EFFECT OF CONSERVATION PRACTICE AND ORGANIC MANURES ON SOIL PROPERTIES AND PERFORMANCE OF SOYBEAN (*Glycine max* L.)

Thesis

submitted to

NAGALAND UNIVERSITY

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of

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in

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by

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2024

To my parents,
brothers,
and all my friends,
without whom, none of my
success would be possible.

DECLARATION

I, **Paardensha Ivy Chinir,** hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

This is being submitted to SAS, Nagaland University for the degree of Doctor of Philosophy in Soil and Water Conservation.

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This is to certify that the thesis entitled **"Effect of conservation practice and organic manures on soil properties and performance of soybean (*Glycine max* L.)"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in the discipline of Soil and Water Conservation, is the record of research work carried out by Ms. Paardensha Ivy Chinir, Registration No. Ph.D./SWC/00350 under my personal supervision and guidance.

The result of the investigation reported in the thesis has not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN SOIL AND WATER CONSERVATION

This is to certify that the thesis entitled **"Effect of conservation practice and organic manures on soil properties and performance of soybean (*Glycine max* L.)"** submitted by Miss Paardensha Ivy Chinir, Admission No. Ph- 285/19, Registration No. Ph.D./SWC/00350, to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Soil and Water Conservation has been examined by the Advisory Board and External examiner on……………….

The performance of the student has been found **Satisfactory/Unsatisfactory.**

Members	**Signature**
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2. …………………….. (External Examiner)	……………………………
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Dated *:* *(Paardensha Ivy Chinir)*

Place *: Medziphema*

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LIST OF ABBREVIATIONS AND SYMBOLS

@	At the rate of
&	And
Al	Aluminium
A.O.A.C	Association of Official Analytical Chemists
BCR	Benefit Cost Ratio
BC	Before Christ
C	Carbon
CO_2	Carbon dioxide
CEC	Cation exchange capacity
cm	Centimetre
cm hr^{-1}	Centimetre per hour
c mol	Centimole
c mol (p^+) kg^{-1}	Centimoles of positive charge per kilogram of exchange
CD (P=0.05) cm	Critical difference at 5 per cent probability
CV	Co-Efficient of Variation
conc.	Concentrated
DAS	Day after sowing
ºC	Degree Celsius
EC	Electrical Conductivity
et al.	*et allia* (and others/ co-workers)
etc.	Etcetera
Fig.	Figure
FYM	Farm Yard Manure
g	Gram
g cm^{-3}	Gram per cubic centimetre

i.e.	Id est (that is)
ICAR	Indian Council of Agricultural Research
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
HI	Harvest Index
ha	Hectare
hr	Hour
HC	Hydraulic Conductivity
L	Litre
Max	Maximum
MSL	Mean Sea Level
MWD	Mean Weight Diameter
m	Metre
MT	Metric Tonnes
µg	Microgram
µg g^{-1} soil	Microgram per gram of soil
Min	Minimum
mm	Millimetre
MOP	Muriate of Potash
NU	Nagaland University
N	Nitrogen
NS	Non-significant
NEH	North Eastern Hill Region
No.	Number
OC	Organic carbon
$^{-1}$ or /	Per
%	Percentage
P	Potassium
p^{+}	Protons

RDF	Recommended Dose of Fertilizers
₹	Rupees
SAS	School of Agricultural Sciences
Sl. No.	Serial Number
SSP	Single superphosphate
SMBC	Soil microbial biomass carbon
SPD	Split Plot Design
SEm±	Standard error of mean
S	Sulphur
t	Tonne
t ha^{-1}	Tonne per hectare
USDA	United States Department of Agriculture
viz.	Videlicet (Namely)
WHC	Water holding capacity

ABSTRACT

A field experiment entitled **"Effect of conservation practice and organic manures on soil properties and performance of soybean (*Glycine max* L.)"** was conducted during the *Kharif* seasons of 2021 and 2022, on the experimental farm of the School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus. The experiment was laid out in a split plot design (SPD), comprising of eighteen different treatment combinations which was replicated thrice, with two forms of conservation practices in the main plot and nine organic sources in the sub-plots. The pooled data revealed that bench terrace treatment resulted in superior soil properties *viz.,* organic carbon (2.32%), CEC (19.88 [c mol (p^+) kg^{-1}]), hydraulic conductivity (HC) (12.93 cm hr^{-1}), water holding capacity (WHC) (69.25%), mean weight diameter (MWD) (2.31 mm), available N, P, K and S (557.08 kg ha^{-1}, 15.11 kg ha^{-1}, 163.75 kg ha^{-1} and 17.82 kg ha^{-1}) and soil microbial biomass carbon (SMBC) (224.84 µg g^{-1} soil). It also recorded the highest plant height (46.71 cm at 35 DAS, 81.32 cm at 70 DAS and 88.42 cm at harvest), no. of pods $plant^{-1}$ (67.17), seed yield (1961.96 kg ha^{-1}), stover yield (2897.85 kg ha^{-1}), biological yield (4859.81 kg ha^{-1}) and harvest index (40.23%). With respect to organic sources, vermicompost @ 5 t ha^{-1} recorded significantly higher organic carbon (2.37%), HC (13.43 cm hr^{-1}), WHC (70.39%), available N, P, K and S (567.93 kg ha^{-1}, 15.74 kg ha^{-1}, 167.17 kg ha^{-1} and 18.33 kg ha^{-1}) and SMBC (230.05 µg g^{-1} soil) compared to other treatments. The growth parameters, seed yield (2182.46 kg ha^{-1}), stover yield (3171.01 kg ha^{-1}), biological yield (5353.47 kg ha^{-1}) and harvest index (40.65%) were also recorded highest in vermicompost @ 5 t ha^{-1}. Significantly higher protein content (39.69%), oil content (19.31%) and N, P, K and S content in seed (6.35%, 0.50%, 1.53%, 0.30%) and stover (1.26%, 0.24%, 1.26%, 0.33%) were also observed. Regarding gross return and net return, bench terrace + vermicompost @ 5 t ha^{-1} was recorded with the highest gross return (₹

172009.47 ha^{-1}) and net return (₹ 122537.73 ha^{-1}). However, bench terrace + FYM @ 5 t ha^{-1} recorded the highest B: C ratio (3.16). Thus, from the present investigation, considering better soil properties, yield attributes and yield, the treatment C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) is deemed best. However, from the economic point of view since treatment C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}) recorded the highest B: C ratio, it is best recommended to the farmers for earning good revenue while at the same time improving the soil and crop productivity.

Keywords: Vermicompost, Bench terrace, FYM, Organic carbon, seed yield and soil pH

CHAPTER I

INTRODUCTION

INTRODUCTION

Soybean (*Glycine max* L.) also known as 'golden bean', 'miracle bean' or 'wonder crop' is one of the most important legume crops belonging to the *Leguminosae* family and has been cultivated since 2800 BC (Mahna, 2005). Due to the rapid global population and increased demand for soy-based animal feed, the worldwide soybean cultivation area is gradually expanding. The worldwide area, production, and yield of soybean for the year 2023-2024 stands at 145.82 million ha, 429.20 million MT and 2.94 MT ha^{-1}, with the leading soybean producers being Brazil (169.00 million MT) followed by the United States (124.81 million MT), Argentina (51.00 million MT), China (20.70 million MT), and India (12.80 million MT) (USDA, 2024). In India, as per 2024-2025 data, soybean was grown in a projected area of about 13.50 million ha with an estimated production and productivity of 12.80 million MT and 0.90 MT ha^{-1} (USDA, 2024). However, our country's average soybean production per unit area is still comparably deficient compared to other developed and developing countries (Prashnani *et al*., 2024).

