 1:2.5 soil-water suspensions as described by Piper (1967)

3.7.2 Electrical conductivity: The sample used for pH determination was considered for EC and was determined after it had been allowed to settle for 24 hours. The electrical conductivity of the supernatant liquid was calculated using a conductivity meter (Black, 1965).

3.7.3 Available N: The alkaline potassium permanganate technique for determining available nitrogen in soil was estimated as suggested by Subbiah and Asija (1956).

3.7.4 Available P: Soil available P was measured using 0.5M NaHCO₃ (pH 8.5) as an Olsen extractant recommended by Olsen *et al.* (1954).

3.7.5 Available K: Soil available potassium was extracted by shaking for 5 minutes with neutral normal ammonium acetate and potassium in the extract was measured using a flame photometer (Hanway and Heidel, 1952).

3.7.6 Soil Oxidizable Organic Pools

In order to understand different carbon pools in soil, we adopted modified Walkley and Black as proposed by Chan, (2001). The determination of oxidizable carbon was done by using 5 and 10 ml of concentrated sulphuric acid instead of the 20 ml specified by Walkley and Black, (1934). The resulting three acid- aqueous solution ratios of 0.5:1, 1:1 and 2:1 (which corresponded to 12 , 18 , and 24 N, respectively of H₂SO₄) allowed comparison of oxidizable organic carbon extracted under increasing oxidizing conditions (Walkley, 1947). There are four pools of total organic carbon:

Pool 1 (Very labile carbon) - (12 N H₂SO₄) - Organic carbon oxidizable under 12 N H₂SO₄.

Pool 2 (Labile carbon) - (18 N-12 N H₂SO₄) - The difference in oxidizable organic carbon extracted between 18 N and 12 N H₂SO₄.

Pool 3 (Less labile carbon) - (24 N-18 N H₂SO₄) - The difference in oxidizable organic carbon extracted between 24 N and 18 N H₂SO₄. The 24 N H₂SO₄ is equivalent to the standard Walkley-Black method.

Pool 4 (Non-Labile carbon) - (TOC-24 N, H₂SO₄) - Residual organic carbon after reaction with 24 N (TOC-24 N H₂SO₄) - residual organic carbon after reaction with 24 N H₂SO₄ when compared with the total carbon determined by the TOC analyzer.

As TOC analyzer, could not be arranged due to covid-19 crisis, the total organic and inorganic carbon were determined by using the soil filtered with 0.1 N HCl to assess the inorganic carbon followed by sun-drying and heating at 600°C in platinum crucible in a muffle furnace to find out the weight loss which subsequently determined in total organic carbon in percentage (Benby *et al.* 2005).

3.8 Soil Biological Parameters

3.8.1 Dehydrogenase Activity

Dehydrogenase activity was determined by Casida *et al.* (1964). Three gm of field moist soil samples were taken in test tubes. Another test tube was taken without soil to prepare a control. 0.2 gm. of CaCO₃, 1 ml of 3% 2, 3, 5-triphenyl tetrazolium chloride (TTC) and 2.5 ml of distilled water were added in the test tubes. Swirl the test tubes content and placed them in an incubator with a stopper at 37°C for 24 hours. The red color was appeared due to the reduction of 2, 3, 5-triphenyl tetrazolium chloride into triphenyl formazan (TPF). Filtered suspension was taken into 100 ml of volumetric flask. The tubes were washed repeatedly with methanol and quantitatively transferred the supernatant until the reddish color disappears. Diluted the filter with methanol to 100 ml and measured the intensity of the red color in a spectrophotometer at 485 nm wave length.

$$\text{Dehydrogenase activity } (\mu\text{g TPF g}^{-1} \text{ d}^{-1}) = \frac{(\text{S}-\text{C}) \times 100}{\text{W}}$$

S= concentration of TPF in the sample as calculated from the calibration curve,
C=concentration of TPF in control as calculated from the calibration curve,
W=Dry weight of soil (g) obtained from oven drying of the fresh soil.

3.8.2 Soil Microbial biomass carbon

Soil microbial biomass carbon was determined by the fumigation extraction method given by Jenkinson and Powlson (1976). 40 gm. fresh wet soil clod was taken and put it into the 500 ml reagent bottle. 2 ml of ethanol-free chloroform was put in the sample. 2 sets were made for one sample one fumigated and other non-fumigated. For fumigation put ethanol free chloroform in the soil makes it airtight and kept it in the dark for 24 hours. Place another non fumigated one in the refrigerator. Ethanol free chloroform was made by washing the chloroform twice with concentrated H_2SO_4 (each with the equal volume of chloroform) and discard the acid carefully after phase-separation. Washed twice with the same volume of distilled water similarly to make the ethanol free chloroform and collect the bottom whitish phase. After 24 hours released the cork, take out the beaker containing chloroform. After 30 minutes, 25 ml of 0.5 M K_2SO_4 was added and shaking for half an hour. After shaking the suspension was filtered and 10ml of the filtrate was transferred in a 500 ml conical flask. Then 2 ml of $K_2Cr_2O_7$, 10 ml of concentrated H_2SO_4 and 5 ml of orthophosphoric acid were added to each flask. The blank was also run with 10 ml distilled water each along with the same procedure mentioned above. The flasks were kept on a hot plate at $150^\circ C$ for half an hour under refluxing condition. Then the flasks were taken out and about 250 ml of distilled water added immediately. The contents were allowed to cool down and then two to three drops of Diphenylamine indicator were added. The contents were titrated against 0.005 M ferrous ammonium sulphate to get an ocean blue endpoint.

Microbial biomass carbon in soil was calculated as

$$SMBC = \frac{(CF - CUF) \mu g \text{ } g^{-1} \text{ dry soil}}{0.45}$$

Where, CF= Total weight of extractable C in a fumigated sample ($\mu\text{g C ml}^{-1}$),
CUF = Total weight of extractable C in Non-fumigated sample ($\mu\text{g C ml}^{-1}$)

3.8.3 Soil Microbial Biomass Nitrogen

Microbial biomass nitrogen was determined by chloroform fumigation and extraction method (Brooks *et al.*, 1985) in which soil was similarly fumigated like in SMBC, followed by extraction with 0.5 M K_2SO_4 . The difference between N content of fumigated and un-fumigated soil was expressed as microbial biomass N. For this purpose, 10 ml aliquot was digested with 10 ml conc. H_2SO_4 after addition of digestion mixture followed by alkali distillation followed in case of total N.

$$\text{SMBN} = \frac{N_f - N_{uf}}{K_{EC}}$$

N_f = Concentration of N in fumigated sample

N_{uf} = Concentration of N in unfumigated sample

K_{EC} = Efficiency of extraction of MBN & the value is 0.68 (Brooks *et al.*, 1985)

3.9 Statistical Analysis

The experiment was laid out in Randomized Block Design (RBD). All data sets were analyzed using analysis of variance (ANOVA) as described by Gomez and Gomez (1984). The level of significance used in “F” test was given at 5%. Critical difference values have been given in the table at 5% level of significance. The skeleton of analysis of variance and formula used for various estimations are given below:

