

**EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON ACTIVE
POOL OF SOIL ORGANIC MATTER IN BLACK GRAM (*Vigna mungo*)
UNDER DRYLAND SUBTROPICS OF JAMMU**

by
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**Thesis submitted to
Faculty of Agriculture
In partial fulfilment of the requirements
for the degree of**

**MASTER OF SCIENCE IN AGRICULTURE
SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**



Division of Soil Science and Agricultural Chemistry

Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu

Main Campus, Chatha Jammu-180009

2023

CERTIFICATE-I

This is to certify that the thesis entitled “**Effect of Integrated Nutrient Management on Active Pool of Soil Organic Matter in Black gram (*Vigna mungo*) under Dryland Subtropics of Jammu**” submitted in partial fulfillment of the requirements of the degree of **Master of Science in Agriculture (Soil Science and Agricultural Chemistry)** to the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is original work and has similarities with published work not more than minor similarities as per UGC norms of 2018 adopted by the University. Further the level of minor similarities has been declared after checking the manuscript with **URKUND** software provided by the University.

The work has been carried out by **Mr. Aditya Barwal**, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.

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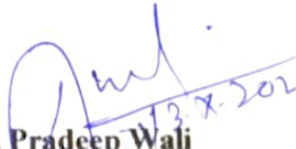


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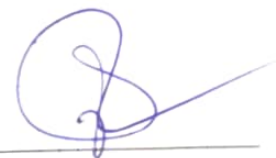
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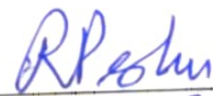
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ABSTRACT

Title of the thesis : **Effect of Integrated Nutrient Management on Active Pools of Soil Organic Matter in Black gram (*Vigna mungo*) under Dryland Subtropics of Jammu**

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Abstract

The present investigation entitled “**Effect of Integrated Nutrient Management on Active Pool of Soil Organic Matter in Black gram (*Vigna mungo*) under Dryland Subtropics of Jammu**” was carried out during *Kharif* 2022 at the Research Farm of ACRA Dhiansar, Jammu. The experiment was laid out in an RBD with three replications and nine treatments which were T₁-Control, T₂-100% recommended NPK, T₃-100% recommended NPK + Sulphur, T₄-100% recommended NPK + *Azophos*, T₅-100% recommended NPK + Sulphur + *Azophos*, T₆-75% recommended NPK + 25% P through FYM + Sulphur + *Azophos*, T₇-75% recommended NPK + 25% P through Vermicompost + Sulphur + *Azophos*, T₈-50% recommended NPK + 50% P through FYM + Sulphur + *Azophos* and T₉-50% recommended NPK + 50 % P through Vermicompost + Sulphur + *Azophos*. The variety ‘Uttara’ of black gram was sown in the first week of July at 30 cm × 10 cm spacing using the seed rate of 20 kg ha⁻¹. The soil of the experimental plot was sandy loam in nature having pH value of 6.70 and EC of 0.21 dS m⁻¹. It was moderately fertile being low in organic carbon (3.2 g kg⁻¹) and available nitrogen (134.43 kg ha⁻¹) whereas moderate in phosphorus (10.23 kg ha⁻¹) and potassium (110.74 kg ha⁻¹). The effect of treatments has been observed significantly higher in biological properties of soil including nutrient use efficiency, yield attributes and yield of black gram and non-significant effect was observed in physico-chemical properties except phosphorus and potassium. Non-significant differences were seen in case of active carbon pool except very labile carbon pool. Overall, the best treatments recorded were the treatments with the combination of inorganic and organic treatments and among them, the best one was treatment T₇- 75 % recommended NPK + 25% P through Vermicompost + Sulphur + *Azophos* over control in black gram.

Keywords: Integrated nutrient management, black gram, active pool of organic matter, organic and inorganic fertilizers.


Signature of Major Advisor


Signature of Student

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ABBREVIATION

%	=	Percentage
@	=	at the rate of
°C	=	Degree centigrade
ANOVA	=	Analysis of variance
CD	=	Critical differences
cm	=	Centimeter
cm²	=	Centimeter square
CV	=	Coefficient of variation
df	=	Degree of freedom
<i>e.g.</i>	=	for example
<i>et al.</i>	=	et alia (and others)
etc.	=	et cetera (and so forth)
FOA	=	Faculty of Agriculture
Fig.	=	Figure
FYM	=	Farm yard manures
g	=	Gram
ha	=	Hectare
i.e.	=	<i>id est</i> (that is)
kg	=	Kilograms
L	=	Linnaeus
m	=	Meter
mg	=	Milligram
Mm	=	Millimeter
P₂O₅	=	Phosphorus pentoxide
IARI	=	Indian Agricultural Research Institute
AR	=	Analytical reagent
K₂SO₄	=	Potassium sulphate
H₃PO₄	=	Phosphoric acid

ml	=	Milliliter
MSE	=	Mean error sum of squares
MSS	=	Mean sum of squares
No.	=	Number
P₂O₅	=	Phosphorus pentoxide
ppm	=	Parts per million
q/ha	=	Quintal per hectare
SE	=	Standard error
SE (d)	=	Standard error deviation
SE (m)	=	Standard error means
t/ha	=	Tonnes per hectare
UV	=	Ultra violet
Var.	=	Variety
viz.	=	Videlicet (namely)
w/v	=	Weight/volume
UT	=	Union Territory
dS m⁻¹	=	Deci siemens per metre
EC	=	Electrical conductivity
N	=	Nitrogen
P	=	Phosphorus
K	=	Potassium
HCl	=	Hydrochloric acid
SMBC	=	Soil Microbial biomass carbon
KMnO₄-C	=	Permanganate oxidizeable carbon
H₂SO₄	=	Sulphuric acid
m⁻²	=	Meter square
CFU	=	Colony-forming units
µg TPF⁻¹ min⁻¹)	=	Microgram per triphenylformazan per minute
HClO₄	=	Perchloric acid
HNO₃	=	Nitric acid
RDF	=	Recommended dose of fertilizer
kg	=	Kilogram
q	=	Quintal
PSB	=	Phosphate Solubilizing Biofertilizers

FYM	=	Farmyard manures
K₂O	=	Potassium oxide
B: C	=	Benefit Cost Ratio
MOP	=	Muriate of Potash
DAP	=	Diammonium phosphate
C	=	Carbon
S	=	Sulphur
INM	=	Integrated Nutrient Management
ACRA	=	Advanced Centre for Rainfed Agriculture

INTRODUCTION

The word 'pulse' is derived from the Latin word 'puls' or 'pultis', which means 'thick soup'. There are more than 1800 different species of pulse crops, making them a significant element of the legume family. As a result of the world's population rapid growth, it becomes difficult for agricultural professionals to provide both food for survival and preserve natural resources. We must conserve natural resources in order to prevent this problem and ensure that they continue to be productive. India is the world's leader in terms of both area and production of pulses, but due to its high population, the supply of pulses is not sufficient to meet the per capita need of 70 g day⁻¹. India must substantially increase its production of pulses in order to deal with this shortage. After cereals, pulses are given secondary priority. The pulse crops are a great supplement to any diet since they are high in protein, fiber, vitamins, and minerals, such as magnesium, iron and zinc, as well as being low in fat. This is especially relevant for Indians, who cannot supply their bodies with protein due to the fact that they are vegetarians. As a result, pulses are a crucial tool for assisting people in overcoming hunger and nutritional deficiencies. As compared to cereal crops, pulse crops contain a lot more protein. Pulse crops and microorganisms work together to fix atmospheric nitrogen in the soil, improving soil fertility in addition to being essential for human health. The appropriate management of nutrients is a major factor in pulse productivity. The main yield barrier for pulse crops is low organic matter content in light-textured soils combined with the limited and inadequate application of macro and micronutrients to the crop (Ghosh *et al.*, 2003). Chickpea, arhar, lentil, urd bean, mung bean, moth bean, horse gram, pea, khesari, cowpea, and other pulses are among the most widely cultivated in India.

Black gram is originated in India, where it is a highly valued pulse crop that has been grown for centuries. The fourth-largest pulse crop in India is black gram, which accounts for 24 per cent of all pulse production. Black gram is planted in the *kharif* or summer in the northern region of the country, while it is grown in the *rabi* season as a green manuring crop in the eastern and southern parts of the country. It is a 25 per cent protein staple food that has nearly three times as much protein than cereals. It satisfies the vegetarian population's need for protein. In Jammu & Kashmir (J&K), the total area under pulses is 16,137 ha with an average productivity of about 10.1 thousand tonnes (Anon, 2021). Black gram is currently grown on

50.31 lakh ha of national land, yielding 32.84 lakh tons at a productivity of 350 kg ha⁻¹ (Directorate of Economics and Statistics, 2021).

Black gram is sown as a sequential, mixed, catch, and sole crop in a variety of cropping systems. It perfectly integrates every ingredient, which includes protein (24%) and carbohydrate (60%) as well as fat (1.3%), minerals, and vitamins. It is also 5–10 times higher in phosphoric acid (P₂O₅) than other pulses. Consumed as "daal" in both peeled and unpeeled forms with roti and boiling rice, or various delightful dishes can be made, such as idli, dosa, papad, bara, karhi, pudding, halva, and imurthi etc. Whole black gram plants are utilized as nutritional fodder for animals.

Long-term production and environmental protection are difficult to maintain in the current intensive cropping system unless we establish a balance between the nutrients that are applied and those that are removed by the crop from the soil, this balance can be achieved by altering the current agricultural system in which our crop is required to obtain nourishment from many sources. Based on soil testing, field tests, and nutrient balances under the particular soil crop condition, the precise amount of fertilizer and manure to be applied to the crop should be determined. Balanced nutrition includes both externally given nutrients as well as those that are naturally available in the soil. These days, a variety of sources are available, including fertilizer, cakes, dry blood and bone, farmyard manure, compost, vermicompost, bio-fertilizer (Rhizobium for atmospheric nitrogen fixation, PSB), green manuring, etc.

By decreasing the yield per unit of applied fertilizers and having adverse consequences on the environment, the use of imbalanced chemical fertilizers has reduced the efficiency with which nutrients are used. Crop productivity and soil fertility are negatively impacted by the prolonged use of chemical fertilizers. The search for alternate plant nutrition sources was sparked by all of these considerations. Utilizing organic manure and fertilizer effectively can help the soil, plants, and ecosystem recycle nutrients, which may be essential to establish a long-term viable agricultural production system (Sha *et al.*, 2018). Through increased microbial activity, alternative management strategies, such as organic inputs, may be able to improve soil health and make it more sustainable. Improved soil quality and long-term farming viability are enhanced by improved soil life.

An improvement in Soil Organic Matter (SOM) content is essential for ensuring sustainable production in tropical soils. SOM influences soil fertility and productivity in the tropics, particularly when the soils are extensively weathered, have little to no nutrient reserves

and are managed without the use of any additional organic or inorganic fertilizers (Feller and Beare, 1997). The current state of Indian agriculture presents numerous difficulties, endangering not just sustainability and production but also decreasing farm income, leading to an increase in input usage. Inherent reproductive potential and a shift towards natural farming are the main problems with one of the most obvious difficulties, climate change. Climate change and food insecurity are the two biggest dangers facing humanity in the twenty-first century. Both are connected to the carbon (C) cycle on Earth (Mandal, 2011). Variables like soil texture, structure and fertility determine the maximum levels of output for a specific agroecosystem, which indirectly regulates soil C inputs. Organic soil matter is not uniform in terms of its physical and biochemical makeup. SOM has been conceptually divided into distinct pools in order to better understand the ways by which C is lost or stored in terrestrial systems (Sherrod *et al.*, 2005). The SOM is separated into three kinetically distinct pools known as the active, slow and passive pools. In the SOM dynamics and nutrient cycling, these pools provide a variety of functional purposes.

The study of soil microbes reflects energy flow, serves as a catalyst for the transformation of all substances, and casts light on a labile pool of C, N, P, S, and micronutrients (Mishra *et al.*, 2008). Enzymatic activity, which is crucial in the early phases of oxidation of soil organic matter, controls these transformation processes. Additionally, it aids in enhancing soil structure, which is necessary to maintain both soil health and crop productivity. The rate of organic matter turnover caused by the action of microorganisms affects soil fertility as well. The distribution of soil organic carbon between active and passive pools establishes its relative oxidation susceptibility. Even in partially recovered sodic soils, the FYM-treated plot's lower active to passive ratio (1.63) and potential for greater soil organic carbon (SOC) sequestration compared to the baseline stock demonstrated the plant's acceptability for long-term sustenance under heavy cropping (Choudhary *et al.*, 2018).

For black gram to produce more yield, proper fertilization is crucial. It can symbiotically repair atmospheric nitrogen to suit its nitrogen needs. The nutrients like phosphorus and sulphur require special consideration (Thakur and Negi 1985; Nandal *et al.*, 1987). Being a pulse crop, black gram needs a lot of phosphorus (P). Phosphorus is essential for photosynthesis, sugar metabolism, energy storage and transfer, cell division and enlargement, genetic information transfer, root growth, nodulation, and nitrogen fixation in plants are all examples of biological processes.

However, there hasn't been enough research done on the combined effects of organic and inorganic fertilizers on black gram, especially in the sub-tropical zone in the Jammu division of J & K. In light of the details mentioned above, a field trial was carried out to look into the effect of integrated nutrient management on the active pool of organic matter in black gram (*Vigna mungo*) under dryland subtropics of Jammu with the following objectives:

1. To assess the effect of integrated nutrient management on the active pool of soil organic matter in black gram under dryland conditions.
2. To assess the effect of inorganic and organic sources of nutrients on physico-chemical properties of soil in black gram under dryland conditions.
3. To study the effect of the combined application of organic manures, biological and inorganic fertilizers on the yield of black gram.

REVIEW OF LITERATURE

2.1 Effect of Integrated Nutrient Management on crop and nutrient

An attempt has been made in this chapter to review the literature available on the black gram and other related crops in the country and abroad with respect to integrated nutrient management and soil organic matter “**Effect of Integrated Nutrient Management on Active Pool of Soil Organic Matter in Black gram (*Vigna mungo*) under Dryland Subtropics of Jammu**”. Various aspects of the effect of farm yard manure, vermicompost, biofertilizers, yield, the effect of fertility levels, nutrient uptake and nutrients are presented below under different heads and subheadings.

The effect of organic and inorganic fertilizers on the crop and nutrients of black gram has been reported by many workers.

2.1.1 Yield and yield attributes of black gram

Sharma *et al.* (2000) reported that the black gram produced at its highest yield when N was applied at the rate of 20 kg ha⁻¹. The use of N 20 kg ha⁻¹ and Rhizobium inoculation considerably enhanced the number of pods, clusters, and branches plant⁻¹, test weight, and biological yield.

Rajkhowa, *et al.* (2002) noticed in mung bean that application of fertilizer @100% RDF + VC@ 2.5 tons ha⁻¹ can increase plant height (52.7cm), pod plant⁻¹ (12.7), grain pod⁻¹ (12), seed index (4.6 g), and grain yield (5.35 qha⁻¹) over control.

In a report, Laddha *et al.* (2006) from Bhilwara stated that the highest seed production of black gram was produced in blocks and strips after the application of 15 kg N through compost and 10 kg N with chemical fertilizer.

Yadav, *et al.* (2007) found that Inoculation of Rhizobium + PSB, application of P₂O₅ @ 75 kg ha⁻¹, chicken manure @ 5 t ha⁻¹, resulted in improvement of pod plant⁻¹ (42.69), grains pod⁻¹ (12.75), and grain yield (12.49 q ha⁻¹) of black gram.

A field experimental during *Kharif* 2007 was conducted by Rathore *et al.* (2010) in which they observed that in comparison to 75% and 50% RDF, 100% RDF (20 kg N + 60 kg P₂O₅ + 20 kg K₂O + 20 kg S ha⁻¹) produced significantly more clusters (11.52), pods plant⁻¹

(36.33), pod length (3.88 cm), seeds pod⁻¹ (6.22), seed index (6.28 g), seed yield (1225 kg ha⁻¹), straw yield (8850 kg ha⁻¹), and harvest index (12.22%) of black gram.

Chaudhary, *et al.* (2008) pointed out that maximum plant height, branches per plant (42.30 cm, 17.28, respectively) and dry matter plant⁻¹ (17.65 g) were recorded in treatment where FYM@2.5 tons ha⁻¹ + 50% RDF was applied in check pea crop.

Athokpam *et al.* (2009) observed that with the treatment of 15:60:20 kg NPK ha⁻¹, black gram's maximum seed production was achieved.

Singh *et al.* (2010) observed that with 30 kg N ha⁻¹ given as a basal fertilizer, black gram gave significantly higher seed yield (11.8 q ha⁻¹), straw yield (47.6 q ha⁻¹), and harvest index (19.9%) than the control.

In a report given by Hussain *et al.* (2011) stated that in comparison to control, the application of 30 kg N and 60 kg P ha⁻¹ resulted in a significantly higher black gram seed yield, plant height, branches per plant, seeds pod⁻¹, harvest index, and 1000-seed weight.

Vairavan (2011) noticed application of NPKS @100%RDF + manure (FYM) @ 5 tons ha⁻¹ gave maximum plant height (36 cm) number of branches plant⁻¹ (2.4), number of pods plant⁻¹ (26.8), Grain yield (836 q ha⁻¹) B: C ratio (2.51) over other treatments in black gram.

An experiment was done by Sheikh *et al.* (2012) in which they stated that the highest number of pods plant⁻¹ (37.17), number of grains pod⁻¹ (6.17), test weight of seeds (34.60 g), and seed yield (10.31 q ha⁻¹) of black gram were significantly produced by the application of 25 kg P + 10 kg N ha⁻¹ over the control.

Kumawat *et al.* (2013) observed that in comparison to 20 kg ha⁻¹ and the control, the application of 40 kg P ha⁻¹ resulted in significantly higher seed yield (10.65 q ha⁻¹), haulm yield (23.00 q ha⁻¹), and biological yield (33.66 q ha⁻¹) in black gram.

The response of nutrient integration was noticed by Kokani *et al.* (2014) such as FYM @5 tons ha⁻¹, phosphorus (40 kg ha⁻¹) and sulphur (@ 20 kg ha⁻¹) and found that maximum plant height (36.73 cm), branches plant⁻¹ (5.02), seed yield (11.49 q ha⁻¹) and Stover yield (26.5 q ha⁻¹) were recorded over control in black gram.