Soybean is highly rich in protein (40–42%), and moderate in cholesterol-free oil (18-20%) with valuable amino acid lysine of about 5% which is deficient in most cereal crops and represents the largest source of plant protein worldwide (Guo *et al.,* 2022). Approximately 85% of soybean is used for oil extraction, the other 10% for seed and only 5% for food purposes (Gasparetto *et al.,* 2022). Since the starch content in soybean is low, it is best for diabetic patients and its oil is not only used for human food but for various pharmaceuticals, disinfectants, printing ink and soaps. Like other leguminous crops, the requirement of N was substantially fulfilled through rhizobium, simultaneously building up the soil fertility by fixing large amounts of atmospheric N through the root nodules (Jamanal and Sadaqath, 2017) and leaving residual nitrogen equivalent to 45 to 60 kg ha^{-1} for the succeeding crop (Kumar *et al*., 2012). Due to these promising findings, the All India Co-ordinated Research Project (AICRP) on Soybean was started in 1967 to develop soybean as an oilseed as well as a rich protein source (Agarwal *et al*., 2013).

A warm season crop, soybean requires an optimum temperature of 26ºC to 32ºC and an annual average rainfall of 75 – 125 cm for its proper growth and development. Day length is the key factor in the soybean varieties as they are short-day plants. Being a *kharif* crop, it is best cultivated from June to July (Patel *et al*., 2014). Sandy loam soil with good organic manure content and a fair degree of water retention capacity, is best for the cultivation of soybean. Thus, the Indian climate and cropping patterns are best suited for soybean. The seeds are borne in hairy pods, which grow in clusters of three to five with each pod containing two or three seeds resembling those of peas.

The North-Eastern region of India is regarded as one of the major soybean-producing belts, and the crop is effectively grown on slopes, *jhum* land, terraces, and plains. In Nagaland, the estimated area under soybean production is 2,424 ha with a total production and productivity of 2501 MT and 1032 kg ha^{-1}, respectively. It is considered a favourite food for most of the population and used widely since time immemorial in the form of fermented soybean, "Akhuni", which is a special food additive, a probiotic, fermented soybean product with high culinary and health values (Jamir and Sharma, 2021). Despite its widespread use in the state, its lower productivity compels the farmers to give it relatively little consideration for large-scale cultivation as a single crop as compared to other neighbouring states.

Soil is a limited natural resource and serves as the most cost-effective medium for growing crops, because of which the preservation of soil quality knocks as a great challenge and opportunity for everyone in this 21st century (Dey, 2016). With the escalating population, the degradation of soil health in many cultivated areas, manifested through loss of soil organic matter and depletion of native soil fertility due to imbalanced and unscientific use of fertilizer, has emerged as a major factor responsible for the stagnation in agricultural production and has been posing a serious threat to our national food security for the last few years. For instance, crop productivity in the highlands of Rwanda was seen decreasing because of the intensive farming practice on steep slopes causing soil loss and declining soil fertility (Kagabo *et al*., 2013). For sustained productivity, soil erosion on agricultural lands must be controlled through appropriate soil and water management measures as they play a vital role in controlling water erosion. Therefore, resource conservation becomes a top priority with the restoration of precious soil resources by way of innovative means of management being the need of the day.

Productive runoff farming often leaves the donor catchment area unproductive, and this uncropped area could be used to grow a crop using a conservation bench terrace (CBT) system, alternatively known as *Zingg* terraces. Originally developed by Zingg and Hauser (1959), it is a mechanical measure successfully applied on mildly sloping lands for erosion control, water conservation and improvement of crop productivity. The CBT system consists of a terrace ridge to impound runoff water on a level bench (*i.e*., recipient area) and a donor watershed, which is left in its natural slope and produces runoff that spreads on the level bench. In India, the CBT system has been successfully tried in the semi-arid region at Bellary (Sastry *et al.,* 1975) and Kota (Prakash and Verma, 1984) and the sub-humid region at Dehradun (Sharda *et al.,* 2002). A study conducted in a sub-humid climate of India indicated that the CBT system reduced runoff from 36.3% to 7.4% of rainfall and reduced soil loss from 10.1 to 1.19 Mg ha^{-1} compared to the conventional system of sloping borders (Sharda *et al*., 2002).

In general, terracing conserves soils regardless of the cultivation system used to produce field crops, and it is of great significance for global sustainable development. However, building level terraces is a crucial strategy to improve agricultural development in hilly areas as the topsoil of newly built terraces tends to be severely disturbed resulting in low nutrient content and making it difficult to obtain a yield similar to that of conventional farmland in the short period. Manure application can thereby improve the soil organic matter and soil physical properties. Therefore, fertilization measures can improve the soil quality and crop yield of newly built terraces (Shi *et al*., 2022).

The long-standing use of inorganic fertilizers without any addition of organic fertilizers damages the physical, chemical, and biological properties of soil and causes pollution of soil and reduction of crop productivity (Moghadam *et al*., 2014 and Santosa *et al.,* 2017), hence there is an urgent need to reduce the usage of chemical fertilizers and in turn increase the usage of organics. Thus, the harmful effects of chemical fertilizers have shifted the interests of researchers towards organic amendments like vermicompost and manures, which can increase the production of crops (Joshi *et al*., 2014).

The long-term manurial studies conducted in many places have revealed the superiority of integrated nutrient supply systems in sustaining crop productivity when compared to chemical fertilizers alone (Gaur, 1991). Organic manures *viz.* poultry manure, pig manure, FYM and vermicompost help improve the soil structure, aeration, and water-holding capacity and further stimulate the activities of microorganisms which provides the plant with the macro and micronutrients through enhanced biological processes, increased nutrient solubility, and altered soil pH (Alabadan *et al.,* 2009). Vermicompost increases the chlorophyll content, carbohydrate and protein content and improves the quality of the fruits and seeds (Moghadam *et al*., 2014). Farmyard manure (FYM) increases the level of soil organic matter (Heidari *et al.,* 2020) and microbial biodiversity (Albiach *et al*., 2000) which gradually releases nutrients and reduces their loss by leaching, thereby increasing the uptake by plants

(Zamil *et al*., 2004). The effect of the combined application of organic fertilizers in soybeans showed that the combined use of farmyard manure and vermicompost led to a significant increase in grain yield compared to their application alone (Maheshbabu *et al*., 2008). Though they contain relatively low concentrations of nutrients, their use over inorganic fertilizers as a nutrient source is largely seen (Kannan *et al.,* 2005).

Keeping the above facts in view, the present investigation entitled "Effect of conservation practice and organic manures on soil properties and performance of soybean (*Glycine max* L.)" was conducted to evaluate the effect of conservation practice in addition to the locally available organic manures on the improvement of the soil physicochemical properties as well as growth, yield, and nutrient uptake of soybean with the following objectives.

1. To assess the effect of conservation practice and organic manures on soil properties
2. To evaluate the effect of conservation practice and organic manures on yield and yield attributes of soybean
3. To evaluate the benefit-cost ratio of different treatment combinations.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In this chapter, attempts have been made to review the study undertaken by many workers in different parts of India and the world on various aspects of the **"Effect of conservation practice and organic manures on soil properties and performance of soybean (*Glycine max* L.)"** under the following headings:

1. Effect of conservation practice on the soil physicochemical and biological properties
2. Effect of conservation practice on the growth attributes of soybean
3. Effect of conservation practice on the yield attributes and yield of soybean
4. Effect of organic manures on the soil physicochemical and biological properties
5. Effect of organic manures on the growth attributes of soybean
6. Effect of organic manures on the yield attributes and yield of soybean
7. Economic analysis

2.1 Effect of conservation practice on the soil physicochemical and biological properties

Chaplot *et al.* (2009) noticed higher levels of soil organic carbon in terraced lands when compared to sloped lands due to reduced soil erosion post-terracing and biomass accumulation.