Table 3.6: The skeleton of the analysis of variance

Source of variation	DF	SS	MSS	F cal	F tab (5%)
Replication (r)	(r-1)	RSS	RMS	RMS/EMS	
Treatment (t)	(t-1)	TrSS	TrMS	TrMS/EMS	-
Error	(r-1) (t-1)	ESS	EMS	-	
Total	rt-1	TSS	-	-	-

The following formula was used for standard error, critical difference and coefficient of variance estimations:

$$(a) \text{SEm} \pm = \sqrt{EMS/r}$$

$$(b) \text{CD} = \text{SE}(m) \times \sqrt{2} \times t \text{ value at 5\% error (df)}$$

$$(c) \text{CV (\%)} = \sqrt{SEM/GM} \times 100$$

Where,

R = Number of replication

T = Number of treatment

DF = Degree of freedom

SS = Sum of square

MSS = Mean sum of square

Sem($\pm$) = Standard error of mean

EMS = Error mean squares

CD = Critical difference

CHAPTER-IV

RESULTS AND DISCUSSION

In this chapter, the results obtained from the experiment entitled **Studies on soil organic carbon fractions in relation to nutrient management practices on rice-wheat cropping system in a *Vertisol*** are widely discussed with the help of review literature and different statistical tables and graphical figures related to numerous soil attributes contributing to this below discussion i.e. physicochemical and biological properties after harvesting of rice, kharif -2020.

4.1-Effect of nutrient management practices on physicochemical properties of soil.

4 .1.1- Soil pH and EC

Effect of various nutrient practices i.e. alone inorganic fertilization (GRD, STCR approach for 5 and 6 t/ha yield target, with and without organic manure on pH and EC after harvesting of rice are presented below

The data on soil reaction (pH) and EC as shown in the Table 4.1.1 after harvesting of rice had no statistical effect. Highest pH value was noticed in T4 among all treatments (7.83), which has received inorganic fertilizers as per STCR based dose for 6 t ha⁻¹ whereas lowest value was observed with the treatment that received the application of FYM and STCR based application of inorganic fertilisers to achieve 6 t ha⁻¹ yield. The highest value for EC was found to be with T3 and T5 i.e STCR based inorganic fertilizers application for yield target of 5 t/ha and STCR based inorganic fertilizer application along with 5 t/ha of FYM for yield target of 6 t/ha.

The lowest value (7.57) in case of pH was found in T5, which might be due to release of various organic acids as FYM was mineralized, though it remained non-significant due to buffering capacity of soil. Similar trends were also observed by other workers like Jadhao *et al.* (2014), Challa *et al.* (2015).

The lowest value in case of pH was found in T5, (7.57), it might be due to release of various organic acids as FYM was mineralized, though it remained non-significant due to buffering capacity of soil. Exact trends were also observed by Jadhao *et al.* (2014) and Challa *et al.* (2015).

Table 4.1.1 Changes in soil pH and EC in relation to different nutrient management practices after rice in rice-wheat cropping system.

	Treatments Details	pH	EC (dSm ⁻¹)
T1	Control	7.70	0.16
T2	GRD (100:60:40)	7.73	0.18
T3	YT 5 t/ha (98:09:32)	7.75	0.19
T4	YT 6t /ha (137:17:46)	7.83	0.18
T5	YT 6t/ha (116:09:37)	7.57	0.19
	+FYM 5 t/ha		
	SE m(±)	0.05	0.01
	CD at 5%	NS	NS

4.1.2- Status of post-harvest available N, P and K in soil

The data presented in Table 4.1.2 and depicted in Figs.4.1, 4.2 & 4.3 regarding status of available N, P and K in soil after harvesting of rice in kharif 2020 show that application of long-term fertilizer nutrients significantly differed in macronutrient status of soil.

The available N was recorded in the range from 164 to 199 kg/ha and in treatment T5 that received the fertilizer dose to achieve a yield target of 6 t/ha along with 5 t/ha FYM showed significantly higher status of available N (199 kg/ha) followed by T4, T3, T2 and T1. The overall status of available N was found in low rating and numerical increment with in the low rating for this nutrient had no practical importance as a source of soil nutrient. However, with the application of fertilizer N as 93 kg/ha applied with FYM which roughly contributed around 25 kg/ha N to build

up to available N at higher value. Contrary to this, in T4 treatment that received 115kg/ha N through chemical fertilizers recorded 189 kg/ha of available N which was less than the T5 treatment. This might be due to various losses of applied fertilizer N through various mechanisms as volatilization, leaching, nitrification and de-nitrification etc. Control plot had the least value of available N among all the treatments. Lesser effect of treatments on available N was quite evident. This type of trait was observed by other workers like Xiaoguang *etal.*(2020), and Jadhao *et al.*(2019).

The data recorded on available P under different nutrient management practices as shown in Table 4.1.2 revealed that treatment (T2) that received GRD of fertilizer N, P and K (80:60:40) produced significantly highest available P (26 kg/ha) which may be due to continuous application of fertilizer P @60 kg/ha without considering the soil test level of P. The next treatment T5 that received the fertilizer dose to achieve a yield target of 6 t/ha along with 5 t/ha FYM ranked second in available P followed by T4, T3 and T1. The lowest available P status was found in T1 (control) viz 6.4 kg/ha⁻¹, where no external application of fertilizers (organic or inorganic) is being given since last seven year or 13th crop cycle. Other workers like Dadhich *et al.* (2011), Patel *et al.* (2018), Xiaoguang *et al.* (2020) also observed the similar results at various soil types with crops.

The available K level in soil after rice is ranged from 416 to 543 kg/ha from control to T5 that received the fertilizer dose to achieve a yield target of 6 t/ha along with 5 t/ha FYM⁻¹ followed by T4 and T3. The minor changes in available K recorded due to less crop response to applied fertilizer K as the experimental field had well native K. Although available K data showed statistically significant but its practical importance is almost negligible. The superiority of T5 over any other treatments was due to the fact that higher amount of K was added to the soil through the organic source over the years to achieve the target yield. Similar results were also reported by Jadhao *et al.* (2019) & Xiaoguang *et al.* (2020).

Table 4.1.2 Available soil macronutrients under different nutrient management practices

Treatments details		Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)
T1	Control	164e	6.42e	416d
T2	GRD (100:60:40)	173d	26.0a	470c
T3	YT 5 t/ha (98:09:32)	179c	18.4d	485c
T4	YT 6t /ha (137:17:46)	189b	22.0c	508b
T5	YT 6t/ha (116:09:37) + FYM 5 t/ha	199a	24.0b	543a
	SEm(±)	3.65	0.35	7.49
	CD (P=0.05)	10.82	1.04	22.18