Singh *et al.* (2017) found that application of manure 75% (FYM @ 22.5 q ha⁻¹ + bone meal @ 125.03 kg ha⁻¹) and inorganic fertilizer 25 % (MOP @ 6.25 kg ha⁻¹ + DAP@7.75 kg ha⁻¹) gave maximum pods plant⁻¹ (24.55), grains pod⁻¹ (7.07), grain, straw yield (8.72, 25.11q ha⁻¹) and HI (33.60%) as compared to other treatments.

Singh *et al.* (2018) reported that application of N @ 75% RDN + FYM @ 2.5 tons ha⁻¹ in black gram gave maximum plant height (60.2 cm), branches plant⁻¹ (9.9), pod plant⁻¹ (67), and seed yield (11.56 q ha⁻¹) as compared to 100% RDN only.

Meena *et al.* (2021) concluded that the application of NPK fertilizer at 125% RDF (25:56:25 kg ha⁻¹) + FYM (5 tons ha⁻¹) + Rhizobium + nutrient mobilizer treatment resulted in the highest growth and yield parameters and yield of black gram. This treatment was also found to be statistically at par with the application of 100% RDF (20:45:20 kg ha⁻¹) + FYM (5 tons ha⁻¹) + Rhizobium + nutrient mobilizer treatment. Both of these treatments were found to be effective for the cultivation of black gram with maximum yield and were sustainable and economically effective.

2.1.2 Nutrient use efficiency

A study was conducted by Thenua and Kumar (2007) to see how intercropping, phosphorus levels, and bio-fertilizers affected the growth and yield of black gram. The results showed that the application of 60 kg P₂O₅ ha⁻¹ resulted in the highest seed and stover yield, harvest index, and uptake of nitrogen and phosphorus. This was significantly higher than the control.

Kumawat *et al.* (2015) revealed that the application of 100% RDF + 50% RDN + 5 kg Znha⁻¹ (F₇) and 50% RDF + 100% RDN + 5 kg Znha⁻¹ (F₈) resulted in significantly higher uptake of nitrogen, phosphorus, potassium, sulfur, and zinc by pigeon pea and black gram, as compared to other treatments.

Danga *et al.* (2021) stated that black gram seeds that received 125% RDF (30 kg N, 4.5 kg P, and 9.6 kg K per hectare) had the highest uptake of nitrogen, phosphorus, and potassium, respectively. Similarly, seeds that received FYM (farmyard manure) had the highest uptake of these nutrients, at 27.35 kg N, 3.83 kg P, and 8.24 kg K per hectare, respectively. This was significantly higher than the uptake in the control plot.

2.1.3 Soil physico-chemical nutrients (pH, EC, OC, N, P, K)

Three field trials were conducted over three seasons to study the effect of FYM (farmyard manure) on the soil nutrient status of black gram. The results showed that the application of FYM @ 10 tons ha⁻¹ significantly increased the available nitrogen, phosphorus, and potassium in the soil, by 13.66 q ha⁻¹, 4.18 q ha⁻¹, and 2.77 q ha⁻¹, respectively, compared to the control treatment (Muthuvel *et al.*, 1986).

It has been demonstrated that fertilizing mung bean crops with nitrogen at 40 and phosphorus at 60 kg ha⁻¹ is ineffective because the yield is equivalent to 20 kg nitrogen. 38 kg of nitrogen and 54 kg of phosphorus per hectare of agricultural land are the most profitable and productive fertilizer levels. (Shrinivas and Mohammad, 2002).

Rajkhowa *et al.* (2002) found that after the green gram crop, the availability of N (273 kg ha⁻¹), P₂O₅ (9.39 kg ha⁻¹), and K₂O (182 kg ha⁻¹) has risen due to the application of VC @ 2.5 tons ha⁻¹ + 100% RDF.

Gupta (2006) revealed that with the inoculation of rhizobium + PSB + azotobacter in chickpeas, the rhizobium inoculation reached maximum nitrogen balance (172.4 kg ha⁻¹) following crop harvest. An improvement in the balance of phosphorus (24.8 kg ha⁻¹) was also discovered as a result of higher N fixation.

Ingale *et al.* (2007) researched that Vermicompost and biofertilizer were used to boost soil WHC, carbon content, and the amount of available N (287 kg ha⁻¹), P (21 kg ha⁻¹), and K (294 kg ha⁻¹) in black gram.

Singh *et al.* (2008) found that under the urd bean - wheat cropping sequence, the usage of FYM at 5 tons ha⁻¹ + PSB removed carbon (0.25%) and effective NPK from soil (145 kg ha⁻¹, 13.8 kg ha⁻¹, or 275 kg ha⁻¹, respectively).

Vinutha *et al.* (2008) searched that the pH of the soil was slightly enhanced at the 100% lime treatment (6.33), and it was also noted that the pH was decreased in the K minus plot treatment (100 percent NP) as compared to control. Additionally, FYM + NPK treatment had significantly more organic carbon in the soil (7.52 g kg⁻¹) than K minus plot, or 100% NP (4.70 g kg⁻¹).

Vaiyapuri *et al.* (2008) conducted an experiment in Tamilnadu and found that green manuring considerably enhanced the soil's physical and physico-chemical qualities over control, including organic carbon, total and available nitrogen, available phosphorus, and available potassium levels.

Kumpawat (2010) revealed that the usage of 75% RDF + VC @ 0.63 tons ha⁻¹ significantly increased the black gram and succeeding mustard crop's nutrient uptake (N and P).

Sutaria, *et al.* (2010) stated that P (40.86 kg ha⁻¹) and K (398 kg ha⁻¹) have been determined as the nutritional conditions of soil which were in higher demand in VC @1 t ha⁻¹ + 50% RDF in black gram crop.

Tanwar *et al.* (2010) found that in comparison to applying solely 100% inorganic fertilizer on clay loam soil, FYM treatment at 5 tons ha⁻¹ and P 12.5 kg ha⁻¹ combined with PSB inoculation in chickpeas can increase soil fertility.

Kumawat *et al.* (2013) found that following pigeon pea harvest, the application of nutrients with 100% RDF + 50% of RDN by VC + Zn @5 kg ha⁻¹ significantly increased total absorption and availability of soil nutrients, such as NPK, S and Zn 28.1, 3.3, 26.7, 2.29, and 0.062 kg ha⁻¹, respectively.

Singh *et al.* (2014) revealed that application of VC (2 tons ha⁻¹), neem cake (0.4 tons ha⁻¹), and FYM (5 tons ha⁻¹) resulted in significantly higher OC (0.62%) and nutrient availability in the check pea crop, including N (205 kg ha⁻¹), P (20 kg ha⁻¹), and K (203 kg ha⁻¹).

Meena and Ram (2016) revealed that the application of manure (FYM)@ 5 tons ha⁻¹ + inorganic fertilizer (K₂O @ 16.6 kg + S @ 20 kg + Zn 3 kg ha⁻¹) along with Rhizobium + PSB inoculated seed has been found to significantly increase soil organic carbon (0.60%), as well as available nutrients such as N (305 kg ha⁻¹), P (11.70 kg ha⁻¹), K (407 kg ha⁻¹), S (19.10 kg ha⁻¹), and Zn (1.35 mg ha⁻¹) in black gram.

Qureshi and Bashir (2016) discovered that in the field pea crop, the application of NPKS at 100% RDF + FYM at 20 tons ha⁻¹ + biofertilizer considerably enhanced soil OC (0.73%), available N, P, and K (272.3, 31.7, and 271.7 kg ha⁻¹, respectively), and available S (34.9 kg ha⁻¹).

Aziz *et al.* (2017) found that following crop harvest, the amount of Al-P, Fe-P, and Ca-P that was available in the soils was greatly increased by the application of fertilizers at 100% RDF, organic manures (FYM) at 10 tons ha⁻¹, and bio-inoculation (INM).

Rambuatsaiha in year 2017 revealed a study on the effects of organic sources on soil during the *Kharif* season showed that the integrated application of VC@ 0.7 tons ha⁻¹ + rhizobium + PSB significantly improved the soil's availability of N (324.7 kg ha⁻¹), P (18.25 kg ha⁻¹), and K (259.0 kg ha⁻¹) after the harvest of green gram.

Rekha *et al.* (2018) found that the soil available N, P, and K (147.98, 38.09, and 288.87 kg ha⁻¹, respectively) for the pearl millet crop was significantly enhanced by the application of NPK @ 75% RDF + manure (FYM) + microbial consortia (Azospirillum and Azotobacter).

Singh *et al.* (2018) found that in comparison to 100% RDN (208, 12.8, 253, 9.9 kg ha⁻¹, respectively), application of 50% RDN + FYM @ 5.0 tons ha⁻¹ significantly improved soil available NPK and S status (217, 14.8, 263, 10.6 kg ha⁻¹) following the crop black gram harvest.

2.1.4 Soil biological parameters (soil microbial biomass carbon, soil organic carbon pool, permanganate oxidizable carbon, soil dehydrogenase activity, and bacterial count)

Tembhare *et al.* (1998) analyzed that over the course of 24 years in a soybean-wheat rotation on Typic Haplustert soil at Jabalpur, balanced fertilization had a beneficial impact on improving the soil's organic carbon content. After 10 years of growing cotton on Vertisols, a similarly significant rise in organic C was seen in the NPK + FYM plots compared to NPK alone.

Babhulkar *et al.* (2000) observed a considerable increase in black soil's organic carbon content as a result of fertilizing soybeans with farmyard manure and synthetic N and P fertilizers.

Blair (2000) found that between 5% and 30% of organic carbon was the KMnO₄-oxidizable fraction. Compared to the total organic carbon content, this oxidizable fraction was significantly more susceptible to soil management.

In 2003, Tolanur and Badanur reported that the incorporation of FYM, either alone or in combination with recommended doses of fertilizers, significantly improved the organic carbon content of both surface and sub-surface soils in vertisols. This might be explained by increased soil microbial activity and improved root development.

Wani *et al.* (2003) studied that the vertisols in the semiarid tropics were managed more effectively for better productivity and soil carbon sequestration, and the results showed that organic C, available N, P, and K, and microbial biomass C and N in the soil significantly increased.

Bhattacharyya *et al.* (2004) found that in surface (0–15 cm) and subsurface (15–30 cm) of N, P, and K + FYM treated plots, both oxidizable and non-oxidizable organic carbon contents of the soil were higher, and significantly higher than the other treatments.

In 2005 Graham and Haynes reported that there is a strong correlation between the activity of the soil microbial population, enzyme activity, and organic carbon content. Long-term fertilizer application improved soil organic matter storage, soil microbial biomass, and soil enzyme activity due to the improvement of the water-soluble phase of carbon.

Varalakshmi *et al.* (2005) revealed that after groundnut and finger millet crops in treatments where FYM was treated along with inorganic fertilizers, there was a significantly higher level of organic carbon. The treatment of 100% RDF + 7.5 t ha⁻¹ after the groundnut harvest (9.5 g kg⁻¹) and after the harvest of finger millet (10.4 g kg⁻¹) showed the maximum organic carbon content.

In 2006 Raji and Ogunwale found that between 1977 and 1995, the soil organic carbon content in the unamended soil in Samaru, Northern Nigeria, was 1.81 t C ha⁻¹, or 10 g C m⁻², after 45 years of cow dung and NPK treatments to the soil. During the same 45-year period, continuous NPK application very slightly increased SOC (3%) relative to unaltered soil, whereas manure containing NPK increased SOC by 115%.

Shrestha *et al.* (2006) reported significant variations in KMnO₄-oxidizable soil organic C content as a result of the cropping system and cultivation length. The cultivation-induced decline in KMnO₄-oxidizable C, however, was greater in the surface layer than in the subsurface layer.

Sleutel *et al.* (2006) studied the two long-term field tests employing physical fractions on soil organic pools and revealed that fertilization had a distinct impact on both the amount of free particulate organic matter (POM) present in the two fractions and their relative proportion on the total SOC. This rise in SOC was significantly decreased for the amount of OC present in the silt + clay-sized fraction and was equal to or less for the POM occluded in micro aggregates (53-250µm).

Walía and Kler (2006) suggested that compared with recommended chemical fertilizer treatments, the microbial biomass C was higher with organic farming treatments M20-W20-RI, M-W15-GMRI, M10-W15-RI, and M10-W15-R0 by 67.2, 53.8, 52.5, and 48.1 percent, respectively. In comparison to a chemical fertilizer treatment alone, the integrated treatments also boosted microbial biomass C by 31.1 and 20.9 per cent under the approved doses of GM-RI and GM-R treatments.

Antil and Singh (2007) reported that when only NP fertilizers were used, the organic carbon content improved dramatically, however when organic manure alone or in combination

with NP fertilizers were applied, the organic carbon content decreased from its initial value. Surface soil stored more organic carbon and had a higher level of nitrogen than underneath soil.

Chung *et al.* (2007) examined the relationship between steady-state soil carbon input and soil organic carbon (SOC) concentration in a temperate agricultural ecosystem in Lexington and Kentucky had shown that pools of soil organic carbon with low capacity for carbon sequestration do not stabilize extra carbon even when soil carbon input increases, indicating carbon saturation of these fractions.

Fan *et al.* (2007) stated that the changes in SOC from a 26-year rainfed fertilization trial demonstrated that, with the exception of unfertilized and treatment receiving only N, SOC steadily rose with time in all treatments. The treatment receiving manure + NP showed the greatest rise in SOC, followed by straw + NP and manure simply. Manure and root residue contributed about 24% of the total carbon input, while straw and root residue contributed about 14% of the total carbon input.

Kuntal *et al.* (2007) revealed that the soil's ability to accumulate organic matter was significantly influenced by the balanced application of organic amendments and inorganic fertilizer. The maize-wheat and moong/soybean-wheat systems field experiment revealed that the KMnO_4 -oxidizable C was higher in organic farming treatments (FYM @ 20 t ha⁻¹ to maize, 20 t ha⁻¹ to wheat) ranging from 1.16 to 1.41 mg g⁻¹ as compared with 0.56 mg g⁻¹ in alone fertilizer treatment.

Sohan and Kler (2007) stated that in a long-term field experiment on a soybean-wheat cropping system, the application of organic materials in organic farming treatments (M10-M20-RI, i.e., 10 t of FYM to soybean, 20 t FYM to wheat, and incorporation of crop residues of both crops) had recorded the higher values of MBC (Microbial Biomass Carbon) as well as phosphate compared to the recommended dose of fertilizers treatments alone.

A long-term study was undertaken by Hati *et al.* (2008) to evaluate the impact of manure, lime, and inorganic fertilizer treatment on the organic carbon content in an Alfisol during a rotation of wheat and soybean crops. The results showed that SOC content dropped from the initial value in all of the treatments, but that the decreases in the NPK + manure (8.7%) and NPK + lime (10.9%) treatments were much less than those in the nitrogen fertilizer (28.3%) treatment.

Kumar *et al.* (2008) stated that crop residues and organic manures were applied over an extended period to boost the soil's organic carbon content. The availability of N in the soil was dramatically improved over 100% NPK alone treatment with the application of crop residues coupled with FYM and GM.

Majumdar *et al.* (2008) revealed that management strategies for soil organic carbon pools provide data on the C sequestration pathway, soil quality, maintenance, and crop productivity. Farmyard manure (FYM), paddy straw (PS), and green manure (GM) along with inorganic fertilizers used in a 19-year-old rice-wheat cropping system in sub-tropical India to examine the impact on SOC stock, its different pools, total organic C (C_{tot}); oxidizable organic carbon (C_{oc}) along with its four fractions of very labile ($C_{fract\ 1}$), labile ($C_{fract\ 2}$), less labile ($C_{fract\ 3}$) and mineralizable C (C_{min}).

Purakayastha *et al.* (2008) investigated that before the soil becomes carbon-saturated, soil organic carbon typically rises with carbon input. There is ample evidence that organic manures alone or when combined with inorganic fertilizer can raise SOC content.

Gayatri and Mathur (2009) studied that using 100% NPK + 10 t FYM ha^{-1} and 10 t FYM ha^{-1} + (100% NPK - NPK content of FYM), the microbial biomass carbon increased to its highest level under FYM @ 20 t ha^{-1} , while the control recorded the lowest value of 173 mg kg^{-1} in maize crop and 168 mg kg^{-1} in wheat crop.

A field trial was executed by Nawlakhe and Mankar in 2009 at the AICRP for Dryland Agriculture in Akola in which they showed that the application of half a dose of nitrogen through inorganic fertilizer + half a dose of nitrogen through FYM or *Leucaena* loppings + a full dose of phosphorus in clay soil increased the organic carbon content by 0.102 and 0.080 per cent.

Sekhon *et al.* (2009) analyzed the impact of seven years of fertilization and manuring on different C pools in a rice-wheat cropping system, which simulates alternate flooding (reducing) and upland (oxidation) conditions. They discovered that FYM and green manure-enhanced treatments came in second place to the integration of press mud with 16 mineral fertilizers in terms of an increase in total soil carbon and carbon pools (dissolved organic carbon, SMBC, light fraction, and heavy fraction carbon).

In 2010 Chivhane and Bhattacharyya stated the impact of land use and the bio-climatic system upon the organic carbon pool of shrink-swell soils in the Vidarbha region of Maharashtra in which they identified various fractions of total organic carbon that affect

active and passive pools, which in turn control the liability of organic carbon in soils, as total organic carbon was the most significant soil quality parameter.

Eduard (2010) observed that three basic pools of soil organic matter (SOM) can be distinguished: labile, stable, and inert. The labile fraction (LF), which is more sensitive to tillage, manuring, fertilization, crop rotation, and various other measures than total organic matter, has been the subject of research in recent years. It has been suggested to be a quickly reactive indicator of soil productivity and health.

Garcia-Orenes *et al.* (2010) reported that the soluble carbon fraction provides as a short-term reservoir of plant nutrients and a readily decomposable substrate for soil microbes, making it a crucial component of the soil organic matter cycle in agricultural soils.

Ghosh *et al.* (2010) studied that the soils altered with NPK + FYM had the highest TOC concentrations, while conventional cultivation had the lowest. The majority of SOC was made up of the non-labile or residual SOC fraction, and while the amount of labile carbon was higher under the fallow, the proportion of non-labile carbon was noticeably higher under NPK + FYM. With increasing soil depth, SOC significantly decreased.

Antil *et al.* (2011) found most significant (6.6 g kg^{-1}) SOC value was found under 100% NPK+FYM, followed by 150% NPK treatment (6.5 g kg^{-1}), and the lowest (4.4 g kg^{-1}) was found in the control.

Jha *et al.* (2012) reported that for several land use systems (agriculture, forestry, and horticulture) in Central India, they evaluated the volumes of soil carbon pools and decay constants of active and slow carbon pools. The findings clearly show the potential for soil carbon build-up in agriculture when employing beneficial management techniques (such as applying organic manure).