Terraced fields have significantly impacted the water and soil conservation in hilly-gully loess plateau areas, particularly in arid and semi-arid regions as they significantly increase the soil moisture storage and fertility, especially at depths of 40–180 cm thereby enabling crops to absorb more water during dry seasons and reduce evaporation losses. Over a 3-year monitoring period with increased terrace construction, soil fertility was reported to improve while soil moisture remained stable. Further, when compared to a 15° slope, terraced land showed an increase of 26% in soil organic content, 8% in total nitrogen, 4% in total phosphorus, 12% in fast-acting nitrogen, and 20% in fast-acting phosphorus (Liu *et al.,* 2011).

Terracing with supplemental treatments (*e.g.,* terraced orchards with grass cover and contour hedgerows), rather than sloping orchards, significantly improves the soil physio-chemical properties which include higher hydraulic conductivity, soil organic matter and available N, P, K, aggregate soil stability, while decreasing soil bulk density (Xu *et al*., 2012).

When compared with barren slopes, level ditches, zig terraces and half-moon terraces increased the content of available P/K, total N, and soil organic matter in the first 0-60 cm soil layers by up to 30%, 28.1% and 41.7%, respectively (Zhao and Cai, 2012).

Liu *et al.* (2013) indicated that transforming sloped fields into terraces was essential for conserving water and soil in mountainous areas and applying manure was crucial for the long-term sustainability of agricultural ecosystems on new terraces in semi-arid regions. They further stated that manure application significantly enhances soil water conservation and improves soil structure, with the manure-treated groups *i.e.* MNP (42.2 mm) and M (23.2 mm) maintaining higher soil moisture levels and larger water-stable aggregates in surface and sub-surface layers than non-manure (NP and CK) groups. Additionally, water use efficiency was seen substantially greater in manure-treated soils with an increase of 207%, 51%, and 77% over control.

Cultivated terraces in the Mediterranean areas, increase the infiltration and reduce runoff with the runoff coefficients being 10-25%, thereby providing favourable conditions for agricultural crop productivity and soil fertility (Arnáez *et al*., 2015).

Wei *et al.* (2016) pointed out that terracing plays a very prominent role in controlling erosion (11.46 ± 2.34), followed by runoff reduction (2.60 ± 1.79), biomass accumulation (1.94 ± 0.59), soil water recharge (1.20 ± 0.23), and nutrient enhancement (1.20 ± 0.48). When the terrace was further treated with 50+ 50 (GM) a higher reduction of runoff (16–40%) and soil loss (13–50%) was observed by Singh *et al.* (2017), leading to higher conservation of natural resources.

Liu and Zhou (2017) also reported a maximum increase of 3.4 g kg^{-1} in the soil organic carbon of a newly built terrace. They further noticed that when the terrace plots were treated with manure, the largest aggregates (>2 mm) had important implications for C sequestration, whereby an increase of 29.4% and 30.6% in the total soil organic carbon for M and MNP treatments over control was observed.

Mesfin *et al.* (2018) reported that the installation of bench terraces combined with soil fertility management practices such as application of organic manure and compost are crucial for transforming unproductive mountains and hillslopes into productive landscapes while contributing significantly towards sustainable land management in the area. The percentage of large soil aggregates, not just water-stable aggregates (WSA) were found to remain the same or increased from control plots to terraced sites, highlighting the positive impact of these practices on soil structure and fertility.

Belayneh *et al.* (2019) reported from their study on the effect of conservation practices on soil physicochemical properties, that conserved plots resulted in a minimal mean soil bulk density while non-conserved plots were noted with a relatively higher bulk density, which could be due to the washing away of fine organic matter rich soils by erosion and in so doing exposed slightly heavier soil particulates.

Among the four locations studied by Mesfin *et al*. (2019), Teshi and Ruba Feleg sites had the highest soil water content (SWC) retention due to superior soil aggregation, as measured by water-stable aggregates (WSA) and larger soil aggregates which was induced by both pre-terracing conditions and careful soil management during terracing implementation. The study further found that terraced plots showed a significant 110% increase in soil water content (SWC) compared to non-terraced control plots which thereby suggests that minimizing soil disturbance during terrace construction is crucial for maximizing water conservation in terraced systems. Moreover, they concluded that terracing can effectively modify land to conserve water and enhance soil quality, which are key beneficial for the growth of crops as they provide a stable and fertile environment for their roots thereby helping to maintain adequate moisture levels in the soil.

Chen *et al.* (2020b) noted that terraces in China's landscape increased the soil organic carbon sequestration by an average of 32.4% compared to that of the sloping lands as they eliminated water erosion and soil carbon loss.

Chen *et al*. (2021) observed from their study on the "Effects of terracing in three key mountainous regions of China" that terracing has a significant impact on soil properties. They found that the influence of terracing increases the organic carbon in the soil and total nitrogen when compared to sloped lands. Their findings further indicate that terracing plays a crucial role in altering soil physicochemical properties such as improved soil fertility, reduced soil erosion and enhanced water availability thereby creating a conducive environment that promotes higher crop yields, which can guide decision-makers and land managers in implementing more sustainable land use practices in similar regions, thereby contributing to regional sustainability and wiser land management.

Deng *et al.* (2021) reported that terraces reduce the runoff, sediment and soil erosion by over 41.9%, 52% and 43%–70% while increasing the infiltration, water holding capacity and soil moisture content by 4.24%–12.9% (5.0 to 6.2 times that of sloped land).

Rutebuka *et al*. (2021) reported the field-based evidence for the effectiveness of terraces and their ability to restorative degraded hilly landscapes, stating that bench terraces outperformed the farmer-based progressive terrace at both locations, leading to negligible soil losses and runoff reduction of 70% and 85%, respectively. The study thus confirmed the huge potential of bench terraces to sustainably reduce soil erosion rates, and improve soil fertility when established within an integrated approach, paying attention to correct installation and fertility-supporting agronomic practices.

During the 18-year experimental period conducted by Shi *et al.* (2022) on a newly constructed terrace, soil quality index (SQI) measurements highlighted a clear connection between terrace, soil quality and crop yield, whereby an upward trend in treatments using sheep manure (M), sheep manure combined with mineral nitrogen and phosphorus fertilizer (MNP) over control was observed. Manure application had a better effect on improving the soil quality of terraces as they significantly boosted soil organic carbon, total nitrogen, and microbial biomass carbon. The study further revealed that regardless of the treatment, soil quality improved, with manure having a notably positive impact on the SQI, enhancing soil quality more rapidly initially and sustaining improvements over the long term. Thus supporting that incorporating manure is vital for optimizing soil conditions on terraces, which in turn enhances the ecological function.

Meena *et al.* (2023a) reported that conservation tillage and organic nutrient management increased soil organic C (6.8 g kg^{-1}), available N (129.5 mg kg^{-1}), P (11.0 mg kg^{-1}), K (232.6 mg kg^{-1}) at topsoil (0–15 cm) and deeper layers (15–60 cm), thus ensuring the long-term sustainability of soil fertility.

Adopting soil conservation practices such as cover crops, level seeding, and terracing improves soil microbial properties, with an increase in the inoculum potential of arbuscular mycorrhizal fungi, higher levels of acid phosphatase activity, and elevation of microbial biomass C and N (Spliethoff *et al*., 2023).

Tian *et al.* (2023) found a reduction of 19.40% in soil erosion with terraces, indicating their significant effects on soil erosion control, which improved the soil physiochemical conditions and increased crop yields.

Chen *et al.* (2024) noticed that terraces conserved 2.36×10^{10} m^3 of water which was 91.30–98.32 % per unit area and prevented the erosion of 1.82×10^9 t of soil which was 42.12–89.20 %. On average, the annual water conservation from terraces reached 7.60×10^8 m^3, with a growth rate of 1.89×10^7 m^3 per year while for soil, an annual average of 5.86×10^7 t of soil, with an increase of 1.67×10^6 t per year was observed.