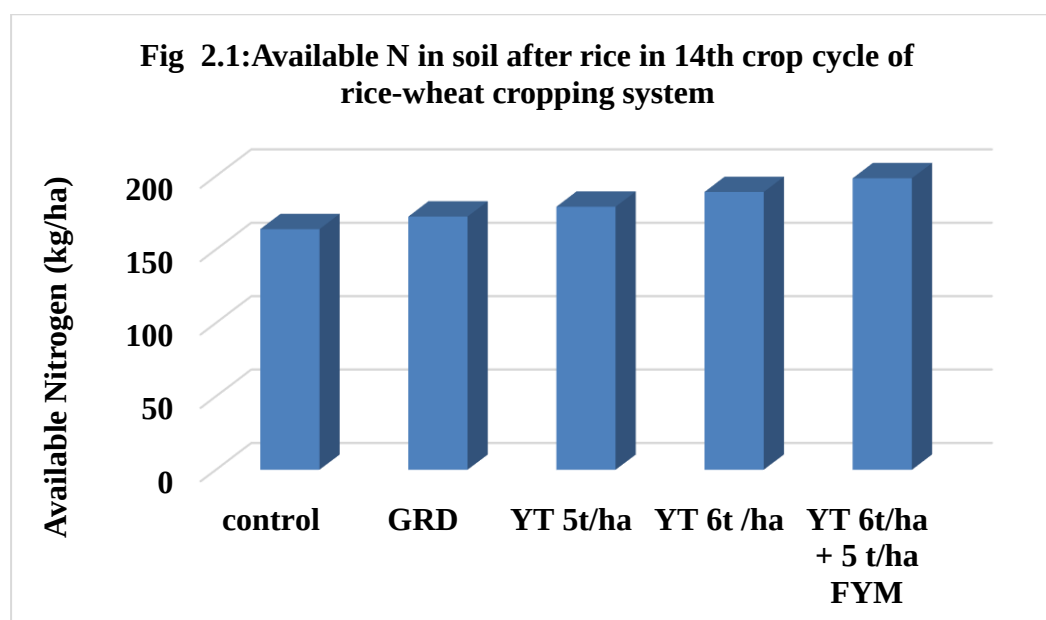


Fig 2.2:
Available P in soil after rice in rice-wheat cropping system

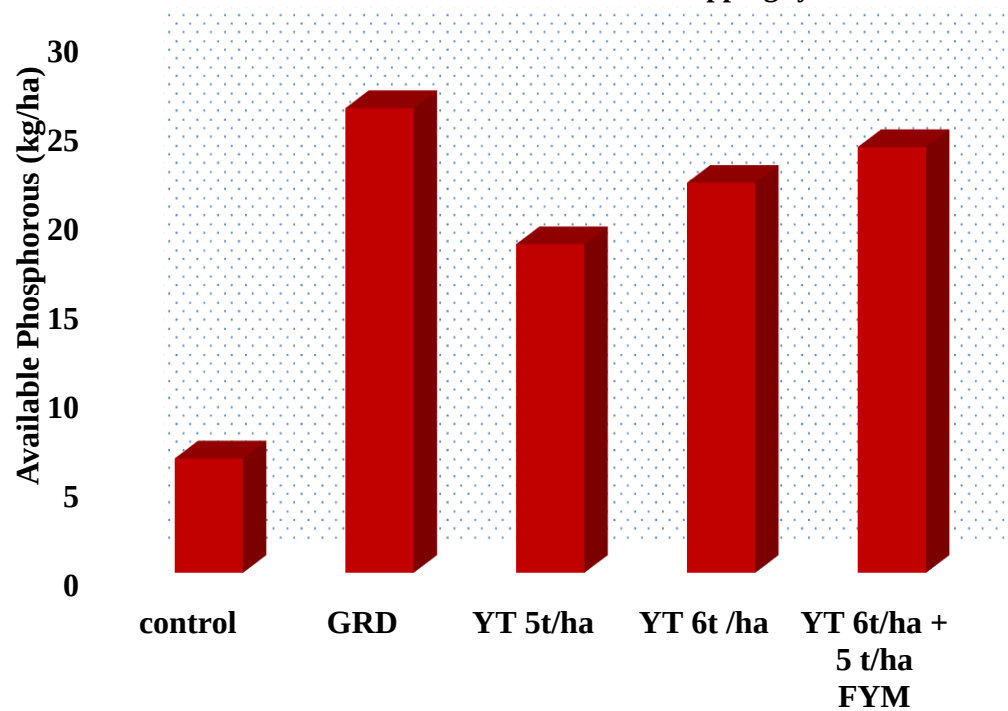
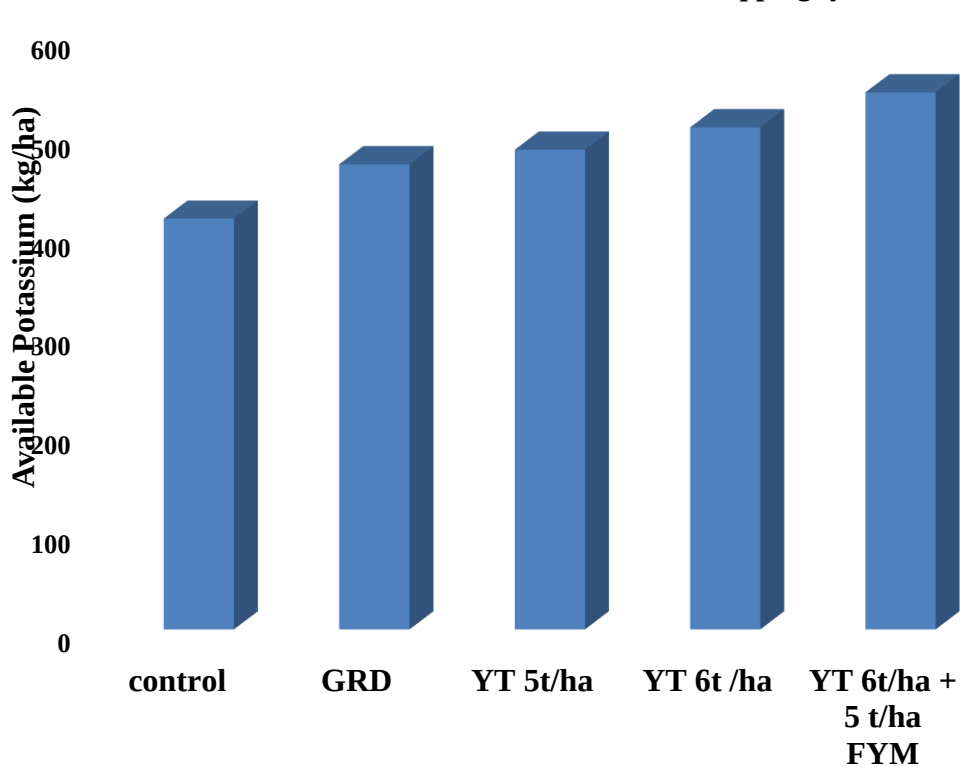


Fig 2.3:
Available K in soil after rice in rice -wheat cropping system



4.2: Effect of different nutrient management practices on biological properties of soil

4.2.1- Soil microbial biomass carbon (SMBC) , Soil microbial biomass nitrogen (SMBN) and DH Activity

Table 4.2 indicate that SMBC and SMBN in soil under study significantly varied with nutrient management practices. The STCR based fertilizer application with FYM (T5) significantly enhanced the level of SMBC and SMBN and found in the desired range of their ratio (9-8). These two parameters were the next in their levels under other treatments (T4, T3 & T2) and statistically at par. Control plot had shown the least value for both SMBC and SMBN as there was no external application of either any carbon source through organic manure or any sorts of inorganic fertilizers addition. The dehydrogenase activity status recorded after the harvest of rice was significantly increased in T5 that received the fertilizer application along with FYM for 6 t/ha yield target than all other treatments. Its higher level is clearly indicated due to internal build-up of microbial population enhanced by INM approach adopted continuous for the last 13th crop cycle which might have increased substrate utilised by microbial community causing substantial elevation in dehydrogenase activity. This finding is in agreement with other scientists like Wanjari *et al.* (2013) and Patra *et al.* (2020).