Mohanarao *et al.* (2012) studied that the application of FYM @ 10 t ha^{-1} +100% NPK, which proved to be significantly superior to all other treatments, produced the highest level of organic carbon (6.77 g kg^{-1}) in the long-term manuring and fertilization. A 19-year duration of integrated nutrient management witnessed an increase in organic carbon, which can be linked to the addition of farmyard manure, which increased root biomass and the growth and activity of microorganisms.

A field experiment was conducted by Sharma *et al.* (2013) at the Regional Agriculture Research Station in Assam where they incorporated seven different crop residues and evaluated the rate at which the crop residues decomposed in the soil and the effects that this had on CO_2

emission, carbon mineralization, carbon density, and carbon sequestration in agricultural lands. They summarized that the carbon density was 31.2% higher for the horse gram residue than for the control.

Ortas and Lal (2014) studied the influence of long-term fertilization on the soil organic carbon (SOC) concentration and resulted in the conclusion that the SOC concentration was higher in organic manure-treated plots than in inorganic fertilizer-treated plots and that the combined application of fertilizer and manures raised the SOC concentrations in soil. The SOC concentration varied greatly from year to year.

Sankar *et al.* (2014) in the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) at the Akola Centre in Maharashtra conducted investigations on long-term experiments to determine soil quality. In these semi-arid Vertisol soils, they claimed that 25 kg N (FYM) + 25 kg N (urea) + 25 kg P ha⁻¹ produced the most significant results, with a maximum mean SOC of 0.71% over the years.

Brar *et al.* (2015) conducted a 36-year field study at Punjab Agricultural University (PAU), Ludhiana, India, using a randomized complete block design with four replications to examine the effects of inorganic fertilizers and farmyard manure (FYM) on soil organic carbon (SOC), soil physical properties, and crop yields in a maize (*Zea mays*)-wheat (*Triticum aestivum*) rotation. According to their findings, the SOC pool grew to 11.6 mg ha⁻¹ with 100%NPK+FYM from the lowest level of 7.3 mg ha⁻¹ in control.

Das *et al.* (2016) (after 18 years of continuous RWS) carried out a field experiment to investigate the impact of fertilizers and manures on SOC pools, and their correlations with crop yields. The results revealed that at a soil depth of 0-7.5 cm, total organic C significantly increased when fertilizers and organic sources were used in combination (from 13 to 16.03 g kg vs. 11.5 g kg for the unfertilized control and 12.17 g kg for the sole fertilizer treatment).

Nath *et al.* (2015) revealed that the soil organic carbon pools in rice-based farming systems and discovered that the rice farming methods affected the various SOC pools. As a result, rice farming systems can be an important tool for classification in terms of controlling soil C sinks.

Joshi *et al.* (2017) reported that the impact of continued nutrient management strategies on the distribution of active organic pools at different depths (SOC, WSC, AHC, SMBC, and SMBN). According to the published data, long-term nutrient-deficient crop cultivation

depleted active organic pools, but adding organic manures or inorganic fertilizers resulted in a considerable increase in these fractions compared to the unfertilized control.

Khan *et al.* (2017) studied that the integrated nutrient management system (INMS) has become more significant in preserving the fertility and health of the soil as well as enhancing the yield of crops. In order to determine the impact of INM on soil carbon pools and soil quality in the rice-brown sarson cropping system with various treatment combinations, a field experiment was carried out at the Mountain Research Centre for Field Crops Khudwani (SKUAST-Kashmir) in 2013 (in progress since March 2008). Results showed that adding organic manure, such as FYM, is crucial for sustaining crop output and maintaining soil quality.

In 2017 Tomar studied that paired with *Azotobacter chroococcum* and farmyard manure, inorganic fertilizers have a considerable impact on crop productivity and soil fertility restoration. The accumulation of organic carbon and microbial biomass carbon in soil was improved by FYM application alone. Similar to this, NPK fertilizers enhanced the soil's organic carbon status.

Reddy *et al.* (2017) conducted a field experiment to diversify integrated nutrient management (INM) for rainfed cotton using phospho-compost (PC) and poultry manure (PM). In comparison to those receiving 100% NPK, they reported that all INM intervention plots had increased nutrient uptake due to an improvement in soil nutrient status. The INM treatments had higher soil labile carbon values (333-452 mg kg⁻¹), and the PC-amended plots had higher values by a larger margin (402-452 mg kg⁻¹). The INM had higher carbon management index (CMI) values than the NPK and FP treatments.

Phalke *et al.* (2017) studied the incorporation of in-situ decomposed residues along with byproducts of industrial waste when combined with NPK increased the below and above-ground biomass production, SOC stock, and carbon pools, according to research on the effects of in-situ recycling of sugarcane crop residues and its industrial wastes on various soil carbon pools under soybean (*Glycine max* L.) and maize (*Zea mays* L.) systems.

Kumar *et al.* (2018) conducted a field experiment to evaluate the impact of four crop rotations—soybean + P. pea (S + PP, 2:1), soybean- wheat (S-W), maize + P. pea (M + PP, 1:1), and maize + gram (M - G)—as well as their residue management (residue retained vs. burnt) on soil organic carbon fractions in black soil (Vertisols) of Central India. The results proved that RT (0.42, 0.19 & 0.19%) and NT (0.41, 0.17 & 0.17%) had significantly higher soil organic carbon levels than CT (0.35, 0.13 & 0.14%). Particularly, the VLC, LC, and LLC

fractions in the 0–5 cm depth and the NLC fraction were higher in NT (0.46%) compared to RT (0.42%) and CT (0.40%).

A study to examine the long-term effects of organic fertilizers and manure on soil organic carbon pools under soybean and safflower intercropping was undertaken by Mundhe *et al.* (2018). They stated that the plot receiving 100% NPK + FYM at 5 mg ha⁻¹ had a much larger active component of soil organic carbon. Utilizing FYM when combined with chemical fertilizers or by itself has significant effects on the soil's organic carbon pools.

MATERIALS AND METHODS

The following sub-headings have been applied to present the details of the materials and methods used throughout the course of the investigation:

3.1 Experimental site

3.1.1 Location

The study was carried in Jammu district of J&K, which is in northwest of India at Research Farm, ACRA, Rakh Dhiansar, SKUAST-Jammu, J&K UT (32° 39" N 74° 53" E, 332 m amsl). Field tests were carried out during the kharif season of 2022 under rainfed conditions.

3.1.2 Climate conditions

Agro climatically the location represents Zone V of Jammu and Kashmir and is characterized by subtropical climate. The place experiences hot dry summer, a hot and humid rainy season, and cold winter months. The maximum temperature goes up to 45° C during summers (May to June) and the minimum temperature falls to 1°C during winters. The mean annual rainfall is about 1000-1200 mm. The meteorological data recorded during the crop period is taken from Agrometeorology Dhiansar, Division of Agronomy, and has been given in Appendix-I. The temperature during the experimentation period ranged from 20°C to 40°C. The total amount of rainfall received was 950 mm. The relative humidity during the experimentation period ranged from 68 to 79 percent.

3.1.3 Soil characteristics

Prior to the start of the experiment, four random places in the field were sampled for surface soil from 0 to 15 cm depth. To create each composite sample, the collected soil samples were pooled. Soil sampling was carried out after crop harvesting according to treatment. The resulting composite soil sample was air-dried, crushed, and passed through a 2 mm sieve before being examined for various chemical properties. Fresh samples were used to determine the biological properties of the sample. Table 3.1 lists the initial analyzed values (0–15 cm) for various soil parameters, including chemical and physical components. The soil at the experimental site was found to have a sandy clay loam texture, be slightly acidic in reaction, have low levels of available nitrogen, but medium levels of available phosphorus.

Table 3.1. Initial physico-chemical properties of experimental site

S. Number	Soil Component	Value obtained
1.	pH (1:2.5)	6.70
2.	E.C (dSm ⁻¹)	0.21
3.	Organic carbon (g kg ⁻¹)	3.27
4.	Available Nitrogen (kg ha ⁻¹)	134.43
5.	Available Phosphorus (kg ha ⁻¹)	10.23
6.	Available Potassium (kg ha ⁻¹)	110.74
8.	Mechanical composition (%)	
	Sand	65
	Silt	19
	Clay	16
	Textural class	Sandy loam

3.2 Field studies

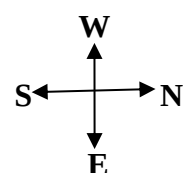
3.2.1 Experimental details (Treatment and layout plan)

The field trial was laid out during *Kharif* 2022 at Research Farm, ACRA, Rakh Dhiansar, SKUAST- Jammu with the following 9 treatment combinations:

Table 3.2. Treatment details

TREATMENTS	SPECIFICATION
T ₁	Control (unfertilized)
T ₂	100% recommended NPK
T ₃	100% recommended NPK + Sulphur
T ₄	100% recommended NPK + <i>Azophos</i>
T ₅	100% recommended NPK + Sulphur + <i>Azophos</i>
T ₆	75% recommended NPK + 25% P through FYM + Sulphur + <i>Azophos</i>
T ₇	75% recommended NPK + 25% P through Vermicompost + Sulphur + <i>Azophos</i>
T ₈	50% recommended NPK + 50% P through FYM + Sulphur + <i>Azophos</i>
T ₉	50% recommended NPK + 50 % P through Vermicompost + Sulphur + <i>Azophos</i>

The recommended dose of 16:40:20 of N, P₂O₅ and K₂O was applied through urea, diammonium phosphate, and muriate of potash respectively. Sulphur was applied at the rate of



R₁		R₂		R₃
Plot size 3x2 m		Plot size 3x2 m		Plot size 3x2 m
BUND (0.5 m)		BUND (0.5 m)		BUND (0.5 m)
T ₁		T ₄		T ₉
BUND (0.5 m)		BUND (0.5 m)		BUND (0.5 m)
T ₈		T ₃		T ₂
BUND (0.5 m)		BUND (0.5 m)		BUND (0.5 m)
T ₇	1 m	T ₅	1 m	T ₇
BUND (0.5 m)		BUND (0.5 m)		BUND (0.5 m)
T ₄	I	T ₉	I	T ₁
BUND (0.5 m)	R	BUND (0.5 m)	R	BUND (0.5 m)
T ₅	R	T ₆	R	T ₄
BUND (0.5 m)	I	BUND (0.5 m)	I	BUND (0.5 m)
T ₃	R	T ₁	R	T ₈
BUND (0.5 m)	G	BUND (0.5 m)	G	BUND (0.5 m)
T ₂	A	T ₇	A	T ₆
BUND (0.5 m)	T	BUND (0.5 m)	T	BUND (0.5 m)
T ₉	I	T ₈	I	T ₅
BUND (0.5 m)	O	BUND (0.5 m)	O	BUND (0.5 m)
T ₆	N	T ₂	N	T ₃
BUND (0.5 m)	C	BUND (0.5 m)	C	BUND (0.5 m)
	H		H	
	A		A	
	N		N	
	N		N	
	E		E	
	L		L	

Fig 3.1: LAYOUT PLAN OF THE EXPERIMENT



Plate 1 Collection of soil sample

20 kg ha⁻¹ and *Azophos* was applied at the rate of 10 kg ha⁻¹. The quantity of various fertilizers needed to supply the required levels of nutrients was determined on a per-plot basis.

3.2.2 Soil sampling: -

The soil samples were taken for the analyses of chemical and biological properties at different intervals.

Details of the experiment:

Experimental site: Research Farm of ACRA Rakh Dhiansar, SKUAST -Jammu.

Table 3.3. Details of layout plan.

S. No	Particulars	
1.	Variety	Black gram cv. Uttara
2.	Design	RBD
3.	Treatments	09
4.	Replications	03
5.	Plot size	Gross: 2 x 3 = 6 m ²
6.	Spacing	30 x 10 cm (R-R X P-P)
7.	Date of sowing	15/07/2022
8.	Date of harvesting	11/09/2022
9.	Spacing between replications	1 m
10.	Spacing between treatments	0.5 m

3.3 Biofertilizer (*Azophos*)

The dried and powdered *Azophos* obtained from IARI; New Delhi was applied in the black gram as a seed treatment at rate of 20 g kg⁻¹.

3.4 Laboratory studies

3.4.1 Soil analysis

Surface soil samples (0–15 cm) were taken to determine the various chemical properties viz. pH, electrical conductivity, organic carbon, available N, P, and K, microbial biomass carbon, dehydrogenase enzyme activity, bacterial count, permanganate oxidizable carbon total organic carbon and oxidizable soil organic carbon pools.

Table 3.4. Methods used for analysis of soil properties

Parameters	Methods	Reference
Soil pH (1:2.5 soil: water suspension)	Glass electrode digital pH meter	Jackson, 1973
Electrical conductivity (dS m⁻¹ at 25°C)	Electrical conductivity meter	Jackson, 1973
Soil organic carbon (g kg⁻¹)	Wet digestion method	Walkley and Black (1934)
Available Nitrogen (kg ha⁻¹)	Alkaline permanganate method	Subbiah and Asija, 1956
Available Phosphorus (kg ha⁻¹)	0.5 M NaHCO ₃ Extractable, Olsen method	Olsen <i>et al.</i> , 1954
Available Potassium (kg ha⁻¹)	Flame photometer.	Jackson, 1973
Microbial biomass carbon (mg kg⁻¹)	Fumigation extraction method	Vance (1987)

3.5 Observations recorded

3.5.1 Growth and yield parameters

Five plants were randomly chosen and tagged in each plot for recording values of all growth parameters during the crop growing period, with the exception of those in which plants from the second border rows were chosen for recording observations.

3.5.1.1 Plant height (cm)

With the aid of a meter scale rod, the height of each of the five tagged plants was calculated from the net plot area of each plot to the tip of the uppermost fully opened leaf. To determine the average plant height per plot, the observations were averaged.

3.5.1.2 Plant population (m⁻²)

In each plot, two spots of one square meter were chosen randomly and marked. Each chosen spot on the plot had an average number of plants, which was recorded and reported as plant population (m⁻²).

3.5.1.3 Number of pods per plant

In order to calculate the number of pods per plant, the number of pods from each of the five tagged plants was counted independently from the net plot area of each plot.



Plate 2 Plants at Flowering Stage



Plate 3 Crop after 60 days of sowing

3.5.1.4 100-seed weight

From each net plot's bulk produce, one hundred seeds were randomly selected, counted, and weighed. The measurement was given as 100-seed weight in grams.

3.5.1.5 Number of nodules per plant

At the time of flowering, one plant from each treatment was removed and the number of root nodules on each plant was recorded.

3.5.1.6 Seed yield

Black gram seeds that had been threshed from each net plot were weighed separately and was expressed in kg ha^{-1} .

3.5.1.7 Stover yield

Stover yield was calculated by subtracting the seed yield from the total biological yield (Seed + Stover) from the net plot, and it was then expressed in kg ha^{-1} .

3.5.2 Plant analysis

3.5.2.1 Preparation of plant samples

To get rid of soil particles and any other foreign components that had attached to the collected plant samples, they were washed three times: once with 0.1N HCl solution, once with distilled water, and once more with double distilled water. Then by gently shaking and pressing the plant samples against filter papers, the surplus water was drained. The cleaned plant samples were stored in numbered paper bags and allowed to air dry for seven days in a screen house. The plant samples were later dried at 60°C till the weight was constant in an air-dried oven. Using an electronic balance, the dry weight of the plant samples from each plot was recorded. In order to prepare the plant samples for laboratory analysis, these were first crushed in a stainless steel grinder, combined, and then stored in labeled plastic bags.

3.5.2.2 Digestion of plant samples

For the purpose of determining the NPK content, 0.5 g of plant samples were digested on a hot plate in a 10:4:1 triacid mixture of AR grade HNO_3 , HClO_4 and H_2SO_4 until a clear, colorless solution was formed. The digested aliquots were transferred to 50 ml volumetric flasks and the volume was adjusted by adding distilled water to meet the required level. For

elemental analysis, the extracts were placed in well-washed plastic bottles after being filtered with Whatman Number 1 filter paper.

3.5.2.3 Nutrient content in plant samples

Black gram plant samples (seed and straw) were taken at harvest from each plot. In a hot air oven, these plant samples were dried at 65°C. According to the procedure followed same for soil analysis, the dried samples were refined and used for N, P and K content analysis.

3.5.2.4 Nutrient uptake

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (Seed/Stover in kg ha}^{-1}\text{)}}{100}$$

3.5.3 Soil biological parameters

3.5.3.1 Soil Microbial biomass carbon (SMBC) (mg kg⁻¹)

By using the fumigation extraction method, the microbial biomass carbon in soil was determined (Vance *et al.*, 1987). A pair of 20 g soil samples were obtained, and one was fumigated in a desiccator with ethanol-free chloroform while the other was retained under the same vacuum conditions without fumigation. After 24 hours, carbon from the microbial biomass was extracted using 40 ml of potassium sulfate (0.5 M K₂SO₄) by vigorously shaking the sample for 30 minutes on a rotary shaker. In the presence of 2 ml of 0.4 N potassium dichromate, 15 ml of diacid (H₂SO₄:H₃PO₄, 2:1), and 8 ml of filtrate, 0.5 M ferrous ammonium sulphate solution was titrated.

The SMBC was calculated as follows:

$$\text{SMBC (mg/soil)} = \text{EC}_F - \text{EC}_{\text{NF}} / K_{\text{EC}}$$

Where, EC_F = Extractable C in the fumigated soil sample.

EC_{NF} = Extractable C in the non-fumigated soil sample.

K_{EC} = 0.38 is the factor; it represents the efficiency of extraction of MBC.

3.5.3.2 Dehydrogenase enzyme activity

Triphenyl formazan was synthesized from triphenyl tetrazolium chloride, which functioned as a hydrogen atom acceptor, to assess dehydrogenase activity (Casida *et al.*, 1964). 1gm soil was weighed and placed in a 15 mL screw cap tube (three replications were kept), then 0.2 mL of 3% w/v 2, 3, 5 triphenyl tetrazolium chloride was added. To guarantee a thin



Plate 4 Root nodules at 60 days after sowing



Plate 5 Whole plant sample

layer of water above the soil surface, 0.5 mL of 1% glucose solution was added. The tubes were incubated at a temperature of 300°C. After 24 hours, 10 mL of methanol was added to the tubes, and they were shaken by hand for one minute. These tubes were placed in the dark for six hours, and the color development was measured using a spectrophotometer.

3.5.3.3 Bacterial count

The total number of bacteria on nutrient agar media was counted by pour plating (Zuberer, 1994). The plates were incubated at 28°C for 5 days before counting the colonies. For bacteria, serial dilutions up to 10^{-6} were prepared. The plates were incubated at 30°C for 5 days. The findings were expressed as colony-forming units (CFU) per gram of soil.