Meena *et al.* (2024) indicated that the highest organic carbon (0.68%), bacterial (29.11×10^7 cfu g^{-1}), fungal (4.77×10^4 cfu g^{-1}), actinomycetes populations (5.67×10^4 cfu g^{-1}), acid phosphatase (44.1 µg g^{-1} h^{-1}), urease (45.3 µg g^{-1} h^{-1}) and dehydrogenase (23.3 µg triphenyl formazan [TPF] g^{-1} h^{-1}) activity in soil were found in the plots with conservation organic system as the organic matter supplies vital nutrients to soil while the conservation tillage reduces the losses of organic carbon in soil, stimulating the microbe occupancy in the soil. The consistent addition of higher plant and root biomass and a lower degree of soil disturbance under conservation organic practices improved the nutrient cycling, increased the organic carbon content, and soil aggregation, thereby resulting in higher SQI scores in both the surface (0.92) and subsurface layer (0.75) of soil.

Alam *et al.* (2024) noticed that when soil was less disturbed in MT there was a reduction in the degradation of soil thereby resulting in a reduced carbon decomposition rate, as a result comparatively more organic matter was accumulated in soil making it superior in terms of pH (5.84), OM (1.38 %), TOC (17.7 t ha^{-1}), and MBC (249 µg g^{-1}) to other tillage regimes. Also, this consequently led to an increase in the availability of nutrients, particularly nitrogen fertiliser, due to the enhanced microbial activity producing the highest values for both TN (0.071 %) and MBN (19.1 µg g^{-1}).

2.2 Effect of conservation practice on the growth attributes of soybean

Das *et al.* (2020) reported that the implementation of conservation agriculture practices coupled with residue retention and incorporation of legumes has demonstrated productivity, profitability, and efficiency in rice and maize-based agricultural systems in the Asian subcontinent. Heidari *et al.* (2020) also stated that in conservation practices, the plant's nutritional needs are well provided, especially in the critical stages of growth due to the slow and continuous supply of nutrients originating from the organic manure mineralization.

Adamicˇ and Leskovšek (2021) discovered that soybean plants grown under the conservation system reached a maximum height of 117.9 cm, which was significantly taller compared to plants in both the conventional system (106.5 cm) and the no-tillage system (95.8 cm). This suggests that the conservation system had a positive impact on soybean plant height, potentially indicating better growth and development in that system compared to the others.

Meena *et al.* (2022a) revealed that under conservation chemical (including FYM), plant height (83.26 cm), number of branches (3.53), dry matter accumulation (17.51 g), leaf area index (3.73) and chlorophyll content in leaves (2.99 mg g^{-1}) of soybean was recorded significantly superior over the rest of the treatments followed by conservation organic, which might be due to better soil environment as a result of less disturbance of soil, good organic matter and moisture availability.

2.3 Effect of conservation practice on the yield attributes and yield of soybean

Posthumus and Stroosnijder (2010) observed a 20% increase in yields with bench terraces, attributed to higher planting density compared to adjacent sloping fields. They noted that soil and water conservation measures, like terraces, are frequently advocated to address soil erosion and enhance agricultural production.

According to Liu *et al*. (2011), terraced land in the agricultural regions of the Loess Plateau has a greater capacity for storing and retaining water compared to sloping land which facilitates more favourable interactions between water and fertilizer. It was further revealed that crop yields in terraced lands, which were three years old, were 27% higher than those in sloping lands with slopes exceeding 10°. Furthermore, the study suggested that crop yields could increase by 27.07% to 52.78% in subsequent cultivation years on terraced lands. Thus, emphasizing the significant benefits of terracing for enhancing water retention, promoting efficient water-fertilizer interactions, and improving crop yields in the Loess Plateau agricultural areas.

Adgo *et al*. (2013) noticed that terraces in Africa when combined with other conservation means (*e.g.*, grass strips), extensively control land degradation and consequently improve crop productivity.

The yield data observed from the study by Sharda *et al.* (2013), indicated that the conservation bench terrace (CBT) system using intercrop-based significantly improved the crop productivity in sub-humid weather *i.e.,* approximately 18% more productive in terms of maize equivalent yields compared to the conventional system, due to enhanced in-situ rainwater conservation.

In a case study conducted in Tanzania by Wickama *et al.* (2014), the average yield of maize was found to be 270% higher in fertile terraced fields compared to bare slope fields, signifying the positive impact of terracing on agricultural productivity in the region and indicating that terraced fields were more conducive to successful maize cultivation and yield improvement compared to non-terraced, bare-slope fields. Wei *et al*. (2016) also noticed that slope land becomes more stable when converted to a terrace, as they enhance the plant seedlings' survival rates, promote ecosystem restoration, and increase crop yields.

From a seven-year fixed plot field experiment conducted by Singh *et al.* (2017), it was observed that 50 + 50 (FYM) maintained significantly higher ($p < 0.05$) productivity of maize (18–74%) and wheat (10–77%) over 100% NPK through inorganic fertilizers in different years.

Age *et al.* (2019) recorded significantly higher soybean seed yield and uptake of nutrients in conservation tillage as compared to conventional tillage under soybean-cotton rotation. Moreover, the seed and straw yield was significantly influenced by the various integrated plant nutrient supply treatments with the application of phosphor-compost in conjunction with chemical fertilizers followed by FYM, GLM and vermicompost, resulting in a significantly higher uptake of nutrients fertilizers under conservation tillage.

Li *et al.* (2019) pointed out that the construction of terraces played a crucial role in improving food security by enhancing crop productivity and yield stability as a result of conserved soil and water.

Alam *et al.* (2020) reported that tillage operation, nutrient management and leguminous crops can significantly influence crop yields in a cropping system.

The highest number of pods per plant (38.2), seeds per plant (110.6) and grain yield (3926.7 kg ha^{-1}), harvest index (45.2%) were obtained in MT-F7 treatment, in which compost, manure, and chemical fertilizers were applied simultaneously in a balanced manner under a reduced tillage system while the biological yield (8789 kg ha^{-1}) was found highest in MT-F7 (Minimum tillage + FYM + Compost). This according to Heidari *et al.* (2020) was because the minimum tillage system increased yield, accelerated sowing, plant early establishing, reduced energy consumption, and less investment in machinery purchases and addition of organic fertilizers such as compost while reducing the massive amount of waste and protecting the environment, could be effective in modulating the use of fertilizers in agricultural ecosystems.

As terraced soils have usually higher organic matter and nutrient contents when compared with non-terraced agricultural plots, the conversion of slope land into terraced fields could increase the arable land by 20%–40%, which is significant to increase in grain yield (about 44.8%). Furthermore, terracing also increases moisture by avoiding water loss, which effectively enhances crop endurance to droughts and consequently increases crop yields. Thus, terracing exhibits its effectiveness in curbing famines and supporting food security, especially in mountainous regions with pressing environmental problems (Deng *et al.*, 2021).

The importance of terraces in increasing productivity by managing runoff on hillslopes was well pronounced by Hörbe *et al.* (2021) whereby the soybean and corn yield were found to increase by 490 kg ha^{-1} and 1100 kg ha^{-1} in the TC *i.e.,* 12% and 10% higher than the non-terraced area. These higher crop yields demonstrate the efficiency of terraces in reducing water deficits and enhancing their productivity since their presence was associated with higher water availability and soybean and corn terraces controlled runoff. In addition, Hörbe *et al.* (2021) further indicated that during a period of drought, the crop yield productivity was higher in the terraced catchment.

On the contrary, the maximum values of growth parameters and chemical constitute at 70 days from sowing (fresh and dry weight, leaf area chlorophyll content, N, P, K) as well as yield and its components and biochemical traits of grains at harvest stage *e.g.,* the weight of 1000 grain, cob length, No. of rows cob^{-1}, grain and biological yield, total carbohydrates, protein and oil content in grain were recorded with terraces irrigation technique plus compost and melatonin @ 2.0 mmol L^{-1} (Helmy and El-Sherpiny, 2022).

Njiru *et al.* (2022) reported that *Fanya juu* terraces provide a conducive environment and increase intensification to enhance production resulting in higher yields *i.e.,* maize yields increased by 49.8%. Thus, recommending the construction of terraces with a ditch depth of 30 cm for enhanced crop production on hard-setting soils in marginal areas of Kenya.