Table 4.2 Effect of different nutrient management practices on SMBC, SMBN, De-hydrogenase (DH) activity after rice.

Treatments Details		SMBC (mg/kg soil)	SMBN (mg/kg soil)	DH activity (µg TPF/g soil /day)
T1	Control	220.72c	27.29c	26.59c
T2	GRD (100:60:40)	329.07b	36.32b	35.72b
T3	YT 5 t/ha (98:09:32)	337.88b	36.52b	36.5b
T4	YT 6t /ha (137:17:46)	336.76b	34.79b	37.99b
T5	YT 6t/ha (116:09:37) + FYM 5 t/ha	395.36a	46.85a	46.28a
	SEm(±)	5.35	1.28	0.83
	CD(P=0.05)	15.85	3.8	2.45

Fig 3: Variation in SMBC and SMBN under different nutrient management practices after harvesting of rice in rice-wheat cropping system in a *Vertisol*

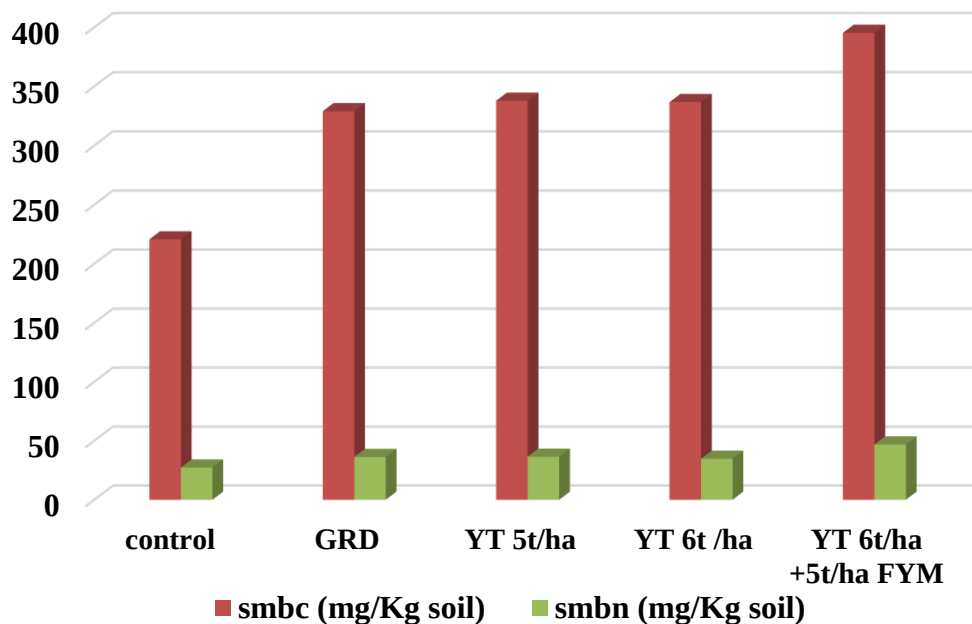
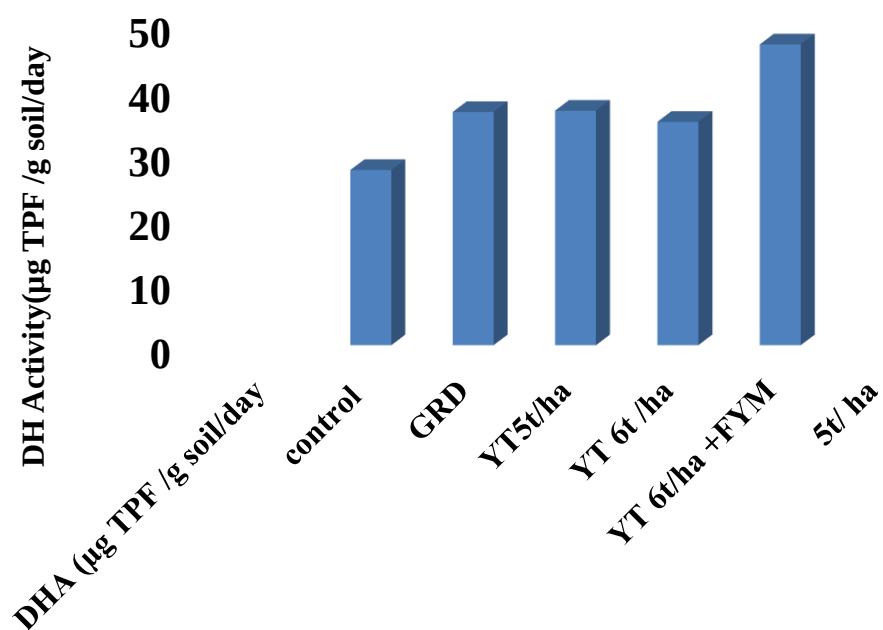


Fig 4: Variation in DH activity ($\mu\text{g TPF /g soil/day}$) under different nutrient management practices after harvesting of rice in rice-wheat cropping system in a *Vertisol*



.4.3 Effect of different nutrient management practices on organic carbon fractions.

Soil organic carbon (SOC) is the carbon found in the SOM accounting for roughly 58 percent of the total organic mass. The oxidizable total soil organic carbon is divided into several fractions, each with a different degree of breakdown, recalcitrance, and turnover rate.

These fractions have different biochemical and microbial degradation rates, as well as different levels of sensitivity to changes in climatic and ecological conditions. Presence of different SOC fractions in soil is a key factor in the processes of nutrient cycling and availability, soil aggregation, stability and soil carbon accumulation. Wet oxidation method was used to quantify the oxidizable soil organic carbon (Walkley and Black 1934). The modified Walkley and Black technique, as detailed by Chan *et al.* (2001) was used to divide this into four pools i.e very labile fraction (VLF), labile fraction (LF), less labile fraction (LLF), and non-labile fraction (NLF).

Long-term experiment is also used to track variations in TOC pools caused by cropping patterns, soil management methods, fertiliser application, and residue management among other things. Various studies have demonstrated that different soil management regimes may have a significant impact on TOC labile pools, and that these impacts are dependent on a variety of factors, including regional climate, soil type, residue management technique, and crop production. As a result, unique soil/climate/cropping systems must be identified when studying the mechanisms and kinetics of soil C sequestration. Furthermore only a few studies have looked at the effects of farmland relinquishment and cropping practises on labile TOC pools (Majumdar *et al.* 2008), which may motivate efforts to improve soil quality in specific locations.