3.5.3.4 Permanganate oxidizeable carbon

Blair *et al.* (1995) developed a method for measuring $\text{KMnO}_4\text{-C}$, which was later revised by Vieira *et al.* (2007). After mixing an air-dried soil sample for 15 minutes with 30 mL of 0.02 M KMnO_4 , it was centrifuged for 5 minutes at 2000 rpm. After a 1:24 dilution with distilled water, the absorbance of the diluted supernatant solutions was measured at 560 nm.

3.5.3.5 Total organic carbon

The total SOC content was determined using the dry combustion method (Houba *et al.*, 1995). In a nutshell, a 10-gram finely crushed soil sample was oven dried for 24 hours at 105 °C, weighed, and then dry combusted for 2 hours at 450 °C in a muffle furnace with the weight reduction recognized as carbon loss.

3.5.3.6 Oxidizable soil organic carbon pools

The oxidizable carbon measurement was repeated using 5 and 10 mL of concentrated H_2SO_4 instead of the 20 mL H_2SO_4 suggested by Walkley and Black (1934). The acid-aqueous solution ratios of 0.5:1, 1:1, and 2:1 (equivalent to 12 N, 18 N, and 24 N of H_2SO_4) allowed comparison of oxidizable organic carbon extracted under increasing oxidizing conditions. According to Chan *et al.* (2001), the amount of oxidizable organic carbon was assessed using 5, 10, and 20 ml of concentrated H_2SO_4 , permitting the separation of total organic carbon into four fractions of decreasing oxidizability.

Pool I (Very labile C)	Organic C oxidizable under 12.0 N H_2SO_4
Pool II (labile C)	The difference in SOC extracted between 18.0 and 12.0 N H_2SO_4

Pool III (less labile) The difference in SOC extracted between 24.0 and 18.0 N H₂SO₄ (24.0-N H₂SO₄ is equivalent to the standard Walkley and Black method)

3.6 Statistical analysis

For evaluating the collective influence of organic and inorganics chemical fertilizers along with biofertilizers on soil physico-chemical as well as biological properties and on yield of black gram, analysis was done by using the Analysis of Variance technique (ANOVA), for Randomized Block Design (RBD).

RESULTS

The results obtained from the present investigation entitled “**Effect of Integrated Nutrient Management on Active Pool of Soil Organic Matter in Black gram (*Vigna mungo*) under Dryland Subtropics of Jammu**” have been presented under the following heads:

- 4.1 Effect of integrated nutrient management on growth parameters**
- 4.2 Effect of combined application of organic manures, biological and inorganic fertilizers on yield attributes and yield of black gram**
- 4.3 Effect of integrated nutrient management on soil physico-chemical properties in black gram**
- 4.4 Effect of inorganic and organic sources of nutrients on biological properties of soil**
- 4.5 Effect of integrated nutrient management on nutrient use efficiency**

4.1 Effect of integrated nutrient management on growth parameters:

4.1.1 Plant height (cm)

The data displayed in Table 4.1 indicate that the applied INM treatments exerted non-significant impact upon this parameter. The maximum plant height (43.86 cm) was recorded in case of T₇ (75 % recommended NPK + 25% P through Vermicompost + Sulphur + *Azophos*), closely followed by T₈ (39.98 cm) > T₅ (39.90 cm) > T₆ (38.93 cm). The height was lowered down in case of T₂ (100 % recommended NPK) and T₄ (100 % recommended NPK + *Azophos*) valued from 36.12 to 35.25 cm. The equally lowest height (31.98) was observed in case of T₁ (control) and T₃ (100 % recommended NPK + Sulphur) which was 32.78.

4.1.2 Effect of integrated nutrient management on Number root of nodules plant⁻¹ of black gram

A perusal of the data in Table 4.1 revealed that the number of root nodules of black gram varied from a lowest value of 13 in control when no fertilizer was applied to a highest of 19 (T₉) when 50% recommended NPK + 50 % P through Vermicompost + Sulphur + *Azophos* was applied in combination. The per cent increase in number of root nodules with the successive application of T₂, T₄, T₇ and T₈ over control was 15.38, 23.07, 30.76 and 38.46

percent respectively. In the presence of fertilization significantly increased in the number of nodules of black gram was observed which was highest observed in the plots treated with the combination of organic and inorganic fertilizers as compared to the plots treated with the inorganic fertilizers alone and control (13).

4.2 Yield attributes and yield of black gram

4.2.1 Effect of integrated nutrient management on Number of pods plant⁻¹ of black gram

In each treatment number of pods per plant was calculated in three different replications and the data was then statistically analyzed. The data presented in Table 4.3 and the graphic representation in Fig. 4.1 showed that the INM treatments had a big impact on pods per plant.

Out of the INM treatments T₇ and T₉ resulted in an equally significantly higher number of pods (32.25 to 28.92 pods plant⁻¹) over all the remaining INM treatments. However, this was followed by T₈ which recorded 24.28 pods plant⁻¹ and then in T₆ which produced a significantly lower number of pods (20.94 pods plant⁻¹). The pod formation was further discouraged up to a significant extent with the decrease in the applied organic-cum-inorganic fertilizers without FYM and vermicompost. Consequently, the significantly least number of pods (13.49 pods plant⁻¹) was observed in the case of control (T₁) treatment.

4.2.2 Effect of integrated nutrient management on seed yield kg ha⁻¹ of black gram

The seed yield was calculated as per the prescribed formula under each of the treatments. The data were subjected to statistical computation. The best INM treatment T₇ was having (75 % recommended NPK + 25% P through Vermicompost + Sulphur+ *Azophos*) which yielded up to 775 kg ha⁻¹ and was found at par with T₉ yielding 768 kg ha⁻¹ followed by T₆ (757 kg ha⁻¹) > T₅ (743 kg ha⁻¹) > T₈ (734 kg ha⁻¹) which was at par with T₅. The performance of T₃ (692 kg ha⁻¹) and T₄ (678 kg ha⁻¹) was statistically at par. The seed yield decreased up to a significant extent in T₃, T₄, and T₁ treatments. The lowest yield (568 kg ha⁻¹) was obtained under T₁ (control) treatments.

4.2.3 Effect of integrated nutrient management on stover yield kg ha⁻¹ of black gram

The data pertaining to stover yield after statistical analysis are presented in Table 4.5 and exhibited through bar diagrammed as in Fig. 4.2. It is apparent that this parameter was influenced significantly due to different INM treatments. The treatment T₇ (75 % recommended

Table 4.1. Effect of different integrated nutrient management treatments on growth and yield attributes

Sr. No	Treatments	Plant ht.	No. of root nodules plant ⁻¹	No. of pods plant ⁻¹
T ₁	Control	31.98	13	13.49
T ₂	100 % recommended NPK	36.12	15	14.26
T ₃	100 % recommended NPK +Sulphur	32.78	17	16.31
T ₄	100 % recommended NPK + Azophos	35.25	16	16.25
T ₅	100 % recommended NPK +Sulphur + Azophos	39.90	17	18.07
T ₆	75% recommended NPK + 25 % N through FYM+ Sulphur+ Azophos	38.93	18	20.94
T ₇	75 % recommended NPK + 25% N through Vermicompost + Sulphur+ Azophos	43.86	17	32.25
T ₈	50% recommended NPK + 50 % N through FYM + Sulphur + Azophos	39.98	18	24.28
T ₉	50% recommended NPK + 50 % N through Vermicompost + Sulphur + Azophos	35.57	19	28.92
	CD (0.05)	NS	0.3	0.64
	SE m(±)	0.45	0.1	0.21

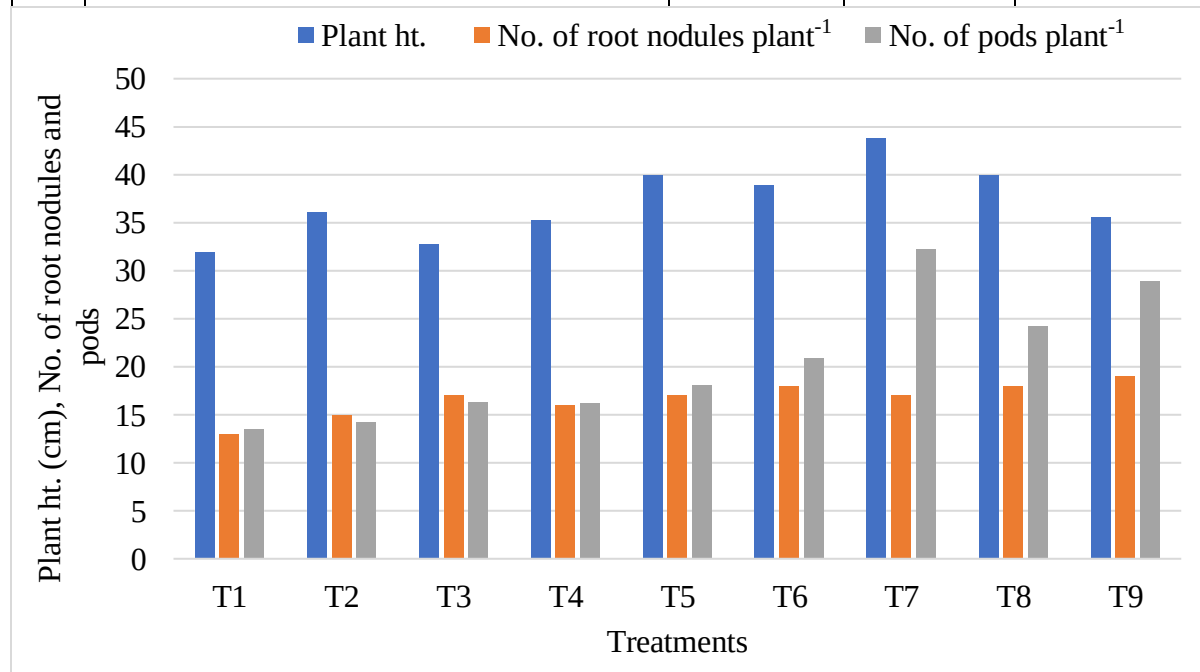


Fig. 4.1 Effect of different integrated nutrient management treatments on plant height (cm), no. of root nodules and pods

Table 4.2. Effect of different integrated nutrient management treatments on seed and stover yield kg ha⁻¹

Sr. No.	Treatments	Seed yield	Stover yield
T ₁	Control	568	1022.4
T ₂	100 % recommended NPK	612	1101.6
T ₃	100 % recommended NPK +Sulphur	692	1245.6
T ₄	100 % recommended NPK + Azophos	678	1220.4
T ₅	100 % recommended NPK +Sulphur + Azophos	743	1337.4
T ₆	75% recommended NPK + 25 % N through FYM+ Sulphur+ Azophos	757	1362.6
T ₇	75 % recommended NPK + 25% N through Vermicompost + Sulphur+ Azophos	775	1395.0
T ₈	50% recommended NPK + 50 % N through FYM + Sulphur + Azophos	734	1321.2
T ₉	50% recommended NPK + 50 % N through Vermicompost + Sulphur + Azophos	768	1382.4
	CD (0.05)	21.39	44.32
	SE m(±)	7.07	12.87

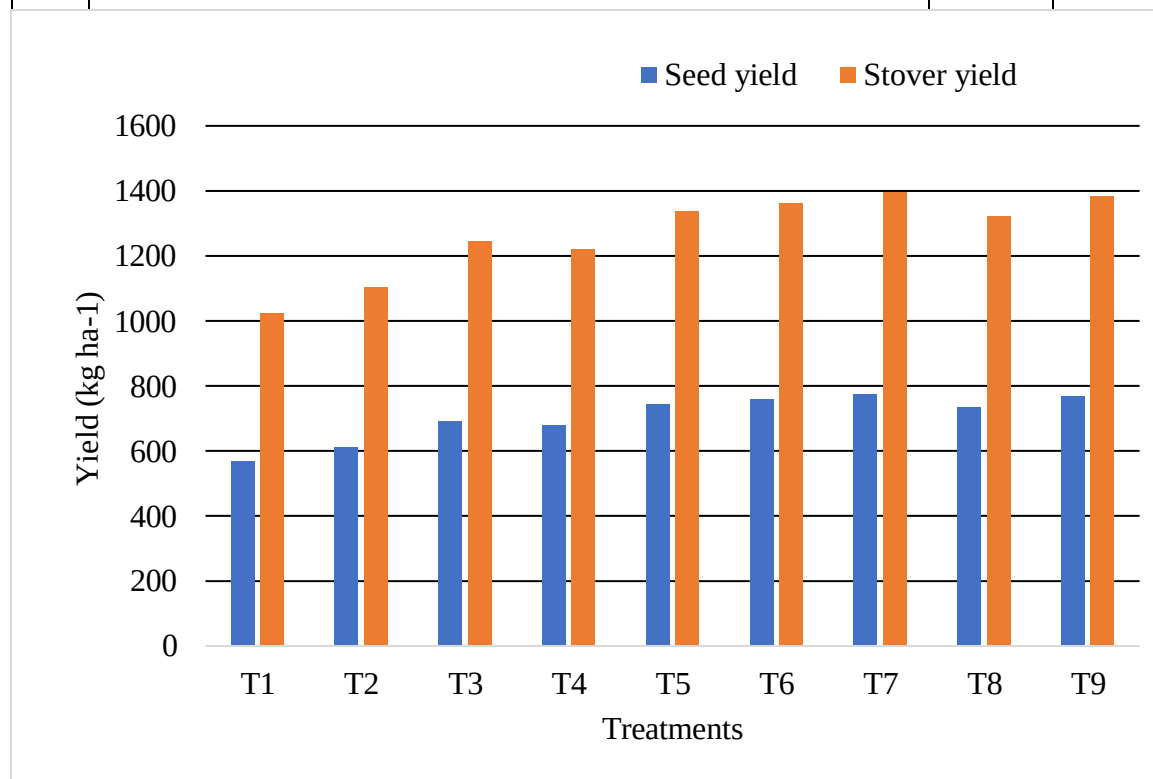


Fig. 4.2 Effect of different integrated nutrient management treatments on seed and stover yield

NPK + 25% P through Vermicompost + Sulphur + *Azophos*) proved significantly superior to all the INM treatments and was found at par with T₉ with the yield of 1382.40 kg ha⁻¹ and T₆ with the yield of 1362.60 kg ha⁻¹. This was followed by T₅ (1337.40 kg ha⁻¹ > T₈ (1321.20 kg ha⁻¹). The stover yield decreased with the decrease in RDF application under inorganic and organic combinations. Accordingly, the stover yield under T₄ and T₃ reached up to the lower extent (1220.40 to 1245.60 kg ha⁻¹). The control treatment (T₁) resulted in significantly the lowest stover yield (1022.40 kg ha⁻¹).

4.3 Physico-chemical properties

4.3.1 Effect of integrated nutrient management on available N of soil in black gram

The data displayed in Table 4.3 indicate that the applied INM treatments exerted a non-significant impact on this parameter. The maximum available nitrogen (144.65 kg ha⁻¹) was recorded in the case of T₈ (50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos*), closely followed by T₉ (144.38 kg ha⁻¹) > T₇ (140.73 kg ha⁻¹) > T₆ (137.58 kg ha⁻¹). The available nitrogen was lowered in the case of T₂ and T₃ (145.68 to 139.80 kg ha⁻¹). The lowest available nitrogen (135.28 kg ha⁻¹) was observed in the case of T₁ (control).

4.3.2 Effect of integrated nutrient management on available P (kg/ha) of soil in black gram

The available phosphorus content improved significantly in different integrated nutrient treatments over control as shown in table 4.3. The maximum build-up of available phosphorus (14.98 kg ha⁻¹) was found in the treatment T₉ receiving 50% recommended NPK + 50 % P through Vermicompost + Sulphur + *Azophos* followed by the treatments T₇ (14.45) > T₃ (13.98 kg ha⁻¹) > T₈ (13.14 kg ha⁻¹) > T₆ (13.12 kg ha⁻¹). Also, treatment (T₉) was found superior to the rest of the treatments. As compared to the control (10.72), T₂ (14.18 kg ha⁻¹) and T₄ (12.82 kg ha⁻¹) showed a better build-up of available phosphorus in the soil. The lowest value of available phosphorus (10.72 kg ha⁻¹) was observed in the treatment (T₁) which was control.

4.3.3 Effect of integrated nutrient management on available K (kg/ha) of soil in black gram

The data in table 4.3 indicated significant effect of integrated nutrient management on the available potassium in soil. The available potassium status ranged from 110.70 kg ha⁻¹ in treatment T₁ (control) to 147.10 kg ha⁻¹ in treatment T₇ (75 % recommended NPK + 25% P through Vermicompost + Sulphur + *Azophos*). Among all the treatments, treatment T₇ recorded highest amount of available potassium (147.10 kg ha⁻¹) which was at par with the treatment

T₈(146.20 kg ha⁻¹) and T₆(145.40 kg ha⁻¹) followed by T₉(144.20 kg ha⁻¹) > T₅(143.20 kg ha⁻¹) > T₄(141.80 kg ha⁻¹) > T₂(138.25 kg ha⁻¹) > T₃(132.90 kg ha⁻¹). Application of 100% NPK through chemicals increased available potassium by 5.8% as compared to treatment T₅ and T₃. The lowest available potassium (110.70 kg ha⁻¹) was obtained in the treatment T₁(control).

4.3.4 Effect of integrated nutrient management on organic carbon (g kg⁻¹) in black gram

The data displayed in Table 4.4 indicate that the applied INM treatments exerted nonsignificant impact upon this parameter. The maximum organic carbon (3.80 g kg⁻¹) was recorded in case of T₉ (50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos*), closely followed by T₇(3.71 g kg⁻¹) > T₈(3.70 g kg⁻¹) > T₂ (3.68 g kg⁻¹). The organic carbon was lowered down in case of T₄ and T₃ (3.40 to 3.20 g kg⁻¹). The lowest organic carbon (3.15 g kg⁻¹) was observed in case of T₁ (control).

4.3.5 Effect of integrated nutrient management on pH of black gram

The data displayed in Table 4.4 indicate that the applied INM treatments exerted nonsignificant impact upon this parameter. The maximum pH (6.81) was recorded in case of T₁ (control), closely followed by T₂(6.78) > T₄(6.78) > T₃(6.76) > T₅ (6.74). The pH was lowered down in case of T₇ and T₉ (6.73 to 6.71). The lowest pH (6.67) was observed in case of T₈ (50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos*).