From the study conducted by Meena *et al.* (2022a) on the "Effect of various crop management practices on growth, yield and net return of soybean [*Glycine max* (L.) Merr.]" significantly higher number of pods $plant^{-1}$ (58.13), seed weight $plant^{-1}$ (7.43g), seed yield (1850 kg ha^{-1}) haulm yield (2824 kg ha^{-1}) were recorded under plots with treatment of conservation chemical due to less disturbance of soil by minimum tillage, application of crop residue and FYM at initial crop growth period and direct influence on dry matter production at successive stages by increased photosynthetic efficiency.

From the study conducted by Verma *et al.* (2023) on the impact of different tillage and residue-management practices and organic nutrition on the performance of soybean [*Glycine max* (L.) Merr.], a significantly higher number of branches plant^{-1} (9.65), pods plant^{-1} (69.2), seeds pod^{-1} (2.68), grain yield (1.63 t ha^{-1}) and gross return (Rs 87,480 ha^{-1}) over control were observed with the application of zero tillage with residue (ZT + R). Thus suggesting that conservation agriculture provides favourable physical conditions for proper plant establishment at early growth stages to soybean crops thereby contributing to higher yield attributes.

Alam *et al.* (2024) reported that MT achieved the highest yield of 1.29 t ha^{-1} with an increasing yield trend of 27.4% over the rest of the conservation tillage practices because of the continuous accumulation of soil organic carbon, retention of soil moisture, and subsequent availability of nutrients through the mineralisation process in the minimally manipulated soil.

Chen *et al.* (2024) found that terraces greatly improved plant growth and increased crop yields through various mechanisms which include reducing soil erosion, improving soil moisture levels, increasing nutrient availability, expanding arable land, and creating controlled farming conditions. As a result of these factors, terraced fields demonstrated significant benefits in terms of crop yield and overall output, with an average increase of 45.30% and 45.63%, respectively. These findings underscore the positive impact of terracing on agricultural productivity and sustainability. These findings highlight the effectiveness of terracing in enhancing agricultural productivity and sustainability.

2.4 Effect of organic manures on the soil physicochemical and biological properties

Applying FYM @ 10 t ha^{-1} led to several positive changes in soil properties including improved soil porosity, increased saturated hydraulic conductivity in both surface and sub-surface layers, and enhanced moisture retention throughout the soil profile, alongside a decrease in bulk density. These improvements were likely due to increased root biomass, enhanced soil aggregation, improved mechanical composition of the soil, and greater proliferation of beneficial soil organisms. Bhattacharya *et al.* (2004) attributed these factors to the higher percolation rate observed over time in FYM-treated plots.

Manivannan *et al.* (2009) reported that the usage of vermicompost enhanced the physical conditions of the soil, supporting better aeration to plant roots, drainage of water, enablement of cations exchange, prolonged nutrient supply, and subsequently improved growth, leading to an increase in bean development, yield, and quality. Thus, concluding that utilisation of vermicompost enhanced soil fertility and crop yield, individually or in combination with inorganic fertilizers.

Lakaria *et al.* (2012) reported 105 and 71% higher soil organic carbon in long-term organic farming practices over absolute control and recommended dose of NPK fertilizers, respectively under soybean-wheat cropping system. Similarly, Liang *et al*. (2014) also reported that the prolonged use of manures increases the organic matter, total N, enzyme activity, invertase, b-glucosidase, urease, acid and base phosphate, and dehydrogenase in soil.

Aher *et al.* (2015) observed from their study that the soil organic carbon (11.3 g kg^{-1}), available N (125 mg kg^{-1}), P (49.7 mg kg^{-1}) and soil enzyme activities *viz.,* dehydrogenase (DHA) (98.20 μ grams TPF/g soil/24 h) and alkaline phosphatase (178.2 μ grams p-nitro phenol/g soil/h) were found significantly higher in the plot managed organically.

The utilization of farmyard manure (FYM) @ 20 t ha^{-1} according to Anand *et al.* (2015) exhibited an enhancement in the soil organic carbon content, carbon stock, microbial biomass carbon and dehydrogenase activity within the *Jatropha curcas* plantations.

Das *et al.* (2015) stated that in North-East India, an infiltration rate of 17.69 cm hr^{-1} in organic fields was observed, thereby showing that application of organic manure improves soil structure and porosity of soil significantly resulting in an enhanced infiltration of the soil.

Velmourougane (2016) observed that with the application of an organic management system (FYM), significantly higher water-holding capacity and lower bulk density of soil in comparison to conventional management systems were noticed in coffee farming. Aher *et al.* (2018) also noticed an improvement in crop performance under the application of organic manures suggesting that it might be due to the cumulative effects on soil available nutrients (gradual build-up of NPK), enhanced organic carbon, higher microbial population, increased enzyme activities and residual effect.

As per the study by Bhatt *et al.* (2018) application of RDF + Zn + FYM, resulted in the highest levels of organic carbon (1.20 % and 0.80 %), cation exchange capacity {35.30 c mol (p^+) kg^{-1} soil and 28.20 c mol (p^+) kg^{-1} soil}, available nitrogen (282.75 kg ha^{-1} and 179.56 kg ha^{-1}) and available phosphorus (28.31 kg ha^{-1} and 12.72 kg ha^{-1}) in both the surface and subsurface soil layers due to enhanced root growth, resulting in more organic residue in soil. The inorganic fertilizers along with organic manure were found to be a viable option for restoring soil organic carbon and nutrient turnover, thereby improving the availability of nutrients in the soil, maintaining soil quality, and helping achieve sustainable productivity of wheat crop for the long run under irrigated moisture regimes.

Islam *et al*. (2018) reported that the application of cow dung, poultry manure, rice straw, compost, recommended fertilizer, and a combination of organic manure showed a significant positive effect on soil organic carbon, total N, available P, and exchangeable K. He further noted that with the treatment of combined organic manure, the soil properties were much improved which thereby maintain good soil quality followed by poultry manure over the recommended fertilizer.

Treatments with organic manures were seen to significantly improve the available nutrient status of the soil. They showed a 13–16% increase in soil organic carbon, 19–22% and 28–33% higher available N and P, 32-50%, 45-63% and 30-45% increase in the N, P and K uptake respectively, over control. Soil enzyme activities, *viz.* dehydrogenase and alkaline phosphatase were also seen to increase by 62–72% and 27–35%, respectively under the treatments receiving organic sources of nutrients over RDF. Aher *et al*. (2019) concluded that this might be due to the higher availability of available nutrients in adequate quantity throughout the crop growth period.

Urra *et al.* (2019) reported that aside from their nutrient value, manure-based amendments increase the soil organic carbon and improve soil structure, thereby improving water infiltration and retention.

Organic manures were found to improve the soil's physical properties, which provide health and favourable soil conditions that enhance nutrient use efficiency thereby leading to better vegetative growth of the plant (Awasthi *et al*., 2020).

From the study conducted by Yadav *et al.* (2020a) organic carbon, available N, P, K and micronutrients*, viz.* Fe, Zn, Cu and Mn in soil were found maximum while bulk density was noted as minimum at the harvest stage of soybean with the application of 100% vermicompost treatment, therefore concluding that the addition of organic nutrient sources creates an environment conducive to the formation of humic acid which stimulate the activity of soil microorganism and direct addition, biological immobilization and continuous mineralization of FYM and vermicompost on surface soil layer increasing the organic carbon content, available N, P, K and decrease bulk density of the soil.