4.3.1: Very Labile Carbon Fractions VLCF)

Table 4.4 suggested that in case of T5 viz one where FYM was applied along with inorganic fertilizers showed the highest value of very labile carbon percentage i.e. (0.49%). No other treatments were at par with T5. The control plot (T1) quantified the lowest among all the treatments as there was no addition of any sorts of inorganic

or organic fertilizers. Other treatments (T3, T4, T2) were statistically at par with lesser intra-variation among them. The outcomes of the researches done by Anantha *et al.* (2020), Babu *et al.* (2020) were certainly in tune with the findings of this experiment.

4.3.2: Labile Carbon Fractions (LCF)

Labile carbon fraction status as shown in Table 4.4 affected significant with various nutrient management practices. Treatment T5 that received fertilizer doses for yield target of 6 t/ha recorded significantly highest value followed by T4, T3, T2 and T1. There was a little variation among the treatments although statistically significant. The control treatment demonstrated comparatively and significantly least amount while fertilized plots has little variation.

4.3.3: Less labile carbon Fractions (LLCF)

As tabulated in the Table 4.4, it is clear that less labile fractions remained the least quantified fraction of organic carbon irrespective of treatments and had the lowest values among other carbon fractions in rice – wheat cropping system in all the treatments. The variation of this fraction also followed the similar trends as with other fractions discussed above. T5 treatment showed 64% higher LLCF over control due to continuous application of soil test-based fertilizer with organic source (FYM) followed by T2 (GRD) i.e. 19% > T4 (STCR based fertilizer application to achieve 5t YT /ha > T3 (STCR based fertilizer application to achieve 6t YT /ha). The findings of the studies done by Anantha *et al.* (2020) and Babu *et al.* (2020) were certainly in tune with the findings of this experiment.

4.3.4: Non labile carbon Fractions (NLCF)

The results on Nonlabile carbon fractions (NLCF) were significant differed with respect to different nutrient management practices. The highest value of NLCF was found in case of T5 (0.55%) might be due to the 13th years of long-term application of STCR based fertilizers application with FYM to achieve 6 t/ha yield and had 37.5% more NLCF over Control. Other fertilized treatments did not have much variation statistically.

The different carbon fractions under study exhibited in the order NLCF>VLCF>LCF>LLCF showed higher values in the treatment that received soil test-based fertilization with INM to achieve the yield goal of 6 t/ha. Kundu *et al.* (2014) have reported the contribution of different carbon fractions to the Total organic carbon (TOC) varied depends on the past fertilization ranging from 35 to 40, 12 to 15, 8 to 12 and 40 to 50 percent for very labile, labile, less labile, and non-labile carbon fractions, respectively.

4.3.5: Total organic carbon Fractions (TOCF)

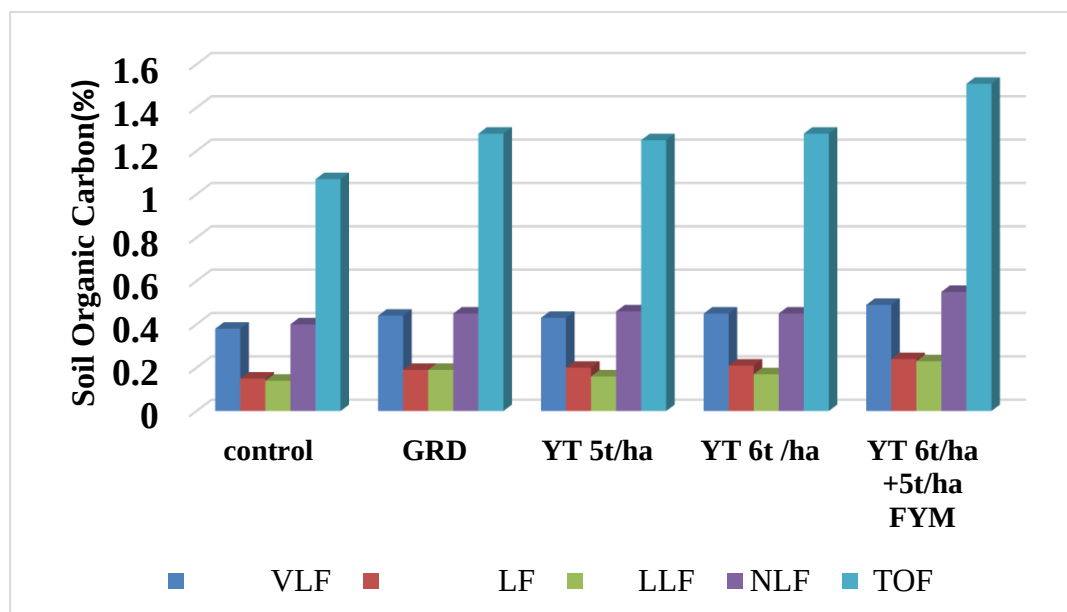
The percentage of total organic carbon fraction as given in the Table 4.4 significantly varied with different fertilizer practices. The highest TOC was recorded in case of the treatment that received FYM along with fertilizer nutrients continuously since last 13 years. The control treatment which did not received any external nutrients since last 13 years of cropping produced significantly lowest level of total organic carbon. Manna *et al.* 2007 and Ghosh *et al.* 2010) reported that if contribution of root and shoot is poor due to poor soil nutrition then total organic carbon level drastically reduced. However, if addition of plant nutrition is maintained either with inorganic or organic or INM the carbon level can be maintained in view of higher root shoot ratio

Table 4.3.: –Organic carbon fractions (%) in 0-15 cm depth in relation to nutrient management practices after harvesting of rice

	Treatments	VLCF (%)	LCF (%)	LLCF (%)	NLCF (%)	TOC (%)
T1	Control	0.38e	0.15e	0.14e	0.40d	1.07e
T2	GRD	0.44c	0.19d	0.19b	0.45c	1.21c
T3	YT 5tonne /ha	0.43d	0.20c	0.16d	0.46b	1.20d
T4	YT 6tonne/ha	0.45b	0.21b	0.17c	0.45c	1.25b
T5	YT 6 tonne /ha + 5 tonne /ha	0.49a	0.24a	0.23a	0.55a	1.51a
	SEm(±)	0.01	0.01	0.01	0.01	0.01
	CD (0.05)	0.03	0.02	0.02	0.03	0,03

*** VLCF =Very Labile Carbon Fractions, LCF =Labile Carbon Fraction, LLCF= Less Labile Carbon Fraction, NLCF=Non-Labile Fraction, TOC = Total Organic Carbon Fraction.*

Fig 5: Organic carbon fractions under different nutrient management practices in vertisol after rice.



**** VLF =Very Labile Carbon Fractions, LF =Labile Carbon Fraction, LLF= Less Labile Carbon Fraction, NLF=Non-Labile Fraction, TOC = Total Organic Carbon Fraction**

4.4 Effect of different nutrient management practices on rice grain and straw yield in rice-wheat cropping system

4.4.1 Grain and Straw Yield

The results of grain and straw yield of rice as influenced by various fertilizer practices are shown in the Table 4.4.1 The grain and straw yields of rice significantly differed with various fertilizer practices. The treatments T5 and T4 that received fertilizer nutrients for yield target of 6 t/ha with or without organic source. In both the treatments, plant nutrients have been applied based on the soil test values of N P and K with INM or only inorganic source and targeted yields have been nearly achieved as both the treatments are statistically at par. Similarly, treatments T3 and T2 that have received the nutrients with yield target based and other have received blanket application. The yield data indicated almost the same level and statistically at par. This indicate that soil test-based fertilizer application in case of T3 received less fertilizer P due to higher soil test P and produced the similar level of yield as observed with T2 treatment received blanket fertilizer application.