4.3.6 Effect of integrated nutrient management on EC (dSm⁻¹) of black gram:

The data displayed in Table 4.4 indicate that the applied INM treatments exerted nonsignificant impact upon this parameter. The maximum EC (0.25) was recorded in case of T₈ (50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos*), closely followed by T₉(0.23)>T₇(0.23)>T₆(0.24)>T₅(0.21). The EC was lowered down in case of T₄ and T₂ (0.20 to 0.19). The lowest EC (0.18) was observed in case of T₁ (control).

4.4 Biological properties

4.4.1 Effect of integrated nutrient management on permanganate oxidizable carbon (mg kg⁻¹) of black gram

Application of different integrated nutrient treatments in the soil had a significant and positive impact on permanganate oxidizable carbon (table 4.5). In the soil, KMnO₄-C ranged from 0.40 to 0.66g kg⁻¹ under different treatments. The highest value of permanganate oxidizable carbon (0.66g kg⁻¹) was recorded in treatment T₉(50% recommended NPK + 50 % P through Vermicompost + Sulphur + *Azophos*) among all the treatments and it was followed

Table 4.3. Effect of different integrated nutrient management treatments on available nitrogen, phosphorus and potassium (kg ha⁻¹)

Sr. No.	Treatments	N	P	K
T ₁	Control	135.28	10.72	110.70
T ₂	100 % recommended NPK	145.68	14.18	138.25
T ₃	100 % recommended NPK +Sulphur	139.80	13.98	132.90
T ₄	100 % recommended NPK + Azophos	138.97	12.82	141.80
T ₅	100 % recommended NPK +Sulphur + Azophos	137.06	13.98	143.20
T ₆	75% recommended NPK + 25 % N through FYM+ Sulphur+ Azophos	137.58	13.12	145.40
T ₇	75 % recommended NPK + 25% N through Vermicompost + Sulphur+ Azophos	140.73	14.45	147.10
T ₈	50% recommended NPK + 50 % N through FYM + Sulphur + Azophos	144.65	13.14	146.20
T ₉	50% recommended NPK + 50 % N through Vermicompost + Sulphur + Azophos	144.38	14.98	144.20
	CD (0.05)	NS	0.23	3.04
	SE m(±)	0.68	0.10	0.70

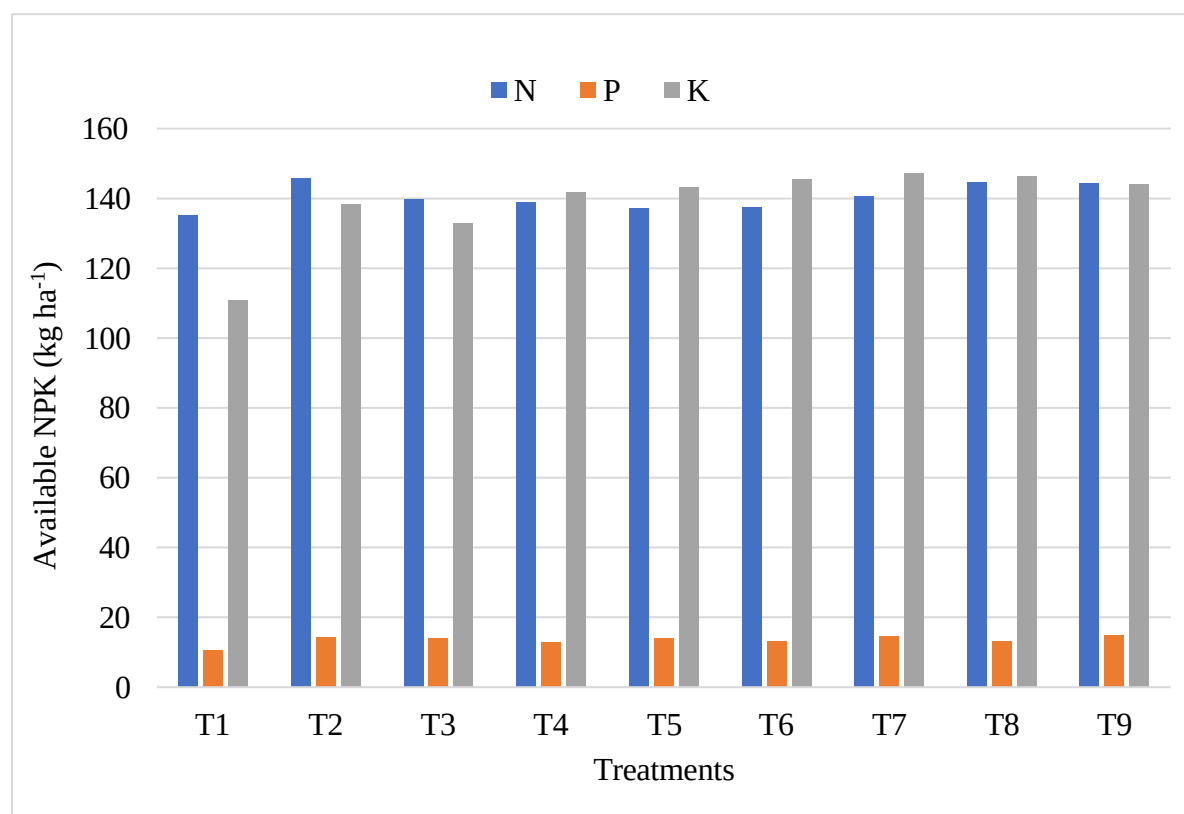


Fig. 4.3 Effect of different integrated nutrient management treatments on available N, P and K (kg ha⁻¹)

Table 4.4. Effect of different treatments of integrated nutrient management on pH, EC and OC

Sr. No.	Treatments	pH	EC (dS m ⁻¹)	OC (g kg ⁻¹)
T ₁	Control	6.81	0.18	3.15
T ₂	100 % recommended NPK	6.78	0.19	3.68
T ₃	100 % recommended NPK +Sulphur	6.76	0.20	3.20
T ₄	100 % recommended NPK + Azophos	6.78	0.20	3.40
T ₅	100 % recommended NPK +Sulphur + Azophos	6.74	0.21	3.62
T ₆	75% recommended NPK + 25 % N through FYM+ Sulphur+ Azophos	6.69	0.24	3.60
T ₇	75 % recommended NPK + 25% N through Vermicompost + Sulphur+ Azophos	6.73	0.23	3.71
T ₈	50% recommended NPK + 50 % N through FYM + Sulphur + Azophos	6.67	0.25	3.70
T ₉	50% recommended NPK + 50 % N through Vermicompost + Sulphur + Azophos	6.71	0.23	3.80
	CD (0.05)	NS	NS	NS
	SE m(±)	0.013	0.002	0.01

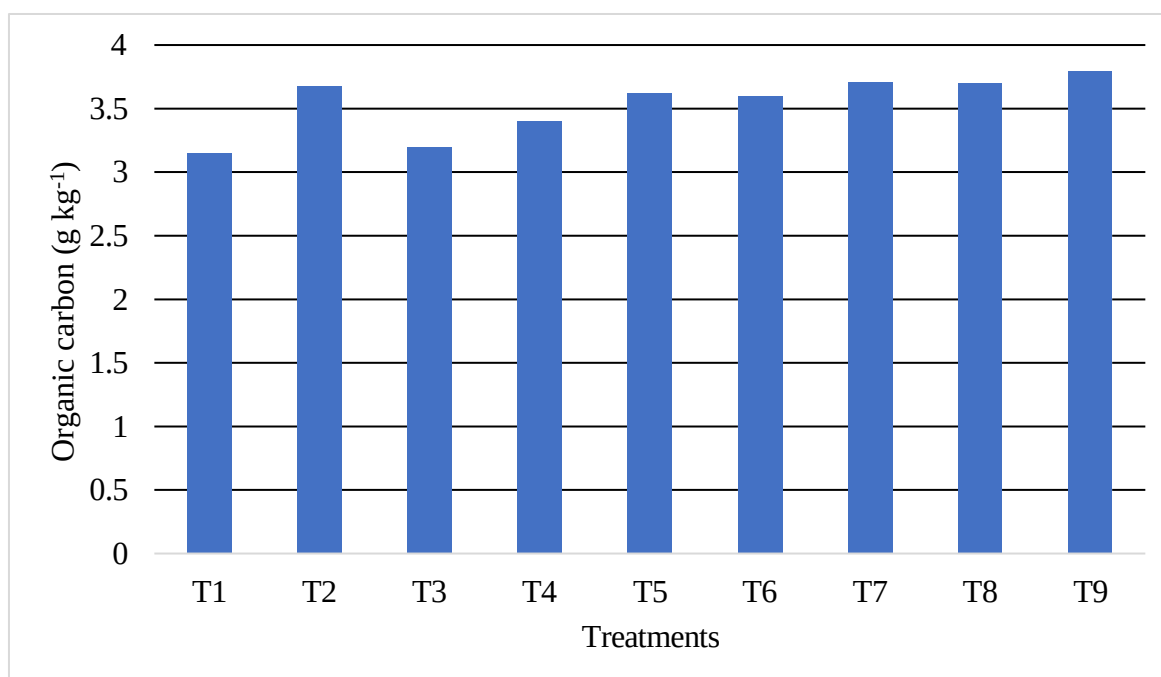


Fig. 4.4 Effect of different integrated nutrient management treatments on OC

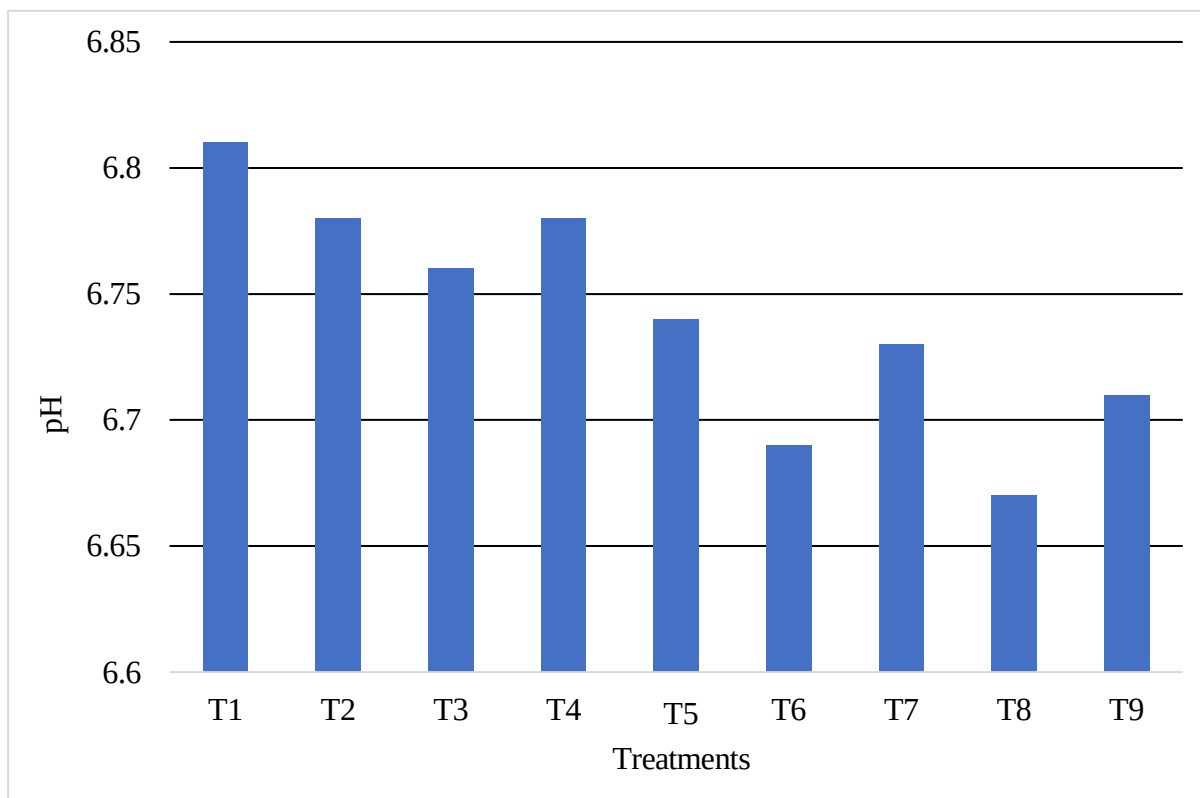


Fig. 4.5 Effect of different integrated nutrient management treatments on pH

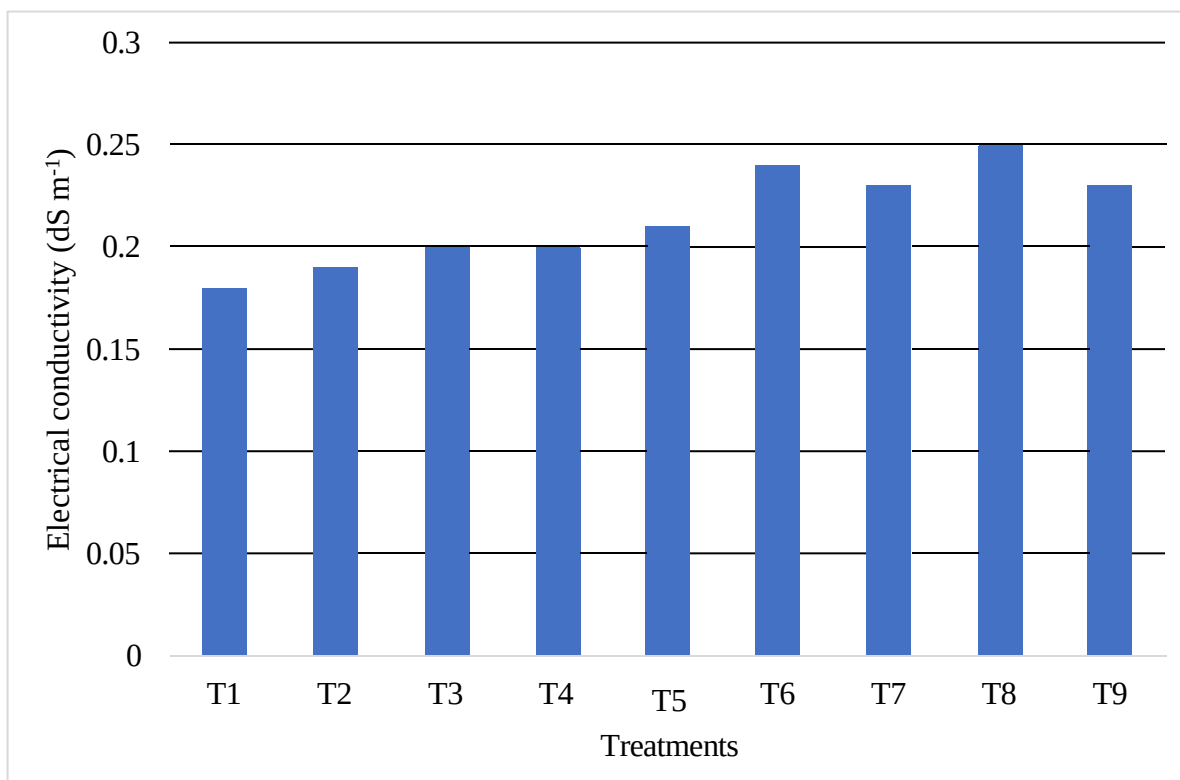


Fig. 4.6 Effect of different integrated nutrient management treatments on EC (dS m^{-1})

by the treatments $T_7 > T_6 > T_8 > T_5 > T_4 > T_3$. The sole application of 100% inorganic fertilizers through chemicals in treatment T_2 showed lower values of $\text{KMnO}_4\text{-C}$ than that in treatments with the combination of organic and inorganic fertilizers. The lowest $\text{KMnO}_4\text{-C}$ (0.40 g kg^{-1}) was recorded in treatment T_1 (control) which was statistically at par with the treatments T_2 (0.43 g kg^{-1}).

4.4.2 Effect of integrated nutrient management on microbial biomass carbon (mg kg^{-1}) in black gram

The application of various INM treatments in the soil showed a significant improvement in MBC as presented in the table 4.5. In the soil, the treatment T_8 receiving 50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos* recorded significantly highest microbial biomass carbon (243.4 mg kg^{-1}) and it was followed by the treatment T_6 (233.6 mg kg^{-1}) $> T_9$ (220.9 mg kg^{-1}). Also treatment T_8 was superior than rest of the treatments. Treatment T_5 (192.8 mg kg^{-1}) and T_4 (192.1 mg kg^{-1}) showed significantly superior values over the treatments T_2 (191.7 mg kg^{-1}) and T_3 (190.5 mg kg^{-1}). Treatment T_5 was statistically at par with microbial biomass carbon in the treatment T_4 , T_2 and T_3 . The lowest content of microbial biomass carbon (180 mg kg^{-1}) was obtained in the treatment T_1 (control).

4.4.3 Effect of integrated nutrient management on dehydrogenase activity ($\mu\text{g TPF}^{-1} \text{ min}^{-1}$) in black gram

A perusal of data given in table 4.5 indicated that after harvesting of black gram crop significantly higher dehydrogenase activity was recorded in integrated nutrient management treatments compared to control. The highest dehydrogenase activity ($2.72 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$) was recorded in treatment T_6 (75% recommended NPK + 25 % P through FYM+ Sulphur+ *Azophos*) and was significantly higher compared to T_8 ($2.64 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$) followed by T_7 ($2.49 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$) $> T_9$ ($2.38 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$) $> T_4$ ($2.23 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$). The dehydrogenase activity was lowered in T_5 ($1.96 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$) which was at par with T_3 ($1.84 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$) and was followed by T_2 ($1.68 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$). The lowest value was observed in control which was T_1 ($1.50 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$).

4.4.4 Effect of integrated nutrient management on bacterial count (CFU g^{-1}) in soil of black gram

After the harvest of black gram, the bacterial population varied between 15.50 and $61.72 \times 10^6 \text{ CFU g}^{-1} \text{ soil}$. The application of organic manure treatments increased the bacterial population after the harvest of black gram crop. A significantly highest bacterial population

was observed in T₇ (61.72×10^6 CFU g⁻¹ soil) consisting of 75 % recommended NPK + 25% P through Vermicompost + Sulphur+ *Azophos* followed by T₉(55.64)>T₆ (49.47) >T₈(47.38)>T₄(39.23)>T₅(34.96)>T₃(28.84)>T₂(22.68). The lowest value of bacterial population was observed in T₁ (control).