Bairwa *et al.* (2021) concluded that the long-term application of balanced and integrated use of nutrients in conjunction with organic manures to soybean and wheat significantly improved the soil properties *i.e.,* increased microbial biomass carbon (344 µg g^{-1} soil) and nitrogen (44.3 µg g^{-1} soil), and microbial population (bacteria, fungi and actinomycetes) counts in soil (39.1 × 10^7cfu g^{-1} soil, 42.7 × 10^4 cfu g^{-1} soil and 39.1 × 10^5 cfu g^{-1} soil) over control. Significant increases in soil organic carbon (8.6 g kg^{-1}), total N (351.0 kg ha^{-1}), and available N (1798.0 kg ha^{-1}) were also recorded with 100% NPK + FYM. Thus, conjoint and judicious use of organics and mineral fertilizers was found promising in the long run.

Meena *et al*. (2022b) reported that the physical properties in soil *viz*., bulk density, particle density, hydraulic conductivity of soil and mean weight diameter were affected by the application of different organic manures and chemical fertilizers. The study further exhibited particle density to be lowest (2.50 Mg m^{-3}) in plots receiving 100% NPK + FYM @ 15 t ha^{-1} (T_3) as compared to control (T_1) (0.168 Mg m^{-3}) which was observed highest while for the mean weight diameter of soil aggregates at surface and subsurface soil 100% NPK + FYM @ 15 t ha^{-1} (T_3) (0.90 mm) was observed highest as compared to control (T_1) (0.62 mm).

Additions of organic manures into the soil resulted in increased water-holding capacity, porosity, infiltration capacity, hydraulic conductivity and water-stable aggregation and decreased bulk density and surface crusting (Ahlawat *et al.,* 2023).

Organic amendments enhances the soil health, soil fertility, nutrient management, yield production, and the generation of macro and micronutrients. (Rani *et al.,* 2023).

Mohan *et al.* (2023) reported that organic manures support the growth and multiplication of soybean and proliferate the beneficial microbial population in the soil and vermicompost being porous with aerated granules show better water holding capacity, consists of vital macronutrients nitrogen, phosphorous and potassium (NPK) thereby supporting plant growth in terms of biomass and height of the plants. Hence, the physicochemical properties and microbial count of the soil were significantly increased during the application of vermicompost and biofertilizer compared to the application of FYM.

Tiwari *et al.* (2023) in their investigation on the impact of different nutrient management strategies on soil properties in soybean and wheat cultivation found that plots treated with a balanced combination of 100% NPK and FYM @ 5 t ha^{-1} exhibited significant improvements in various soil parameters compared to the control group which include increased levels of soil organic carbon, higher availability of N, P, K, S and enhanced soil microbial biomass carbon (SMBC) and soil microbial biomass nitrogen (SMBN). Furthermore, the long-term application of balanced nutrient treatments with organic amendments in the form of FYM @ 5 t ha^{-1} to soybean and wheat, consistently improved the soil's chemical and biological properties. Thus, emphasizing the importance of adopting a holistic approach to soil nutrient management to enhance soil fertility, microbial activity, and overall sustainability in agricultural systems.

Xie *et al.* (2023) observed that the application of organic fertilizers significantly increased the physicochemical properties of soil. The soil organic matter, alkali-hydrolyzed nitrogen, available phosphorus, and available potassium contents of plots with T_{21d} treatment (GI = 62.5%, germination index) reported an increase of 29.9%, 25.0%, 22.2%, and 8.4%, respectively over control.

The treatments with organic manures (green manure, farmyard manure and wheat cut straw) followed an incremental trend in soil quality *i.e.,* higher soil organic carbon, available N and P, Zinc and a better population of soil microorganisms, in comparison to the treatments receiving chemical fertilizers, thereby proving as precursors of sustaining soil health. Further, the best soil characteristics (water-soluble aggregates, exchangeable and non-exchangeable K, fixed and total K) after rice and wheat harvesting were found in plots where 50 % of the recommended NPK was supplemented with farmyard manure (FYM), thus elucidating the importance of integrated nutrient management towards the restoration of soil health along with the increase in productivity and further improvement of the quality characteristics (Walia *et al.,* 2024).

From a soil health point of view, Yadav *et al.* (2024) reported that long-term practices of organic farming improve the overall physical, chemical, and biological properties of soil which included increase soil organic carbon, reduced bulk density, increased microbial diversity and nutrient release, thereby contributing to long-term sustainability and resilience against environmental stressors.

2.5 Effect of organic manures on the growth attributes of soybean

Devi *et al.* (2013) found that soybean cultivation using vermicompost positively influences nodulation by the abundance of microbial load in the soil.

The study conducted by Shaheen *et al*. (2017) showed that sawdust and poultry manure in combination with urea has the potential for growth enhancement and yield increase of soybean as well as improvement of soil properties.

Hapsoh and Hairunisa (2019) reported that application of compost increases leaf N content, leaf K, and soybean production components such as the number of filled pods, number of seeds/plants, weight of seeds/plants, and weight of 100 seeds.

Adekiya *et al*. (2020) reported that the addition of poultry manure as a component of integrated manuring was because of its positive effect on better growth during the early stage of the crop leading to desirable growth and yield. He further stated that the higher production of soil chemical properties of such manure, due to its lowest C: N ratio, lignin and lignin: N ratio, favour quick mineralisation and release of nutrients to the soil compared with other soil amendments.

During the course of the investigation, (T_6) Vermicompost @ 10 t ha^{-1} + 3 sprays of vermiwash was observed with the significantly highest plant height (cm), number of leaves, number of branches at various growth stages, days taken to 50 per cent flowering and maturity which according to Awasthi *et al.* (2020) was due to maximum availability of nutrients in vermicompost and vermiwash as well as better uptake of nutrients from soil and translocation of photosynthates in different parts of plants

Asefa and Wagari (2021) reported that farmyard manure, vermicompost and blended NPS fertilizers had a significant effect on the number of nodules of soybean varieties whereby the highest number of nodules (20.00) was recorded at 75 kg NPS ha^{-1} + 2.5 t VC ha^{-1} in the Boshe variety and the minimum number of nodules from Boshe variety (6.33) and Dhidhessa variety (7.10) were recorded at unfertilized plots and both were not significantly different. An increment of 3.47% over the other treatments was observed with the application of 75 kg NPS ha^{-1} + 2.5 t VC ha^{-1} due to the high amount of nutrients applied through the combined application of vermicompost and blended NPS fertilizer.

Significantly greater plant height (98.10 cm), number of tillers per hill (3.66), and spike length (9.23 cm) were noted in plots where poultry manure was applied as compared to control due to the high nitrogen content and balanced nutrients in poultry manure (Azad *et al*., 2022).

Chatterjee *et al*. (2022) noticed that within the growth parameters the maximum plant height, number of branches, number of leaves and number of nodules were observed in OM_4 ($^1/_4$ RDN through FYM + $^1/_4$ RDN through mixed compost + $^1/_4$ RDN through vermicompost + $^1/_4$ RDN through poultry manure).

Hassan *et al.* (2023) concluded that vermicompost proved to be a very suitable organic fertilizer or substrate with high porosity, aeration, drainage and good water-holding capacity, having significant levels of growth-promoting substances including minerals, enzymes, and phytohormones.

Jaggi *et al.* (2023) revealed that biofertilizers (Rhizobium + PSB) + vermicompost (5 t ha^{-1}) + vermiwash (225 l ha^{-1}) recorded the tallest plants, highest branches, higher dry matter accumulation, and nodules per plant over control and was statistically at par with biofertilizers (Rhizobium + PSB) + FYM (10 t ha^{-1}) + vermiwash (225 l ha^{-1}).

From the study conducted by Joshi *et al.* (2023) 100% Organic NM revealed that maximum plant height (50.35 cm), branches $plant^{-1}$ (5.74), effective root nodules (57), leaf area index (4.90) and dry weight $plant^{-1}$(45.16 g), followed by 25% Organic + NF inputs BJG +25% Inorganic NM, due to the inclusion of different organic manures *i.e*., FYM, vermicompost and neem cake that increased the supply of nutrients and reduced loss of nutrients from an organic source.