Organic manures provided favourable environment for microorganisms like *Azospirillum* which fixes atmospheric nitrogen available to plant and PSB which converts insoluble phosphate into soluble forms by secreting organic acids. similar results were observed by researchers around the world like Majhi *et al.* (2019), Singh *et al.* (2018), and Rao *et al.* (2017). Straw yield also showed similar pattern as seen in case of grain yield.

Table 4.4.1: Rice grain yield and Straw yield under different nutrient management practice

Treatments Details	Grain yield (q/ha)	Straw yield (q/ha)
T1 Control	14.04 c	19.15c
T2 GRD (100:60:40)	53.62b	70.56b
T3 YT 5 t/ha (98:09:32)	50.93b	67.41b
T4 YT 6t /ha (137:17:46)	58.05a	77.17a
T5 YT 6t/ha (116:09:37) + FYM 5 t/ha	60.94a	80.80a
SEm(±)	1.51	2.34
CD (P=0.05)	4.47	6.92

4.4.2 Relation of grain yield with different carbon fractions.

Table 4.4.2 gives the relationship of grain yields with different carbon fractions showed that LCF contributed maximum to the variability of grain yield followed by VLCF, LLCF and NLCF. All these fractions were indicative by the R^2 value of the best fit line regression equation. Table 4.4.3 gives the correlation of different carbon fractions with yield and indicates almost the similar trends as that with regression equations. The relationship between grain yield with different carbon fractions have been depicted graphically in the following Figs. 6.1 to 6.4

Table 4.4.2: Selected regression model to account for yield variation of rice

Sl No	Carbon Fractions	Model for Grain yield	R^2
1	VLCF	$y = 362.74 \text{ VLCF} - 111.54$	0.6185
2	LCF	$y = 466.84 \text{ LCF} - 44.913$	0.6424
3	LLCF	$327.04 \text{ LLCF} - 9.8752$	0.4252
4	NLCF	$y = 213.58 \text{ NLCF} - 50.94$	0.4172

Table 4.4.3: Correlation Coefficient of different carbon fractions with yield

Parameters	VLF	LF	LLF	NLF
Grain Yield(q/ha)	0.786**	0.795**	0.652**	0.675**

**** means significantly correlated at 1% significance level**

Fig6.1: Rice grain yield response to VLF of carbon

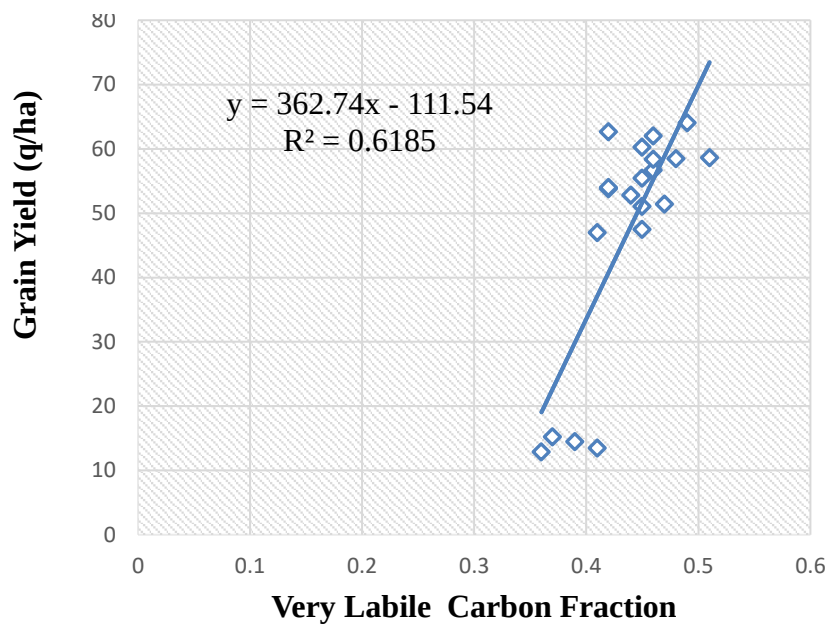


Fig 6.2: Rice grain yield response to LF of carbon

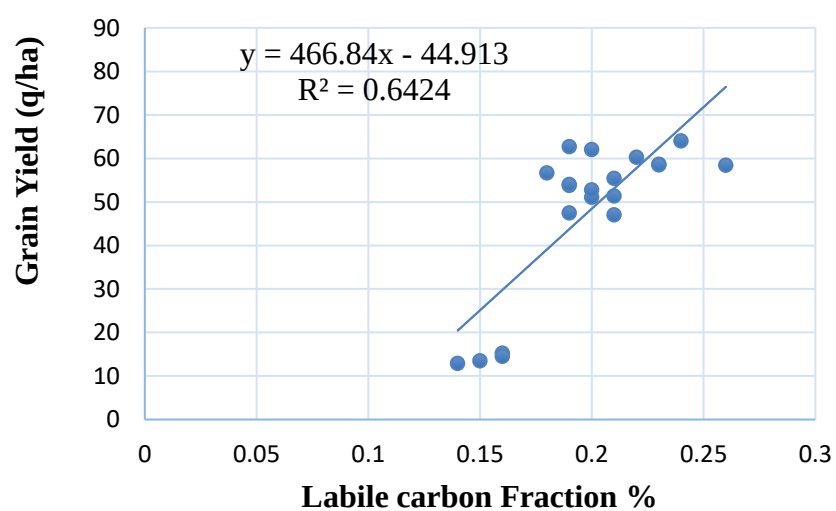
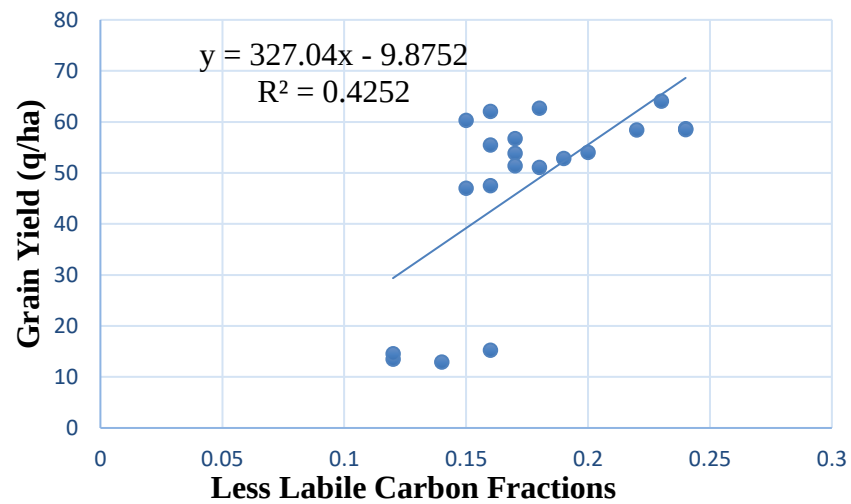
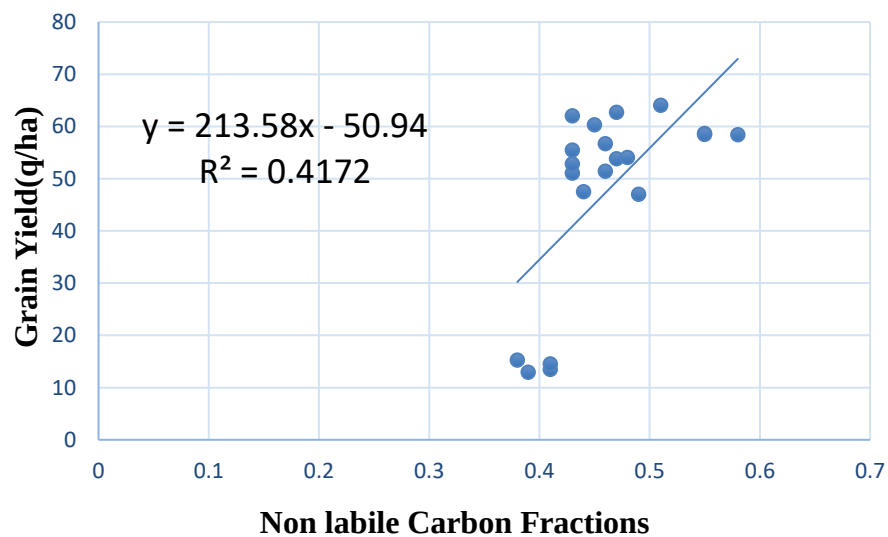