4.4.5 Active carbon pool

4.4.5.1 Very labile carbon (mg g⁻¹)

The presented data in table 4.16 results that the application of inorganic and organic fertilizers significantly increased very labile carbon in T₈(5.45 mg g⁻¹) consisting of 50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos* compared to control (4.01 mg g⁻¹) and was at par with T₆(4.58 mg g⁻¹) followed by T₉ (4.99 mg g⁻¹) > T₇ (4.82 mg g⁻¹) >T₅ (4.77 mg g⁻¹) >T₄(4.72 mg g⁻¹) >T₃(4.58 mg g⁻¹) > T₂ (4.52 mg g⁻¹). The lowest value 4.01 mg g⁻¹ observed in T₁ (control).

4.4.5.2 Labile carbon (mg g⁻¹)

Data revealed that there were no significant differences among the treatments. The highest labile carbon value of 4.65 mg g⁻¹ was recorded in treatment T₈ over rest of the treatments after harvest of black gram crop (Table 4.6) consisting of 50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos* compared to control (3.28 mg g⁻¹) and followed by T₆(4.58 mg g⁻¹) > T₉ (4.02 mg g⁻¹) > T₇ (3.91 mg g⁻¹) >T₅ (3.72 mg g⁻¹) >T₄(3.67 mg g⁻¹) >T₃(3.56 mg g⁻¹) > T₂(3.52 mg g⁻¹). The lowest value 3.28 mg g⁻¹ observed in T₁ (control).

4.4.5.3 Less labile carbon (mg g⁻¹)

It is evident from the data furnished in table 4.6 that there were no significant differences among the treatments. The highest very labile carbon value of 2.97 mg g⁻¹ was recorded in treatment T₉ (3.02 mg g⁻¹) over rest of the treatments after harvest of black gram crop (Table 4.17) consisting of 50% recommended NPK + 50 % P through Vermicompost + Sulphur + *Azophos* compared to control (1.32 mg g⁻¹) and followed by T₇(2.97 mg g⁻¹) > T₈ (2.76 mg g⁻¹) > T₆ (2.71 mg g⁻¹) > T₅ (2.45 mg g⁻¹) > T₄(2.39 mg g⁻¹) > T₃(2.35 mg g⁻¹) > T₂(1.98 mg g⁻¹). The lowest value (1.32 mg g⁻¹) observed in T₁ (control).

4.4.5.4 Total organic carbon (mg g⁻¹)

Data revealed that there were no significant differences among the treatments. The highest total organic carbon value of 17.40 mg g⁻¹ was recorded in treatment T₈ over rest of the treatments after harvest of black gram crop (Table 4.19) consisting of 50% recommended NPK

Table 4.5. Effect of different integrated nutrient management treatments on biological parameters

Sr. No.	Treatments	Permanganate oxidizable carbon (mg kg⁻¹)	MBC (mg kg⁻¹)	Dehydrogenase Activity (µg TPF⁻¹ min⁻¹)	Bacterial count (CFU g⁻¹)
T ₁	Control	0.40	180.00	1.50	15.50
T ₂	100 % recommended NPK	0.43	191.70	1.68	22.68
T ₃	100 % recommended NPK + Sulphur	0.46	190.50	1.84	28.84
T ₄	100 % recommended NPK + Azophos	0.48	192.10	2.23	39.23
T ₅	100 % recommended NPK + Sulphur + Azophos	0.49	192.80	1.96	34.96
T ₆	75% recommended NPK + 25 % N through FYM+ Sulphur+ Azophos	0.57	233.60	2.72	49.47
T ₇	75 % recommended NPK + 25% N through Vermicompost + Sulphur+ Azophos	0.62	211.70	2.49	61.72
T ₈	50% recommended NPK + 50 % N through FYM + Sulphur + Azophos	0.54	243.40	2.64	47.38
T ₉	50% recommended NPK + 50 % N through Vermicompost + Sulphur + Azophos	0.66	220.90	2.38	55.64
	CD (0.05)	0.03	6.79	0.15	2.90
	SE m (±)	0.01	2.24	0.05	0.96

Table 4.6. Effect of different integrated nutrient management treatments on very labile, labile, less labile and total organic carbon (mg g⁻¹)

Sr. No.	Treatments	Very Labile carbon	Labile carbon	Less labile carbon	Total Organic carbon
T ₁	Control	4.01	3.28	1.32	12.54
T ₂	100 % recommended NPK	4.52	3.52	1.98	13.82
T ₃	100 % recommended NPK + Sulphur	4.58	3.56	2.35	14.52
T ₄	100 % recommended NPK + Azophos	4.72	3.67	2.39	13.70
T ₅	100 % recommended NPK + Sulphur + Azophos	4.77	3.72	2.45	14.74
T ₆	75% recommended NPK + 25 % N through FYM+ Sulphur+ Azophos	5.24	4.58	2.71	16.26
T ₇	75 % recommended NPK + 25% N through Vermicompost + Sulphur+ Azophos	4.82	3.91	2.97	15.74
T ₈	50% recommended NPK + 50 % N through FYM + Sulphur + Azophos	5.45	4.65	2.76	17.40
T ₉	50% recommended NPK + 50 % N through Vermicompost + Sulphur + Azophos	4.99	4.02	3.02	16.38
	CD (0.05)	0.33	NS	NS	NS
	SE m (±)	0.11	0.09	0.05	0.45

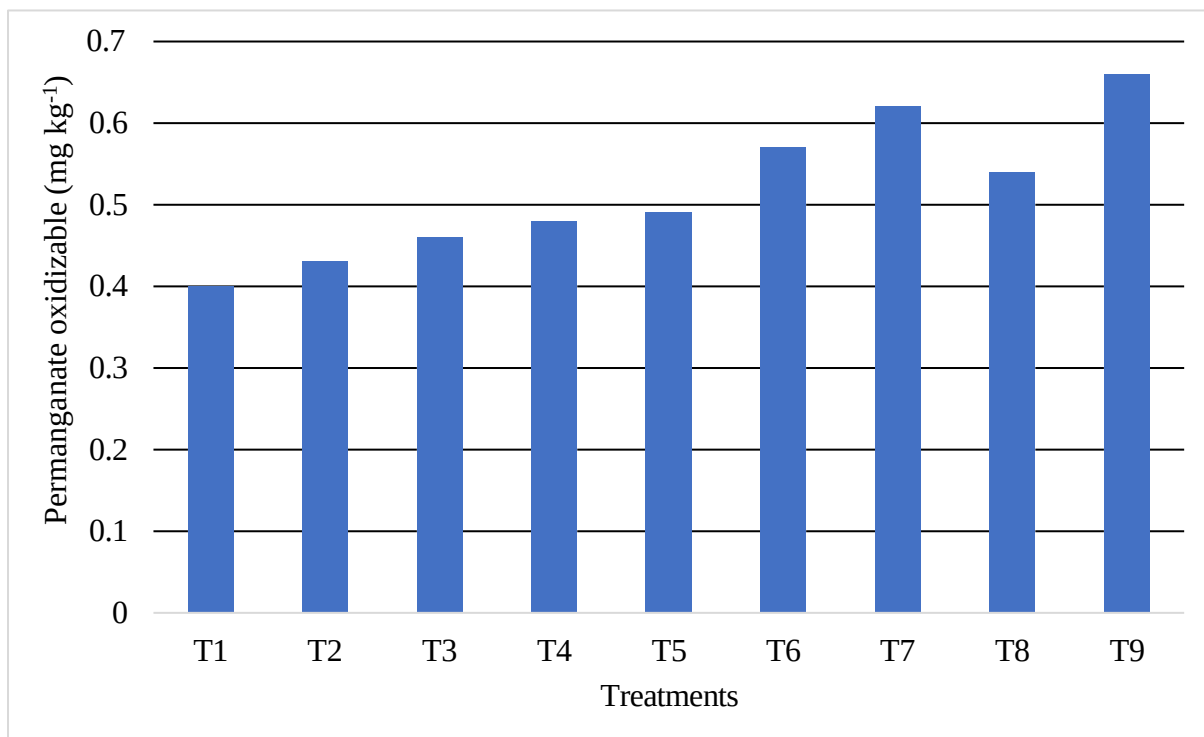


Fig. 4.7 Effect of different integrated nutrient management treatments on Permanganate oxidizable (mg kg⁻¹)

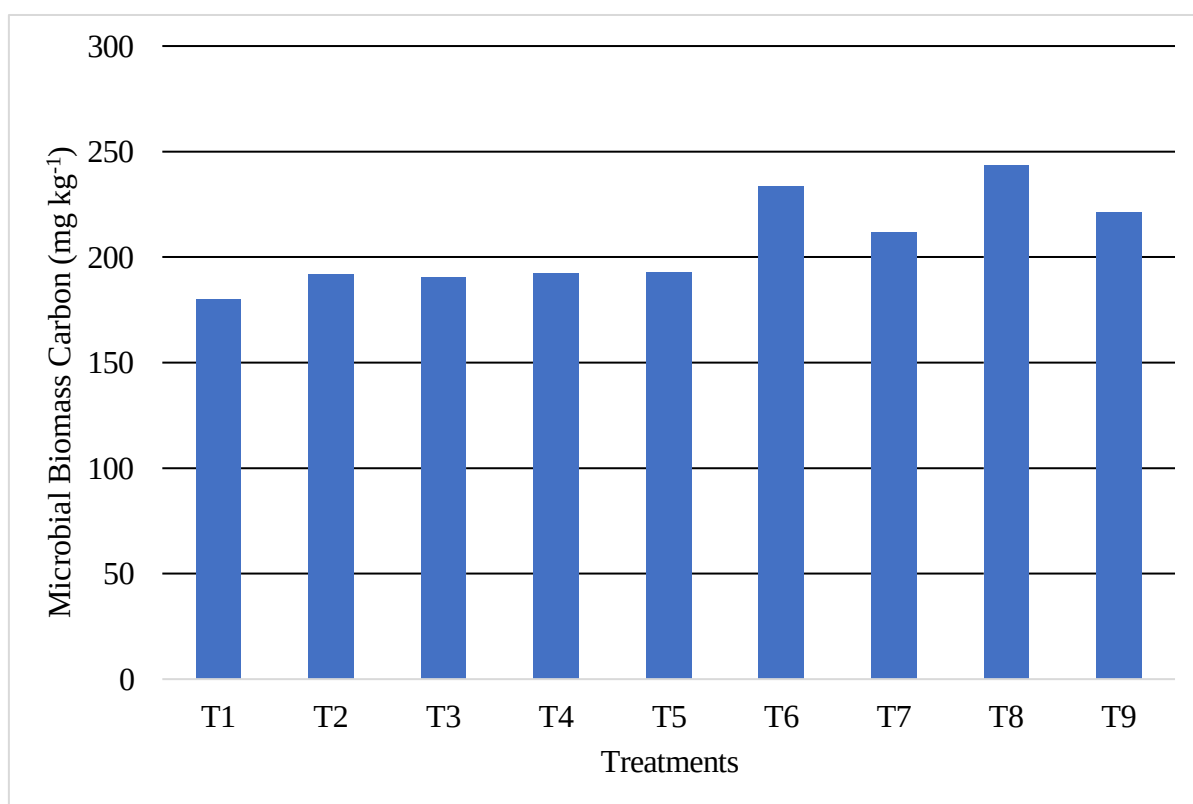


Fig. 4.8 Effect of different integrated nutrient management treatments on Microbial Biomass Carbon (mg kg⁻¹)

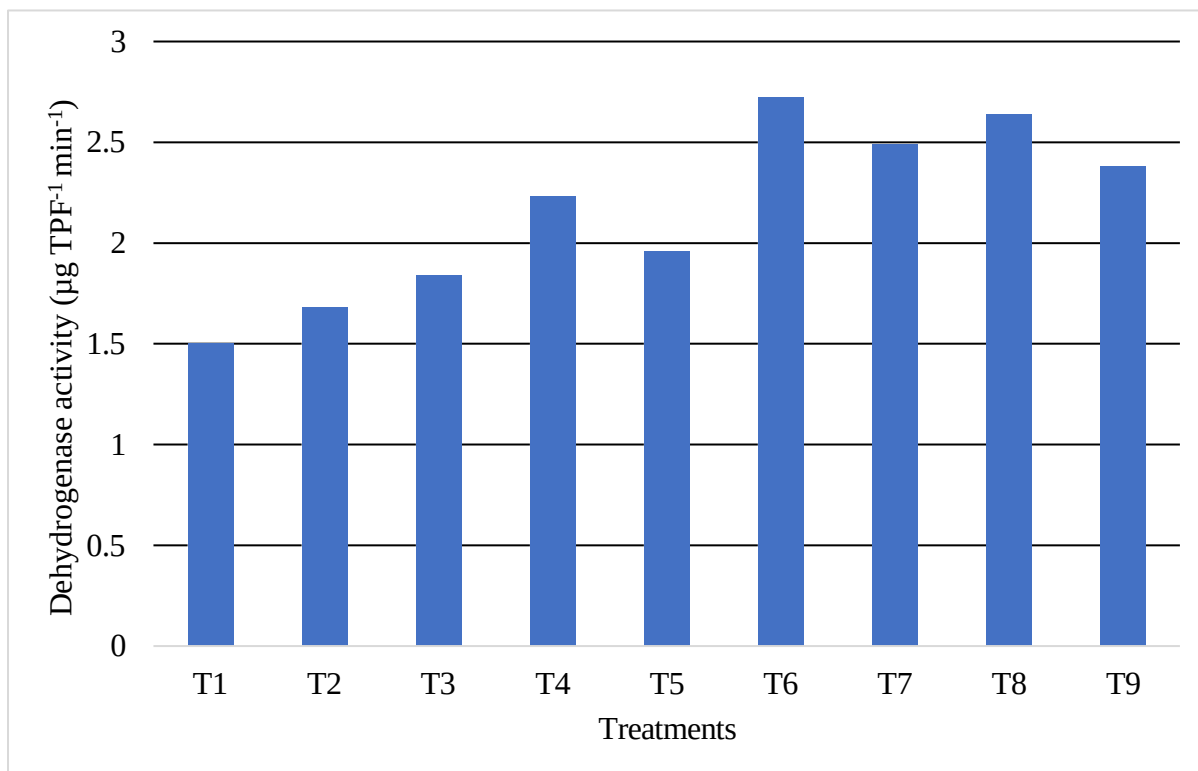


Fig. 4.9 Effect of different integrated nutrient management treatments on Dehydrogenase activity ($\mu\text{g TPF}^{-1} \text{min}^{-1}$)

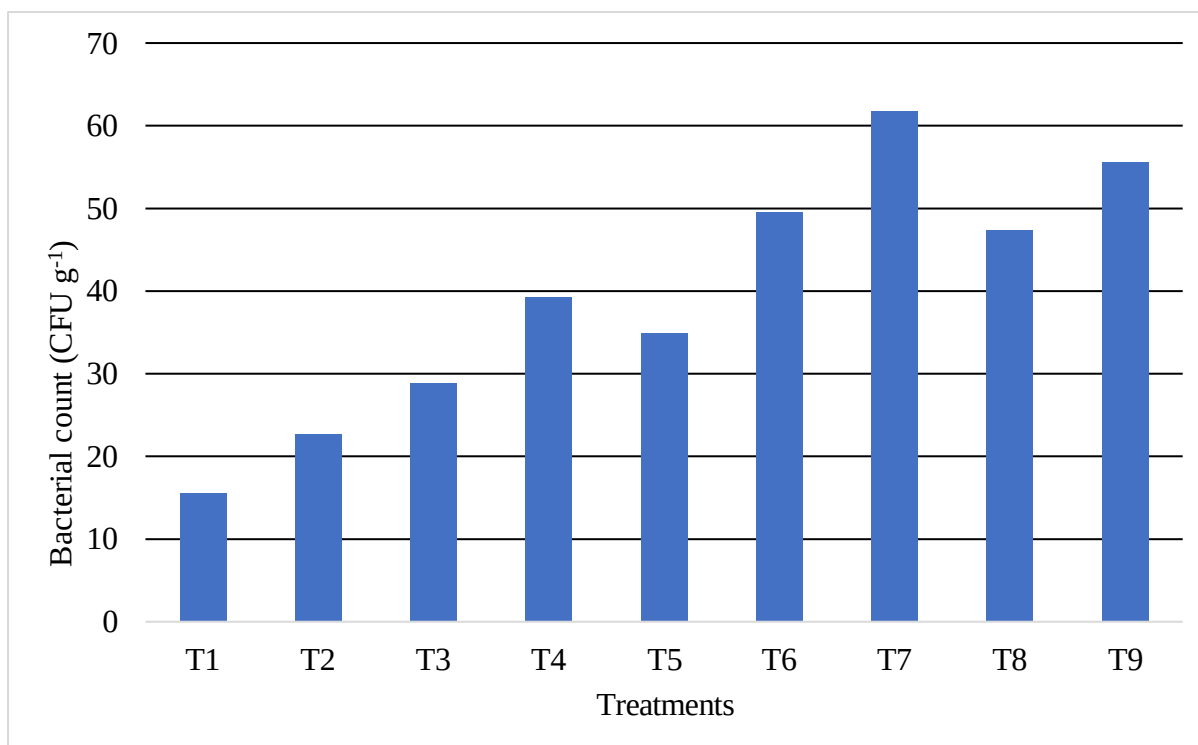


Fig. 4.10 Effect of different integrated nutrient management treatments on Bacterial count (CFU g⁻¹)