Meena *et al.* (2023b) found that the application of 75% RDF + 1.0 t ha^{-1} of vermicompost + Rhizobium inoculation (T_8) resulted in higher plant height (58.70 cm), branches $plant^{-1}$ (5.60), chlorophyll content (2.84 mg g^{-1}), total nodules per plant (47.40), effective nodules (31.59) and dry weight (84.20 mg), thus highlighting that application of vermicompost enhanced soil aeration, drainage, biological activity, and create a favourable soil environment for deeper proliferation of roots and higher nutrient extraction which thereby contribute to vigorous plant growth as a result of improved nutrient availability and uptake.

Nissa *et al.* (2023) reported that treatment comprising RDFN and vermicompost recorded the highest number of pods per plant (72) and 1,000 seed weight (155.39 g) due to the optimum and continuous supply and availability of nutrients through organic sources which help in better uptake of nutrients and thereby increase all the growth attributes.

The maximum number of leaves per plant (43.44), number of branches per plant (13.50) and plant height (62.37 cm) were recorded in T_4 (100% NPK + FYM + PSB) as per the study conducted by Shalu and Rattan (2023). These higher growth parameters were attributed to the integrated application of inorganic, organic and biofertilizers which resulted in a higher initial microbial load supported by enough organic carbon for microbial proliferation.

Sharma *et al.* (2023) revealed that RDF (90%) + SMC (10%) + FYM + RZB + PSB exhibited maximum plant height (140.41 cm), number of primary branches (4.82), pod length (10.29 cm), pod width (1.26 cm), pod weight (6.63 g), number of grains per pod (8.65) and shelling percentage (41.72%) over control, suggesting that incorporation of organic manures and biofertilizers in conjunction with inorganic nutrients improved the soil fertility and microbial properties and thereby higher economics and net returns.

As per the study conducted by Tammam *et al*. (2023), the results indicated that applying vermicompost to the soil might considerably improve the nutrient availability, particularly micro and macronutrients, as it helps increase the soil organic matter composition, which in turn aids in improving soil aeration, sustaining good soil aggregation, protecting against soil erosion, thereby increasing nutrient availability and nutrient content of plants. In addition, increased plant height could also be due to the growth-promoting substances, which are present in vermicompost.

The result from the study by Keerthana *et al.* (2024) observed that application of Vermicompost @ 5 t ha^{-1} + Mo 1.5 kg ha^{-1} recorded the maximum plant height (29.80 cm), nodules (62.10) and plant dry weight (30.96 g/plant), due to the thorough nutrient supply of vermicompost which also stabilises the structure of the soil and encourages soil aggregation, thereby enhancing the air-water balance in soil, boosting its ability to hold water and promoting the deep development of plants' roots which raises the crop productivity.

2.6 Effect of organic manures on the yield attributes and yield of soybean

Kohnaward *et al.* (2012) also noted that the application of 75 kg NPS ha^{-1} + 2.5 t VC ha^{-1} exceeded the minimum hundred grains weight by about 2.52% over treatments due to the positive effects of vermicompost on assimilates translocation, activation of photosynthetic enzymes, chlorophyll formation and improvement of plant growth.

Aulakh *et al.* (2013) reported that application of FYM 10 t ha^{-1} to soybean with or without crop residue increased the yield by 11-13% over the recommended rate of NP, and a 4-10% increase in the case of succeeding wheat crop indicating that the application of FYM in conjunction with the recommended rate of NP to soybean proved significantly better than lone application of recommended rate of NP.

Lassaletta *et al*. (2014) pointed out that the application of manures not only reduces N losses but also improves fertilizer-use efficiency, particularly on sandy textured Mediterranean soils, which are heavily dependent on N fertilizer and prone to nitrate leaching during intensive winter rainfall.

Aher *et al.* (2015) reported that with organic farming practices, seed yield (601 kg ha^{-1}), total biomass (1927 kg ha^{-1}), and harvest index (31.19%) of soybean were significantly greater over the rest of the farming practices, because of the higher organic carbon and available N, P and K, improving crop productivity.

Khare *et al*. (2016) observed that the different yield parameters of soybean *viz*., number of pods $plant^{-1}$ (91.67), number of seeds pod^{-1} (3.93), pod length (6.93 cm), test weight (90.73g), seed yield (23.87 q ha^{-1}), straw yield (40.73 q ha^{-1}) and harvest index (36.94%) were recorded maximum in treatment T_5 (50% Farmyard Manure + 50% Vermicompost) under subabul based agro forestry system. Thus, concluding that the application of 50% Farmyard Manure + 50% Vermicompost would be best recommended to the grower for the cultivation of soybean under a subabul-based agroforestry system during the kharif season in Allahabad condition.

Bhatt *et al.* (2018), pointed out that the highest grain yield (3524 kg ha^{-1}), straw yield (4827 kg ha^{-1}), and biological yield (8352 kg ha^{-1}) were recorded in treatment with $N_{180} + P_{80} + K_{40}$ + Zn (F) + FYM over control due to additional supply and availability of nutrients through FYM, thereby attaining better fertility status and crop productivity.

From the experiment conducted by Islam *et al.* (2018) on the effect of organic manuring on soil properties, dry matter content, yield, and yield attributes of soybean it was reported that treatment of combined organic manure was noted with the highest yield and yield attributing characters. Regarding dry matter content at the flowering stage, combined organic manure (22.35%) performed best followed by poultry manure (20.26%) and cow dung (19.61%) while control (15.09%) treatment showed the lowest performance. Further, the highest seed yield was perceived from the treatment of combined organic manure (1.98 t ha^{-1}) followed by poultry manure (1.90 t ha^{-1}) and the lowest seed yield was found from the treatment of control (1.40 t ha^{-1}).

The results of the study carried out by Aher *et al.* (2019) on the Effect of organic sources of nutrients on the performances of soybean (*Glycine max*) revealed that treatments with organic manures either alone or in combination with *panchagavya* and/or biodynamic application improved the performance of soybean crop, whereby organic treatments recorded a 28–45% increment in seed yield and 24–37% rise in total biomass over control (T_6). Also, an increase in the yield by 5-13% of soybean over those obtained under RDF was reported, which enhanced nutrient removal by soybean crop by 5-13% and significantly improved the micronutrient uptake of soybean crop with organic combinations.

The significantly highest biological yield (2409.09 kg ha^{-1}), seed yield (825 kg ha^{-1}), harvest index (0.36%) and yield attributes *viz*., number of pods $plant^{-1}$ (54.35), number of seeds pod^{-1} (12.00), test weight (140.22 g) of soybean crop as per study from Awasthi *et al.* (2020) were recorded in the treatment T_6 (Vermicompost @ 10 t ha^{-1} + 3 sprays of vermiwash) during the experimental study, thus showing that the yield attributes and yield were significantly influenced by organic manures and natural farming.

Kuntyastuti *et al.* (2020) observed that the use of organic manure + NPK increases the weight of roots, shoot, and yield of soybean by 98% over control. Moreover, the biomass was seen to increase by 633 g m^{-2} during the maturing phase with a maximum growth rate of 18.4 g/m2/day. Thus, concluding that the use of organic manure maintains and improves soil physical, chemical, and biological fertility and increases soil and plant productivity.

Mahmud *et al.* (2020) concluded that the application of vermicompost reduced soil acidity and produced macro- and micronutrient contents (N, P, K, Mg, Ca, S, Fe, Zn, B and Al) in the soil and plants that were comparable to or higher than those produced by the chemical fertilizer treatment.

Debela *et al.* (2021) reported that plots treated with 100 kg NPS ha^{-1} + 2 t Vermicompost ha^{-1} inoculated with Rhizobium TAL-379 strain produced the highest number of pods per plant (87.6), maximum seed yield (4180 kg ha^{-1}) and maximum harvest index (47%). Thus, considering the importance of integrated nutrient management in climate mitigation and adaptation.