Fig 6.3: Rice grain yield response to LLF of carbon**Fig 6.4: Rice grain yield response to NLF of Carbon**

CHAPTER -V

SUMMARY AND CONCLUSION

A field experiment was conducted to study on soil organic carbon fractions in relation to nutrient management practices on rice –wheat cropping system in a *Vertisol* under a long-term experiment in rice–wheat cropping system at Instructional cum Research Farm of Indira Gandhi Agricultural University Raipur (C.G) during *kharif* season, 2020 (after 13th cycle of cropping system) with objectives i. To assess the soil organic carbon fractions as influenced by long term nutrient management practices ii. To estimate the soil biological parameter as influenced by long term nutrient practices and iii. To establish the relationship between yield and organic carbon fractions.

The experiment consisted of with five treatments viz, T1- Control ($N_0P_0K_0$), T2- General Recommended Dose (100:60:40 N: P_2O_5 : K_2O kg/ha), T3- STCR Fertilizer dose to achieve a YT 5 t/ha (98:9:32 N: P_2O_5 : K_2O kg/ha), T4 - STCR Fertilizer dose to achieve a YT 6 t/ha (137:17:46 N: P_2O_5 : K_2O kg/ha), T5- STCR Fertilizer dose with 5t/ha FYM application to achieve a YT 6 t/ha (116:9:37 N: P_2O_5 : K_2O kg/ha).

Summary

The outcomes were concisely written below to have a better and easy understanding of the results.

1. Effect of various nutrient management practices on physico-chemical properties of soil under long term fertilizer management practices.

- Soil reaction (pH) and EC after harvesting of rice had no statistical effect on various nutrient management practices. Highest pH value was noticed in T4 among all treatments (7.83), which received inorganic fertilizers as per STCR based dose for 6 t ha⁻¹ whereas lowest value was observed with the treatment that received the application of FYM and STCR based application of inorganic fertilizers to achieve 6 t ha⁻¹ yield of rice. The highest value for EC was found to be with T3 and T5 i.e STCR based inorganic fertilizers application for yield target of 5 t/ha and STCR based inorganic fertilizer application along with 5 t/ha of FYM for yield target of 6 t/ha.
- The available N was recorded in the range from 164 to 199 kg/ha. T5 that received the fertilizer dose to achieve a yield target of 6 t/ha along with 5 t/ha FYM showed significantly higher status of available N (199 kg/ha) followed by T4, T3, T2 and T1. The overall status of available N were found in low rating. Treatment T2 that received GRD of fertilizer N, P and K (80:60:40) produced significantly highest available P (26 kg/ha). The next treatment T5 that received the fertilizer dose to achieve a yield target of 6 t/ha along with 5 t/ha FYM ranked second in available P followed by T4, T3 and T1. The lowest available P status was found in T1 (control) viz 6.4 kgha⁻¹, where no external application of fertilizers (organic or inorganic) was given since last fourteen year of crop cycle. The available K level in soil after rice was recorded in the range of 416 to 543 kg/ha from control to T5 that received the fertilizer dose to achieve a yield target of 6 t/ha along with 5 t/ha FYM⁻¹ followed by T4 and T3. The superiority of T5 over any other treatments was due to the fact that higher amount of K

was added to the soil through the organic source over the years to achieve the target yield.

2. Biological properties

- The dehydrogenase activity status recorded after the harvest of rice was significantly increased in T5 (46.28 $\mu\text{g TPF/g soil /day}$). Its higher level has clearly indicated due to internal build-up of microbial population enhanced by INM approach adopted continuous for the last 13th crop cycle which might have increased substrate utilized by microbial community, causing substantial elevation in dehydrogenase activity.
- The STCR based fertilizer application with FYM (T5) significantly enhanced the level of SMBC (395.36 mgkg^{-1} soil) and SMBN (46.85 mgkg^{-1} soil) and found in the desired range of their ratio (9-8). These two parameters were the next in their levels under other treatments (T4, T3 & T2) and statistically at par. Control plot had shown the least value for both SMBC (220.72 mgkg^{-1} soil) and SMBN (27.29 mgkg^{-1} soil) as there was no external application of either any carbon source through organic manure or any sorts of inorganic fertilizers addition.

3. Organic carbon fractions under nutrient management practices

- Application of organic manure like FYM with STCR based fertilizer application to achieve a desired yield target had significant response in increasing the non-labile (0.55%) and very labile carbon fractions (0.49%) in T5. Labile fractions and less labile fractions too get enhanced with application of FYM with inorganic fertilizers. $\text{NLCF} > \text{VLCF} > \text{LCF} > \text{LLCF}$ was the trend, that followed in almost all the plots irrespective of treatments. The control treatment which did

not received any external nutrients since last 13 years of cropping produced significantly lowest level of total organic carbon. The highest TOC (1.51%) was recorded in T5 that received FYM along with nutrients through fertilizers continuously since last 13 years.

4. Grain and straw yield under different nutrient management practices

- The grain and straw yields of rice significantly differed with various fertilizer practices. The treatments T5 and T4 that received fertilizer nutrients for yield target of 6 t/ha with or without organic source have nearly achieved the yield goal within the permissible limit of 10% variation. In both the treatments, plant nutrients have been applied based on the soil test values of N, P and K with INM or only inorganic source and targeted yields have been nearly achieved as both the treatments are statistically at par. Similarly, treatments T3 and T2 that have received the nutrients with yield target based and other have received blanket application, the yield data indicated almost the same level and statistically at par. This indicate that soil test-based fertilizer application in case of T3 received less fertilizer P due to higher initial soil test P and produced the similar level of yield as observed with T2 treatment received blanket fertilizer application.