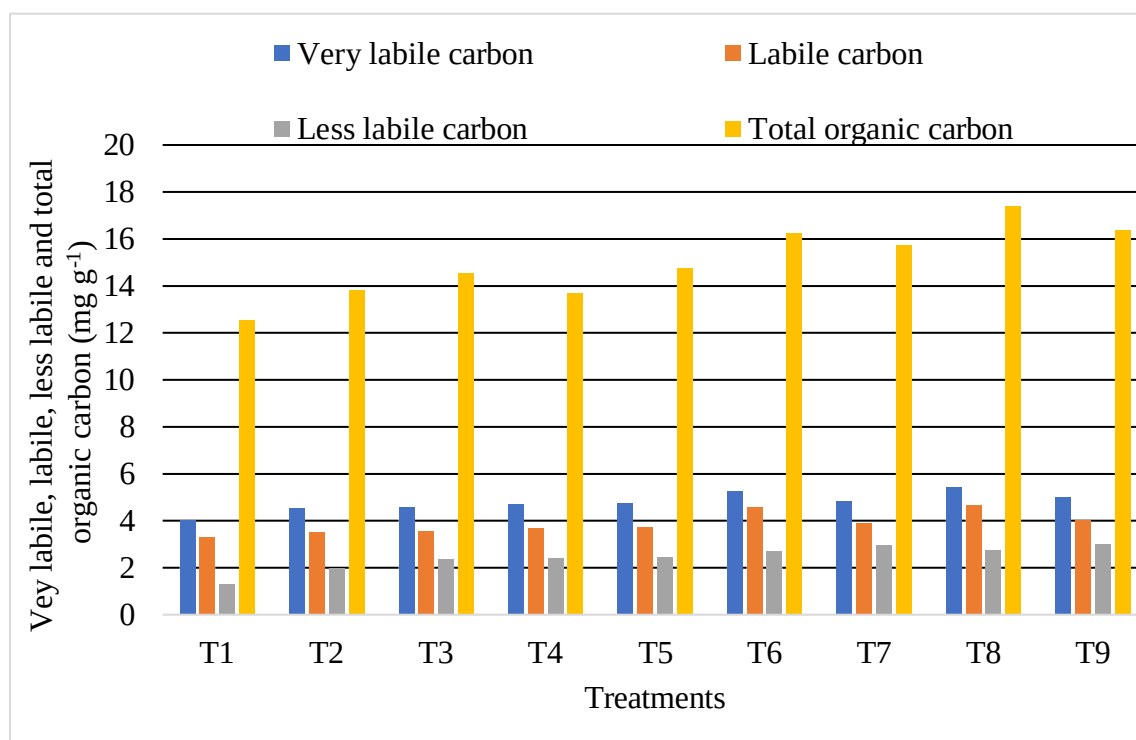


Fig. 4.11 Effect of different integrated nutrient management treatments on very labile, labile, less labile and total organic carbon (mg g⁻¹)

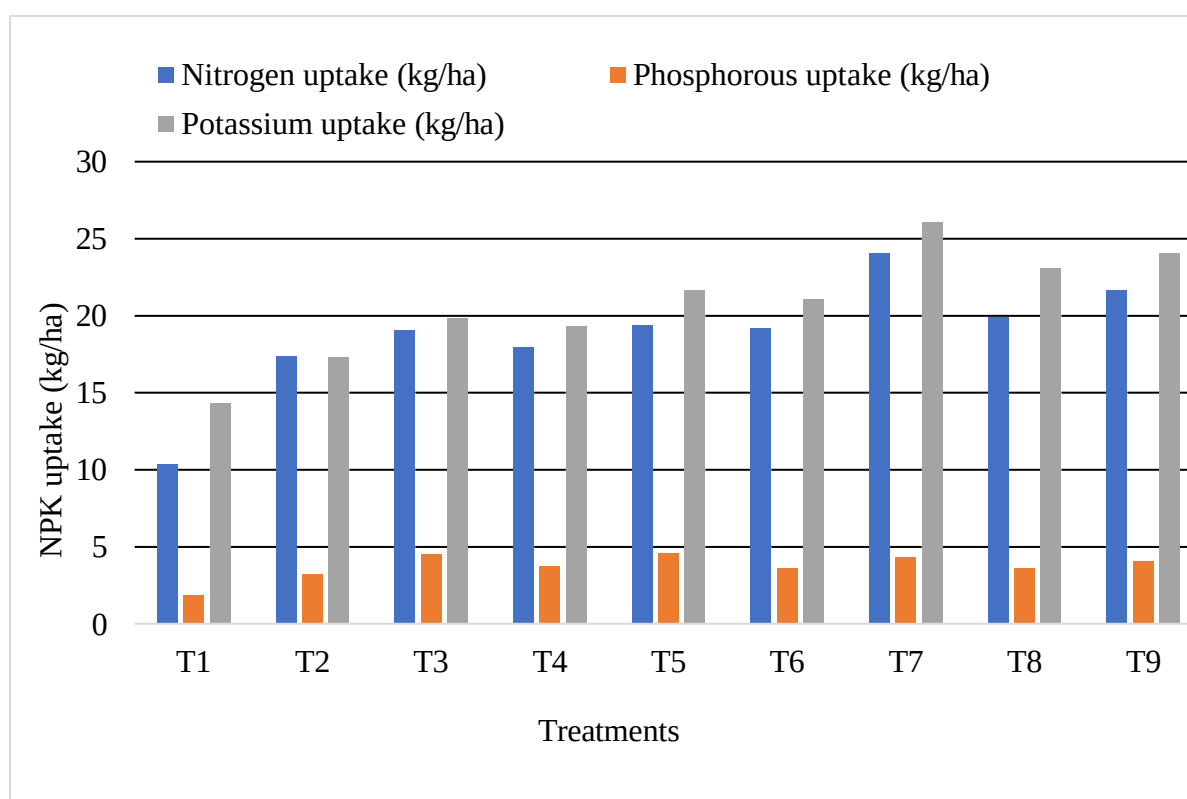


Fig. 4.12 Effect of different integrated nutrient management treatments on Nitrogen, Phosphorous and Potassium uptake by stover (kg ha⁻¹)

+ 50 % P through FYM + Sulphur + *Azophos* compared to control (3.28 mg g^{-1}) and followed by $T_9(16.38 \text{ mg g}^{-1}) > T_6(16.26 \text{ mg g}^{-1}) > T_7(15.74 \text{ mg g}^{-1}) > T_5(14.74 \text{ mg g}^{-1}) > T_3(14.52 \text{ mg g}^{-1}) > T_2(13.82 \text{ mg g}^{-1}) > T_4(13.70 \text{ mg g}^{-1})$. The lowest value (12.56 mg g^{-1}) observed in T_1 (control).

4.5 Nutrient use efficiency

4.5.1 Nitrogen uptake (seed and stover) (kg/ha):

Highest N uptake by grains and stover was recorded in T_7 i.e. 75 % recommended NPK + 25% P through Vermicompost + Sulphur+ *Azophos* (29.07 kg ha^{-1} by seed 24.09 kg ha^{-1} by stover) which was followed by $T_9(26.14 \text{ kg ha}^{-1}$ by seed, 21.67 kg ha^{-1} by stover) $> T_8(25.01 \text{ kg ha}^{-1}$ by seed, 19.91 kg ha^{-1} by stover) $> T_5(24.66 \text{ kg ha}^{-1}$ by seed, 19.40 kg ha^{-1} by stover) $> T_6(24.60 \text{ kg ha}^{-1}$ by seed, 19.18 kg ha^{-1} by stover) $> T_3(22.42 \text{ kg ha}^{-1}$ by seed, 19.08 kg ha^{-1} by stover) $> T_4(22.31 \text{ kg ha}^{-1}$ by seed, 17.98 kg ha^{-1} by stover) $> T_2(20.07 \text{ kg ha}^{-1}$ by seed, 17.40 kg ha^{-1} by stover). While, lowest value (14.42 kg ha^{-1} by seed, 10.33 kg ha^{-1} by stover) was obtained with control (T_1).

4.5.2 Phosphorus uptake (seed and stover) (kg/ha):

As shown in table no. (4.7.) highest P uptake by grains and stover was recorded with application of (T_7) 75 % recommended NPK + 25% P through Vermicompost + Sulphur+ *Azophos* (3.97 kg ha^{-1} by seed, 4.32 kg ha^{-1} by stover) which was at par with $T_5(3.79 \text{ kg ha}^{-1}$ by seed, 4.60 kg ha^{-1} by stover) which was significant over rest of the treatments which were $T_3(3.73 \text{ kg ha}^{-1}$ by seed, 4.54 kg ha^{-1} by stover) $> T_9(3.56 \text{ kg ha}^{-1}$ by seed, 4.03 kg ha^{-1} by stover) $> T_4(3.39 \text{ kg ha}^{-1}$ by seed, 3.75 kg ha^{-1} by stover) $> T_6(3.34 \text{ kg ha}^{-1}$ by seed, 3.62 kg ha^{-1} by stover) $> T_8(3.27 \text{ kg ha}^{-1}$ by seed, 3.58 kg ha^{-1} by stover) $> T_2(3.12 \text{ kg ha}^{-1}$ by seed, 3.18 kg ha^{-1} by stover). While, lowest value (1.98 kg ha^{-1} by grain, 1.84 kg ha^{-1} by stover) was obtained with control (T_1).

4.5.3 Pottasium uptake (seed and stover) (kg/ha):

Highest uptake of K by grains and stover was recorded with application of (T_7) 75 % recommended NPK + 25% P through Vermicompost + Sulphur+ *Azophos* (9.87 kg ha^{-1} by seed 26.08 kg ha^{-1} by stover) which was followed by $T_9(8.77 \text{ kg ha}^{-1}$ by seed, 24.02 kg ha^{-1} by stover) $> T_8(8.39 \text{ kg ha}^{-1}$ by seed, 23.07 kg ha^{-1} by stover) $> T_5(8.32 \text{ kg ha}^{-1}$ by seed, 21.66 kg ha^{-1} by stover) $> T_6(7.72 \text{ kg ha}^{-1}$ by seed, 21.06 kg ha^{-1} by stover) $> T_3(7.54 \text{ kg ha}^{-1}$ by seed, 19.80 kg ha^{-1} by stover) $> T_4(7.32 \text{ kg ha}^{-1}$ by seed, 19.28 kg ha^{-1} by stover) $> T_2(6.55 \text{ kg ha}^{-1}$ by seed, 17.29 kg ha^{-1} by stover). While, lowest value (5.11 kg ha^{-1} by seed, 14.31 kg ha^{-1} by stover) was obtained with control (T_1).

Table 4.7. Effect of different treatments of integrated nutrient management on Nitrogen, Phosphorous and Potassium uptake by seeds and stover

Sr. No.	Treatments	Nitrogen uptake (kg/ha)		Phosphorous uptake (kg/ha)		Potassium uptake (kg/ha)	
		Seeds	Stover	Seed	Stover	Seeds	Stover
T ₁	Control	14.42	10.33	1.98	1.84	5.11	14.31
T ₂	100 % recommended NPK	20.07	17.40	3.12	3.18	6.55	17.29
T ₃	100 % recommended NPK + Sulphur	22.42	19.08	3.73	4.54	7.54	19.80
T ₄	100 % recommended NPK + Azophos	22.31	17.98	3.39	3.75	7.32	19.28
T ₅	100 % recommended NPK + Sulphur + Azophos	24.66	19.40	3.79	4.60	8.32	21.66
T ₆	75% recommended NPK + 25 % N through FYM+ Sulphur+ Azophos	24.60	19.18	3.34	3.62	7.72	21.06
T ₇	75 % recommended NPK + 25% N through Vermicompost + Sulphur+ Azophos	29.07	24.09	3.97	4.32	9.87	26.08
T ₈	50% recommended NPK + 50 % N through FYM + Sulphur + Azophos	25.01	19.91	3.27	3.58	8.39	23.07
T ₉	50% recommended NPK + 50 % N through Vermicompost + Sulphur + Azophos	26.14	21.67	3.56	4.03	8.77	24.02
	CD (0.05)	1.34	0.61	0.20	0.19	0.33	1.04
	SE m (±)	0.44	0.2	0.06	0.06	0.1	0.34

DISCUSSION

The goal of this research initiative is to develop a sustainable and environmental friendly nutrient management system for black gram, a major pulse crop. Conventional nutrient management techniques harm the soil by utilizing only chemical fertilizers. Integrated nutrient management recommends applying a variety of chemical fertilizers, organic manures, and biofertilizers to enhance and maintain the levels of organic carbon, macronutrients, and biological properties in soil. By using the biofertilizers, it strengthens the microbial community, which encrypts organic acids more rarely and releases nutrients from inaccessible forms into accessible forms. In order to analyse the effect of integrated nutrient management techniques, a trial was conducted on black gram.

This study was conducted to look into the **“Effect of Integrated Nutrient Management on Active Pool of Soil Organic Matter in Black gram (*Vigna mungo*) under Dryland Subtropics of Jammu”** at Research Farm, ACRA, Rakh Dhiansar, SKUAST-Jammu, J&K UT. This experiment provided some important results, which have been carefully analysed and discussed in this chapter.

5.1 Effect of integrated nutrient management on growth parameters, yield and yield attributes:

Except for plant height, the application of integrated nutrient management significantly improved yield parameters. This is because manure treatments make more available nitrogen as compared to chemical fertilizers. Vermicompost application was associated with higher levels of beneficial microorganisms, production of growth-promoting hormones, antibiotics, enzymes, and other factors that increase soil health and microorganisms (Barik *et al.*, 2006). Considering yield qualities, FYM and vermicompost were shown to be more effective alternatives. Vermicompost, FYM, and inorganic fertilizers significantly increased plant parameters, maybe as a result of vermicompost's higher nitrogen content and readily available to crops. Edward and Danial (1992), Suvarna Latha and Rao (2001), and Jha *et al.* (2004) also came to similar results. They suggested that a combination of organic and inorganic fertilizers produced greater results than using only inorganic fertilizers, probably because the inorganic fertilizer contained more nutrients and released those more quickly. A significant variation among the treatments was seen in the number of pods per plant and the number of nodules per

plant. A significant difference between the treatments was observed, and the application of organic manure enhanced the quantity of pods per plant compared to the control.

5.2 Effect of integrated nutrient management on nutrient use efficiency:

The data presented clearly indicates that the nitrogen concentration in black gram seeds was significantly raised by the use of both organic and inorganic fertilizers. Nitrogen is stored in organic matter, following mineralization, releases it into the soil. Low nitrogen concentration may have been caused by a limited supply of nitrogen in non-manured plots. Khatik and Dikshil (2001) reported similar results and found that diverse sources of organic manures and inorganic fertilizers responded favourable to increased percentages of nitrogen in rice plants when compared to control treatment.

As far as phosphorus is concerned, applications of organic and inorganic fertilizer mixtures, followed by additional manure combination treatments, were seen to result in significantly higher phosphorus in seeds than 100% of the required NPK alone. Since FYM is a rich source of phosphorus, phosphorus may have deposited in the soils. It might be a result of careful incorporation of organic manure, which enhances the activity of alkaline phosphatase (Guan, 1989). After decreasing the ability of the mineral components to fix phosphorus, organic materials go through mineralization and release phosphorus that is readily available to plants through several metabolic pathways (Brady and Weil, 1996).

Regarding the seed potassium content, no significant variations were found. It's possible that potassium mining took place in the control plots, where no manure was employed as a result of this. When the plant-available potassium is depleted, potassium is made available from non-exchangeable sites, maintaining equilibrium with its various forms. Regarding nitrogen and phosphorus in the stover, there were significant variations between treatments; however, when it came to seed nutritional content, the stover significantly outperformed the control. This is due to the fact that stover has a potassium content that is nearly 9–10 times higher than that of seeds. While examining the effects of applying FYM and vermicompost, Moola Ram *et al.* (2014) equivalently came to similar conclusions.

According to the data presented, integrated nutrient management significantly increased the yield of black gram. T₇ produced a yield that was much greater (775 kg ha⁻¹) than the control (568 kg ha⁻¹) and followed by T₉ (768 kg ha⁻¹). Similar findings have been noted by Singh *et al.* (2017), who revealed that rice grain yield was significantly influenced by various treatments compared to control. It might be because of the favourable physical conditions that result in

improved aeration and extensive root activity, both of which significantly increase the soil's ability to hold moisture and the availability of nutrients when integrated nutrient management is employed. Similar results have also been reported by various workers (Sharma, 1992; Roy *et al.* 2008; Ahmad *et al.* 2008; Choudhary and Suri, 2009; Hassanuzazzaman *et al.*, 2010; Myint *et al.* 2010, Gaind, 2015; Amanullah and Hidayatullah, 2016; Haridha *et al.*, 2020). Inorganic fertilizers and vermicompost were applied in combination at a rate of 17 t ha⁻¹, which boosted grain yield in sandy clay loam soil by more than 9.50% compared to control. The findings in soybean crops have also been supported by a number of researchers (Patil *et al.*, 2008; Laxman Rao *et al.*, 2016; Du *et al.*, 2020). Better tiller production and denser grains of rice result from the improvement and continuous supply of nutrients provided by manures and inorganic fertilizers (Mohandas *et al.*, 2008). Similar trends with regard to stover yield were seen. The highest stover yield, which was significant, proved that a favourable physical environment improved soil aeration, root activity, and, as a result, soil moisture holding capacity and nutrient absorption. These favourable physical conditions also produced higher crop growth and yield-attributing characteristics, which in turn increased the black gram seed and stover yield.

5.3 Effect of integrated nutrient management on soil physico-chemical properties

5.3.1 pH

In terms of pH, none of the treatments, including control, significantly varied. After the black gram crop was harvested, the soil pH did not significantly differ between the integrated nutrient management treatments application and the control. However, compared to control plots, the pH value in organically treated plots was significantly lower. According to several studies (Hati *et al.*, 2008; Srinivasarao *et al.*, 2014, 2018; Dotaniya *et al.*, 2016), the lowering of soil pH may have been caused by the incorporation of organic manures and subsequent microbial decomposition attributed to the aromatic and aliphatic hydroxyl organic acids, as well as carbon dioxide during the decomposition of organic matter. Additionally, it has been causing different organic acids (amino acids, humic acids, etc.) or acid-forming substances as well as carbon dioxide to be released through the breakdown of organic sources to have an acidifying impact. Numerous investigators have confirmed similar findings (Brady and Weil, 2005; Natarajan, 2007).

5.3.2 Electrical conductivity (dS m^{-1})

After the black gram crop was harvested, inorganic treatments had much lower electrical conductivity than organic treatments. Although mineralization and decomposition of organics release free cation, which have been straining the stability of the soil response and salt accumulation, organic manures play a crucial role in the buffering capacity of soils (Tembhare *et al.*, 1998; Srinivasarao *et al.*, 2018). The salts may have been dissolved by the organic acids generated by the organic manures, which may have contributed to the decrease in electrical conductivity. According to Benbi *et al.* (2018), there was no significant difference in EC between the management of organic and inorganic nutrients. Mubarak *et al.* (2009) also noted that due to the low quantity of cations present in soils, crop residues and manures had no significant impact on soil EC.

5.3.3 Organic carbon (mg kg^{-1})

The organic carbon content in the soil was not significantly affected by the INM treatments. The maximum organic carbon was recorded in case of the treatments T₉. The lowest value of organic carbon was observed in the control treatment (T₁). The non-significant impact of the INM treatments on the organic carbon content in the soil may be due to a number of factors. First, the amount of organic matter added to the soil in the INM treatments was relatively small. Second, the INM treatments were applied over a short period of time, which may not have been enough time for the organic matter to decompose and increase the organic carbon content in the soil. Smitha *et al.* (2015) speculated about similar outcomes. They claimed that over the period of three years, regular application of organic manures, such as FYM, vermicompost, and neem cake, improved the soil's organic carbon content. Rao and Krishnan (1963) and Basak *et al.* (2012) observed a minor but steady increase in soil organic carbon even under tropical conditions as a result of the application of organic manures. According to Padbhushan *et al.* (2016), the addition of additional root biomass, root exudates, and plant biomass in the various treatments (Padre *et al.*, 2007; Kaur *et al.*, 2008; and Brar *et al.*, 2013) led to a significant rise in the SOC content in organic manures.

5.3.4 Nitrogen (kg/ha)

In comparison to the control, integrated nutrition management treatments enhanced the amount of nitrogen that was readily available. After the black gram crop was harvested, no appreciable increase in the amount of nitrogen that was readily available was seen when organic, inorganic, and biofertilizers were applied together. The overall release of nitrogen

from organic inputs could have been delayed and there may have been more nitrogen readily available. In general, it has also been found that the legume system increases the availability of a number of mineral nutrients in the soil and causes a build-up of accessible nitrogen (Kumari *et al.*, 2013), which likely led to a reduction in difference between the treatments. The amount of the various organic nitrogen fractions as well as the rate of mineralization affect the availability of nitrogen in soils modified with organic nutrient sources (Mitran *et al.*, 2018). Results from Mandal *et al.* (2013), Venkatesh *et al.* (2013), and Hazra *et al.* (2018) have been used to support our findings.

5.3.5 Phosphorus (kg/ha)

The availability of phosphorus among treatments was significantly affected by the use of inorganic fertilizers when combined with organic fertilizers. Adhikari *et al.* (2013) reported similar findings and noted that the decomposition of poultry manure, which tend to have higher value in soils treated with organic manure, released more readily available phosphorus. Meena *et al.* (2020) also recommended low molecular organic acids, such as citric acid, oxalic acid, and maleic acid, which were generated by microbial metabolic processes and improved the Olsen's phosphorus by organic phosphorus solubilization in organic treatments. The addition of vermicompost and farmyard manure may have had a positive impact on the status of the available phosphorus, which may have resulted in the solubilization of Fe-P, Al-P, and reductant soluble phosphorus (Alamgir *et al.*, 2012; Kumari *et al.*, 2013). Other researchers (Pathak *et al.*, 1992; Singh *et al.*, 2004; Sharma and Singh, 2004; Melero *et al.*, 2008; Surekha *et al.*, 2010) reported similar findings and stated that the combined application of organic and inorganic fertilizers is a good option to enhance nutrient recovery, plant growth, and final yield in contrast to the need for higher nitrogen and phosphorus application rates to achieve better yield.

5.3.6 Potassium (kg/ha)

Treatments for integrated nutrient management enhanced the available potassium in comparison to the control. After the black gram crop was harvested it was found that application of integrated nutrient management greatly improved the amount of potassium that was readily available in the soil. Similar findings were reported by Adhikari *et al.* (2013) who found that soils treated with organic manures and inorganic treatments had higher exchangeable potassium contents than soils treated with synthetic fertilizer alone. According to Choudhary and Suri (2009), FYM application at 10 t ha⁻¹ led to a significantly greater

developing of available potassium content in soil, which may be related to the nutrients' gradual release from organic materials and repeated application of organic materials throughout the year. These results are consistent with those made by Thakur *et al.* (1999), Singh and Chauhan (2002), Choudhary *et al.* (2018), Cai *et al.* (2019), and Du *et al.* (2020), who found that adding inorganic inputs to manure considerably enhanced the available potassium in soils.

5.4 Effect of integrated nutrient management on biological properties

5.4.1 Microbial biomass carbon (mg kg⁻¹)

After the harvest of the black gram crop, the treatment of 50% of the recommended NPK and 50% of the phosphorus through FYM + Sulphur + *Azophos* considerably improved the microbial biomass carbon (243.40 mg kg⁻¹soil) over control (T₁) (180 mg kg⁻¹soil) and T₂, which was 100% of the recommended NPK alone. As a result of the improved carbon and nitrogen availability provided by the application of manures, the microbial biomass carbon levels were more extensive. A higher value of microbial biomass carbon was measured when organic and inorganic fertilizers were administered together compared to when inorganic fertilizers were only applied. In addition, the applied carbon stabilization was higher with these treatments. In comparison to the field's initial condition, which was used as the control, the overall microbial biomass carbon increased significantly after the black gram crop was harvested. Wang *et al.* (2015) noted that manure application significantly contributed to higher microbial biomass carbon than control and inorganic fertilizers alone, and these dynamic changes have been observed in the soil microbial biomass carbon which might be influenced by changes in carbon inputs (Bolinder *et al.*, 1999; Xu *et al.*, 2011). These findings are supported by the available literature. However, the addition of both fertilizer types, particularly manure, boosted the microbial biomass carbon content and its contribution to total organic carbon. Similar outcomes were seen in a tropical agricultural soil (Chakraborty *et al.*, 2011), a dryland in northwest China (Liu *et al.*, 2013), a subtropical paddy soil in China (Yan *et al.*, 2007), subtropical arable soils in India (Rudrappa *et al.*, 2006; Mandal *et al.*, 2007), and a sandy loam soil in Henan. The loss of nutrients brought on by cropping without fertilization may be the cause of the control treatment's lowest value of soil microbial biomass carbon. According to reports, the introduction of legume significantly increased microbial biomass carbon. According to Hernandez *et al.* (2016), this is a result of increased carbon availability for the growth of microbes from both natural and applied carbon sources, as well as through rhizodeposition, particularly in low organic carbon soils. All of the manure treatments had noticeably greater microbial biomass carbon when compared to the control treatment.

According to Dijkstra *et al.* (2009), soil organic carbon and soil microbial biomass have a strong correlation and are major sources of plant nutrients. According to Liang *et al.* (2012) increased soil microbial activity was linked to higher soil nitrogen availability for plants.

5.4.2 Permanganate oxidizable carbon (mg kg⁻¹)

The application of 50% recommended NPK + 50 % P through Vermicompost + Sulphur + *Azophos*(T₉) significantly increased permanganate oxidizable carbon than other treatments and it was followed by 75 % recommended NPK + 25% P through Vermicompost + Sulphur+ *Azophos*(T₇), 75% recommended NPK + 25 % P through FYM+ Sulphur+ *Azophos*(T₆), 50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos*(T₈), 100 % recommended NPK +Sulphur + *Azophos*(T₅), 100 % recommended NPK + *Azophos*(T₄), 100 % recommended NPK +Sulphur (T₃), and 100 % recommended NPK (T₂). Similar findings have been reported by Blair *et al.* (2006), who found that applying farmyard manure for 96 years increased permanganate oxidizable carbon by 70% compared to applying no farmyard manure. According to Liang *et al.* (2012), systems with higher carbon inputs usually have higher permanganate oxidizable carbon levels. According to several researchers (Rudrappa *et al.*, 2006, Purakayastha *et al.*, 2008, and Gong *et al.*, 2009), the use of manures coupled with inorganic fertilizers considerably raised permanganate oxidizable carbon concentrations compared to the inorganic fertilizer alone or control.

5.4.3 Dehydrogenase activity (µg TPF⁻¹ min⁻¹)

As an indicator of overall soil microbial activity, soil dehydrogenase activity (DHA) reveals the soil's fertility status. After the black gram crop was harvested, integrated nutrient management increased dehydrogenase activity compared to the control. After crop harvest, T₆ (75% recommended NPK + 25% P through FYM + Sulphur + *Azophos*) and T₈ (50% recommended NPK + 50% P through FYM + Sulphur + *Azophos*) were found to have significantly higher soil dehydrogenase activity levels, respectively. Similar findings were also observed by a number of researchers (Vajantha *et al.*, 2010; Verma *et al.*, 2020), who suggested that the possible reason is that the extracellular and intracellular enzymes found in the additional organic substrates may increase microbial activity in the soil. The increase in the amount of soil dehydrogenase activity in the biologically modified soils may also be attributed to the microbial populations and application of microbial inoculants that are favored by high rhizospheric activity and that results in increased rhizo-deposition (Sharma *et al.*, 2011; Ramesh *et al.*, 2014). According to the reports (Sharma *et al.*, 2011), the role of legume crops

is to induce increased rhizosphere activity, which in turn stimulates higher soil enzyme activities. According to various reports (Aparna *et al.*, 2014; Tamilselvi *et al.*, 2015; Hernandez *et al.* 2016, organic management techniques have been proven to improve dehydrogenase activity).

5.4.4 Bacterial count (CFU g⁻¹)

The study investigated the effect of integrated nutrient management (INM) on bacterial population in the soil after the harvest of black gram crop. The results showed that the application of organic manure treatments significantly increased the bacterial population after the harvest of black gram crop. The highest bacterial population was observed in treatment T₇, which consisted of 75% recommended NPK + 25% P through vermicompost + sulphur + *Azophos*. The control treatment (T₁), which did not receive any organic manure, had the lowest bacterial population of 15.50×10^6 CFU g⁻¹ soil. The results reported in the studies of Kushwaha (2007) and Mir *et al.* (2013) are in line with the findings found in the current analysis. According to data, the presence of fungi, actinomycetes, and bacteria in CO₂ as a result of biological respiration is a sign of increased activity and a bigger population of different types of microorganisms when *Rhizobium* and PSB are present. Brar *et al.* (2004).

5.5 Effect of integrated nutrient management on active pool of soil organic matter

The study showed that treatment T₈ (50% recommended NPK + 50 % P through FYM + Sulphur + *Azophos*) significantly increased very labile carbon (pool-I) over control but was at par with T₆ (75% recommended NPK + 25 % P through FYM+ Sulphur+ *Azophos*) followed by T₉ (4.99 mg g⁻¹) consisting of 50% recommended NPK + 50 % P through Vermicompost + Sulphur + *Azophos* T₇ (4.82 mg g⁻¹) consisting of 75 % recommended NPK + 25% P through Vermicompost + Sulphur+ *Azophos*, T₅ (4.77 mg g⁻¹) consisting of 100 % recommended NPK +Sulphur + *Azophos*, T₄ (4.72 mg g⁻¹) consisting of 100 % recommended NPK + *Azophos*, T₃ (4.58 mg g⁻¹) consisting of 100 % recommended NPK +Sulphur and T₂ (4.52 mg g⁻¹) consisting of 100 % recommended NPK. The lowest was observed in T₁ which was control. Similar results were made by Ghose *et al.*, 2021, and they demonstrate that the majority of the differences were discovered in pool-I, which was the proportion that was most readily oxidizable. More significantly, the outcomes of pool-I exhibited comparable patterns to those of microbial biomass carbon for various organic manure treatments. As a result, this showed that pool-I is more sensitive than pool-II over short time periods to labels of more labile soil carbon

components. After black gram harvest, non-significant outcomes were seen for labile carbon (pool II) and less labile carbon (pool II) when organic and inorganic fertilizers were applied compared to the control. Similar results were also reported by Ghose *et al.* (2021), who found that long-term studies with organic manure led to a wide increase in soil carbon.

SUMMARY AND CONCLUSIONS

A field experiment was conducted at Research Farm, ACRA, Rakh Dhiansar, SKUAST-Jammu, J&K UT (32° 39' N 74° 53' E, 332 m amsl), field tests were carried out during the *kharif* season of 2022 under rainfed conditions to investigate the “**Effect of Integrated Nutrient Management on Active Pool of Soil Organic Matter in Black gram (*Vigna mungo*) under Dryland Subtropics of Jammu**”. The experiment was laid out in Randomized Block Design (RBD) in 3x2 m² size plots with three replications. All the package and practices were uniformly followed in all the treatments. The experimental soil had pH 6.70, EC 0.21 dSm⁻¹ and OC 3.27 g kg⁻¹.

The salient findings of the present investigation are briefly summarized as under:

The plant height of the black gram was not significantly affected by the INM treatments. However, the treatments that included vermicompost and FYM in combination with inorganic fertilizers resulted in slightly taller plants than the control treatment. The results of this study suggest that the application of INM treatments can significantly improve the number of root nodules, number of pods per plant of black gram, which can lead to improved plant health and yield. The treatments T₇ and T₉ resulted in the highest number of pods per plant, which were 140.29% and 120.23% higher than the control treatment, respectively. This is because the organic fertilizers provide the necessary nutrients for plant, as well as improve the soil health, which can further contribute to improved plant growth and yield.

The seed and stover yield of black gram varied from a lowest value of 568 kg ha⁻¹ and 1022.40 kg ha⁻¹ in the control treatment to a highest of 768 kg ha⁻¹ and 1382.40 kg ha⁻¹ in the treatment T₇. The application of INM treatments significantly increased the seed and stover yield of black gram. This is because the combination of organic and inorganic fertilizers provided the necessary nutrients for seed and stover production.

The available nitrogen in the soil was not significantly affected by the INM treatments. The maximum available nitrogen was recorded in case of T₈, closely followed by T₉ > T₇ > T₆. The lowest available nitrogen was observed in case of T₁ (control). The available phosphorus content in the soil was significantly improved by the INM treatments. The maximum build-up of available phosphorus was found in the treatment T₉ followed by the other treatments. The

lowest value of available phosphorus was observed in the treatment (T_1) which was control. The maximum build-up of available potassium was found in the treatment T_7 followed by the treatments $T_8 > T_6 > T_9 > T_5 > T_4 > T_2 > T_3$. The lowest value of available potassium was observed in the treatment (T_1) which was control. Overall, the results of this study suggest that the application of INM treatments can have a positive impact on the available NPK in the soil.

The organic carbon content in the soil was not significantly affected by the INM treatments. The maximum organic carbon was recorded in case of the treatments $T_9 > T_7 > T_8 > T_2$. The lowest value of organic carbon was observed in the treatment (T_1) which was control. The results of the field trials show that the applied INM treatments had a non-significant impact on the pH of the soil. The maximum pH of 6.81 was recorded in case of T_1 (control). The pH was lowered down in case of T_7 and T_9 (6.73 to 6.71). The lowest pH of 6.67 was observed in case of T_8 . The results of the field trials show that the applied INM treatments had a non-significant impact on the electrical conductivity (EC) of the soil. The maximum EC of 0.25 was recorded in case of T_8 . The lowest EC of 0.18 was observed in case of T_1 (control).

There was a significant impact of different integrated nutrient management (INM) treatments on permanganate oxidizable carbon ($\text{KMnO}_4\text{-C}$), MBC (microbial biomass carbon), dehydrogenase activity and bacterial population in the soil. These are the measures of the labile organic carbon in the soil, and its levels are indicative of soil health and fertility. The treatment with the highest $\text{KMnO}_4\text{-C}$ value was T_9 with a value of 0.66 g kg^{-1} . The lowest $\text{KMnO}_4\text{-C}$ value of 0.40 g kg^{-1} was recorded in treatment T_1 (control). The treatment (T_8) had the highest MBC, at 243.4 mg kg^{-1} . The lowest MBC was found in the control treatment (T_1), which received no INM. The treatment T_6 had the highest dehydrogenase activity, at $2.72 \mu\text{g TPF g}^{-1} \text{ soil min}^{-1}$. The lowest dehydrogenase activity was found in the control treatment (T_1), which received no INM. The highest bacterial population was observed in treatment T_7 which was $61.72 \times 10^6 \text{ CFU g}^{-1} \text{ soil}$. The control treatment (T_1), which did not receive any organic manure, had the lowest bacterial population of $15.50 \times 10^6 \text{ CFU g}^{-1} \text{ soil}$. The sole application of 100% inorganic fertilizers through chemicals in treatment T_2 showed lower values of biological parameters than that in treatments with the combination of organic and inorganic fertilizers.

The application of inorganic and organic fertilizers significantly increased very labile carbon (VLC) in the soil. The highest VLC value was recorded in treatment T_8 (5.45 mg g^{-1}) which was significantly higher than the control treatment (4.01 mg g^{-1}). The study also found that there were no significant differences in the labile carbon (LC) and less labile carbon (LLC) values among the treatments. The highest LC value was recorded in treatment T_8 (4.65 mg g^{-1}).

¹), followed by treatments $T_6 > T_9 > T_7 > T_5 > T_4 > T_3 > T_2$. The highest LLC value was recorded in treatment T_9 (3.02 mg g^{-1}), followed by treatments $T_7 > T_8 > T_6 > T_5 > T_4 > T_3 > T_2$. The highest TOC value of 17.40 mg g^{-1} was recorded in treatment T_8 . The lowest TOC value of 3.28 mg g^{-1} was recorded in the control treatment, which did not receive any INM.

The integrated nutrient management (INM) treatments resulted in a significantly higher uptake of nitrogen, phosphorus, and potassium by black gram plants than the control treatment. The highest uptake of nitrogen, phosphorus, and potassium was recorded with the treatment of 75% recommended NPK + 25% P through Vermicompost + Sulphur+ *Azophos*. This treatment also resulted in the highest grain yield. It resulted in a 100% increase in nitrogen uptake, a 60% increase in phosphorus uptake, and a 90% increase in potassium uptake. These results suggest that INM can be a very effective way to improve the nutrient use efficiency of black gram crops.

CONCLUSION

Results reveal that the carbon active pools are an important parameter for maintenance of organic matter and are positively influenced by application of FYM and vermicompost in black gram.

Application of organic and inorganic fertilizers significantly increased the yield by 26.70% in T_7 (75 % recommended NPK + 25% P through Vermicompost + Sulphur + *Azophos*) along with nutrient uptake over control. Besides this, soil nutrient content and biological properties of soil also improved after harvest over control in black gram.

Hence, the overall conclusion of the study is that the integrated nutrient management of inorganic fertilizers in addition to organic fertilizers like FYM and vermicompost with biofertilizers like *Azophos* improved soil fertility, carbon pools, and yield of black gram in sandy loam soils under rainfed conditions.

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APPENDIX

WEEK	Rainfall	Max T	Min T	RH1	RH2
1 st	100.00	33.33	24.34	88.00	66.71
2 nd	129.90	31.96	24.70	91.14	76.57
3 rd	26.90	34.20	25.30	85.43	66.00
4 th	123.00	36.50	26.17	87.43	63.29
5 th	78.70	35.53	23.63	89.43	60.71
6 th	0.00	34.79	25.29	80.00	55.71
7 th	0.00	35.30	25.06	79.57	56.71
8 th	62.90	33.51	22.81	85.29	62.57
9 th	28.90	34.14	22.83	86.14	59.00
10 th	16.00	33.14	21.76	83.57	57.86

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CERTIFICATE- IV

Certified that all necessary corrections as suggested by the External examiner and advisory committee have been duly incorporated in the thesis entitled “**Effect of Integrated Nutrient Management on Active Pool of Soil Organic Matter in Black Gram (*Vigna mungo*) under Dryland Subtropics of Jammu**”, submitted by **Mr. Aditya Barwal** Registration No. **J-21-M-847**.

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