5. Relationship established among the yield and carbon fractions

- Among the four carbon fractions, LCF was significantly correlated to rice grain yield followed by VLCF > NLCF>LLCF. This explained the relationship of grain yields with different carbon fractions as LCF contributed maximum to the variability of grain yield followed by VLCF, LLCF and NLCF while establishing best fit in to the line. It was observed that R^2 value was highest for LCF followed by VLCF> LLCF>NLCF.

Conclusion

- The variation in carbon fractions under different nutrient management in the experiment suggested that irrespective of long-term application of only inorganic fertilizers or application of both organic and chemical inputs, the highest grade among those fractions has always been Non-Labile Carbon Fraction closely followed by Very Labile Carbon Fraction. Both Labile Carbon Fraction and Less Labile Carbon Fraction quantification were somehow equal in percentage of the total carbon fractions (TCF).
- Soil biological properties like SMBC, SMBN, DH activity elevated with nutrient addition by means of fertilizers and organic manure over 13 years of continuous application in comparison to control.
- Labile fraction was highly correlated with grain yield followed by VLCF>LLCF>NLCF. Regression equation suggested that yield factor variation was least dependent on NLCF which eventually suggested that contribution of non-labile carbon fraction was minimal among all other fractions to grain yield.

Suggestions for further research work

- Similar trend should be followed in case of all the biological properties like SMBC, SMBN, dehydrogenase activity, the quantification of these parameters after the harvest of wheat must be done to have a better understanding of their activities in a crop cycle.
- Development of further regression & correlation equation of different carbon fractions with respect to wheat yield in that particular crop cycle for the year 2020-21 must be done to have a proper idea about the yield variation with respect to carbon fractions.

- The present study was under taken with a single cropping system viz rice-wheat system. This study may be implemented for other cropping system prevailed in this area like wheat-cowpea, rice-moong bean, rice-chickpea, rice-linseed, rice-safflower

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APPENDIX

Dept. of Agricultural Meteorology
Indira Gandhi Agricultural University, Raipur (Chhattisgarh) - 492 012

Station: Labhandi

Weekly Meteorological Data: 2020

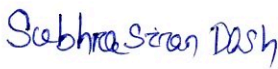
Wk No.	Date	Max. Temp. (°C)	Min. Temp. (°C)	Rain-fall (mm)	Rainy days	Relative Humidity (%)		Vapour Pressure (mm of Hg)		Wind Velocity (Kmph)	Evapo-ration (mm)	Sun Shine (hours)
						I	II	I	II			
23	Jun 04-10	37.1	25.5	44.2	3	80	38	22.8	19.7	5.3	46.0	8.7
24	11-17	34.3	25.9	62.0	2	87	69	23.5	24.1	6.6	26.9	2.3
25	18-24	30.9	24.5	156.8	5	89	72	22.1	22.9	9.8	20.5	0.4
26	25-01	33.9	26.0	20.6	2	85	68	23.7	24.9	5.7	27.3	4.2
27	Jul 02-08	33.6	25.8	95.0	3	88	66	23.7	24.6	7.5	28.9	5.4
28	09-15	33.4	25.0	67.5	3	88	74	23.3	24.0	7.2	25.5	2.8
29	16-22	33.0	26.1	39.8	3	86	71	23.5	24.5	5.9	24.9	4.4
30	23-29	32.3	25.9	29.9	2	86	68	23.2	23.5	5.5	22.8	3.8
31	30-05	33.3	26.0	23.6	2	89	69	23.9	24.8	5.9	26.7	3.3
32	Aug 06-12	30.5	25.5	81.6	3	92	77	23.3	24.3	7.1	22.9	1.5
33	13-19	28.4	25.1	71.2	4	93	86	22.8	23.8	10.4	13.9	0.5
34	20-26	31.0	25.5	29.8	3	89	74	23.0	23.2	7.8	19.9	2.0
35	27-02	29.8	24.6	235.8	4	93	75	22.6	22.9	8.2	19.9	3.7
36	Sep 03-09	32.9	26.0	8.0	2	91	74	24.3	24.8	3.0	22.5	4.9
37	10-16	33.2	26.0	64.0	2	91	67	24.2	23.4	3.4	24.6	6.0
38	17-23	32.7	25.8	16.4	2	89	71	23.1	24.5	2.9	19.5	3.6
39	24-30	32.8	25.3	0.0	0	90	59	22.9	20.4	5.1	24.1	5.3
40	Oct 01-07	31.8	25.0	12.8	1	90	63	22.3	21.6	2.6	20.5	4.0
41	08-14	32.5	25.3	0.0	0	90	66	23.0	22.6	4.4	22.4	5.0
42	15-21	31.9	24.4	7.0	1	90	60	22.4	20.4	5.0	23.3	6.5
43	22-28	32.6	20.1	0.0	0	87	35	16.8	12.7	2.1	24.1	8.0
44	29-04	31.8	17.4	0.0	0	82	30	14.0	10.3	2.2	24.9	7.6
45	Nov 05-11	30.3	12.5	0.0	0	87	28	10.8	8.7	2.1	23.5	8.5
46	12-18	32.7	18.9	0.0	0	87	37	15.7	13.6	2.9	24.9	8.5
AVG		32.38	21.99	43.88		88.29	62.37	21.70	21.25	5.35	24.1	4.6
Total		777.2	527.8	1053.2		2119	1497	520.9	510.2	128.6	580.4	110.9

RESUME

Name : Subhra Siran Dash
Father's Name : Bharat Chandra Das
Date of Birth : 07/07/1996
Permanent Address : Baulanga(A), Akhuadakhini, Patkura, Kendrapara
Phone number : 7504919468, 8260356766
Email i.d. : subhrasirandash@gmail.com

Degree	Year	University/Institute
Higher Secondary	2013	CHSE Board
B.Sc. (Ag.)	2019	COA, OUAT
M.Sc. (Ag.)	2021	COA, IGKV

Professional Experience	:	Rural Agriculture Work Experience
Award/Recognitions	:	NCC 'A', NCC 'B', NCC 'C'
Publications	:	Research Paper accepted


 Signature

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Subhra Siran Dash <subhrasirandash@gmail.com>

Manuscript Accepted: (Ref: Phyto: 10-5-96).

1 message

Pharmacognosy Journal <jpbr.delhi@gmail.com>
To: subhrasirandash@gmail.com

Fri, Oct 8, 2021 at 10:29 PM

Dear **Author**,Ref: **Phyto:10-5-96**

The manuscript titled "**VARIATION IN SOIL ORGANIC CARBON FRACTIONS ON RICE-WHEAT CROPPING SYSTEM IN A VERTISOL WITH VARIOUS TARGET YIELD APPROACH IN A LONG-TERM EXPERIMENT**" is very well written and has been accepted. **Note: After pay fee, Kindly send receipt to our mail id. You are requested not to whatsapp that receipt. Please send the complete filled copyright form.**

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