Azad *et al.* (2022) reported the highest grain yield (3100 kg ha^{-1}), straw yield (5425 kg ha^{-1}) and P and K content in the grain and straw of wheat in plots with NPK + Poultry manure while the N, S, Mg, Zn and B content in the grain and straw were reported significantly highest in NPK + Cow dung over control. Thereby concluding that the application of recommended NPK, along with either cow dung (CD) or poultry manure (PM) showed a satisfactory yield of wheat which could be an efficient practice for achieving sustainable soil fertility and crop yield in the "North-Eastern Barind Tract".

Among the organic manure treatments, Chatterjee *et al*. (2022) recorded the highest number of pods $plant^{-1}$ (108), pod yield (29.7 q ha^{-1}), seed yield (21.4 q ha^{-1}) and biological yield (163.9 q ha^{-1}) in OM_4 (FYM + mixed compost + vermicompost + poultry manure), due to the overall improvement in the soil physicochemical and biological properties leading to a higher soil moisture, air permeability and level of available nutrients at different growth stages of rice bean plant.

MacLaren *et al.* (2022) observed that systems receiving manure applications rather than plant-based amendments had greater yields and further reported that the application of manures could have most, or all the nitrogen fertilizer removed without seeing yield reductions. Thus, concluding that nitrogen supply is an important aspect of the contribution of organic amendments to yields.

Organic amendments applied to soil can increase the activity of soil microorganisms and soil nutrient content, promoting nutrient decomposition and release, as well as plant uptake and utilization of nutrient elements (Phares and Akaba, 2022).

Kumar and Mishra (2023) reported that the organic treatment combinations, 50% recommended NPK+ 50% N as FYM + inorganic sources of micronutrients as per soil test recorded a higher-yielding (14.51 q ha^{-1}) than other organic treatments, which might be due to the organic sources ability to helped release the nutrients making it readily available to plant as and when required by it to produce higher grain yield.

RDFN through inorganic fertilizers + 25% RDFN through VC (474kg ha^{-1}) was recorded with a higher uptake of N, P, K and highest soybean seed yield per hectare at 12.9 q ha^{-1} which was 56.93% higher than the control due to the proper supply of nutrient elements from both organic and inorganic sources, which helped in optimum dry matter partitioning from the source to sink during the reproductive stage of the crop consequently increasing the seed yield. Further, Nissa *et al.* (2023) observed that when 25% of the recommended dose of chemical fertilizers was replaced with the utilization of 474 kg ha^{-1} vermicompost an approximate 39% increase in the seed yield was found.

Rekaby *et al.* (2023) reported that compost and vermicompost could be used as a complete substitute instead of chemical fertilizers in zucchini cultivation because they significantly improve the sandy soil properties as a result of increasing soil organic matter, availability of soil nitrogen, phosphorus and potassium. They further stated that the changes in soil properties, in turn, enhanced the growth, nutrient uptake (N, P and K), fruit quality and yield.

Shalu and Rattan (2023) observed the highest pod length (9.18 cm), number of pods per plant (16.27), pod weight (8.49 g), pod yield per plant (55.24 g), pod yield per plot (4.32 kg) and shelling percentage (52.50) in plots with treatment T_4 (100%NPK+FYM+PSB) due to improved soil physical, chemical and biological properties with the application of organic sources, thus leading to higher availability of all plant nutrients which in turn results in higher yield contributing traits of the plant.

A small intervention of adding FYM 5 t ha^{-1} over 100% NPK caused a 23.58% and 16.31% increase in grain and straw yield, respectively over 100% NPK (Tiwari *et al.,* 2023).

Verma *et al.* (2023) reported that the organic nutrient management practices (ONMPs) showed considerable improvement in the yield attributes, seed, stover and biological yields of soybean crop. Moreover, the application of RDN through VC + biofertilizer + CU + *Panchgavya* + *Jeevamrut* (N_5) was observed to improve the soil's physical properties, meeting the nutrient demand at the peak growth period of soybean as compared to the other treatments.

Xie *et al.* (2023) reported that when compared with control (CK), the T_{21d} treatment (GI = 62.5%) significantly increased the soybean yield by 15.1%, due to improved basic soil physicochemical properties, active organic matter components, enzyme activity, and microbial diversity.

Aslam *et al.* (2024) stated that vermicompost is a rich source of nutrient causing increment in the availability of macro-and micro-nutrients and biocontrol agent for aphid and fungus attack, hence utilized in the integration with synthetic fertilizers to decrease the recommended nutrient dose, further being an alternate nutritional source for biofortification.

Al-Tawarah *et al.* (2024) found that the number of pods per plant (93.33) and yield per plant (1487.9 kg) were significantly superior in vermicompost (VC100%) over those of compost or control, indicating that using vermicompost led to results with a faster effect than those in the case of traditional compost, due to the greater effectiveness of microorganisms and consequently faster effect reflected on the soil properties and the subsequent availability of the nutrient mineral elements.

Irin and Hasanuzzaman (2024) concluded from their study that organic amendments, including biochar, vermicompost, green manure, and farmyard manure significantly improve the mineral nutrient status and growth of plants thereby bolstering the soil fertility and crop productivity in saline soils, mainly through the reduced translocation of harmful salts. In particular vermicompost, biochar and FYM facilitate the soil nitrogen uptake, an essential component for protein synthesis, and enhance various plant processes such as metabolism, protein accumulation, and antioxidant activities enhancing plant growth and productivity.

Keerthana *et al.* (2024) recorded the highest number of pods plant^{-1} (39.39), kernels pod^{-1} (2.00), seed index (40.00 g), seed yield (2.38 t ha^{-1}), haulm yield (4.26 t ha^{-1}) and harvest index (35.74%) in treatments with Vermicompost @ 5 t ha^{-1} + Mo 1.5 kg ha^{-1}. These increases in the yield attributed according to

Keerthana was due to the overall improvement in vegetative growth and nodulation which favourably influenced the flowering and fruiting.

From the three organic fertilizers, utilisation of P3 (Vermicompost) organic fertilizer boosts the overall reproductive growth responses such as pod number (from around 0-4 unit to 42–51 unit), grain number (from around 0-5 unit to 88–90 unit), and grain weight (from around 0–0.37 g to 12–25 g), in soybeans on acidic soil, thus showing that application of organic fertilizers significantly had a positive effect on the performance of soybean (Lestari *et al*., 2024).

Ma *et al.* (2024) observed that organic manure can greatly increase grain oil yield and improve the quality of oilseed flax and that the application of sheep manure significantly increased the content of NSCs in capsules, reduced the content of saturated fatty acids, and increased the content of unsaturated fatty acids in grains.

Yadav *et al.* (2024) compare the long-term effects and impacts of conventional and alternative organic farming practices on yield, in which the short-term organic yields were found to be 19.2% lower than conventional yields while long-term yields were lower in conventional systems by 31% and higher in organic yields by 50%, respectively, due to the long-term improvement in soil health which consequently fosters ecological balance, enhances biodiversity and promotes sustainable agriculture.

2.7 Economic analysis

Posthumus and Stroosnijder (2010) reported that from the 2 to 4-year-old bench terraces located in Peru, increasing per capita incomes by up to 15% was observed due to the increase in crop yields, thereby reducing poverty by 9%.

Over the past 10 years, the construction of the terraced fields has profoundly altered the eco-environment and established firmer and reliable agricultural bases in Zhuang Lang County. Till the year 2006, 4,000 ha of fruits, 666.67 ha of vegetables and 10,000 ha of merchandised potatoes were seen established on terraces. Furthermore, farmer incomes were noticed to grow notably following the construction of terraces attaining 1,550 Yuan per capita (Liu *et al*., 2011).

Terraces are being identified as part of a "cultural landscape" heritage as they play a vital role in aesthetic appreciation and spiritual enrichment. The Longji terraces in China were designated as China Nationally Important Agricultural Heritage Systems (China-NIAHS) in 2014 and GIAHS in 2018, respectively, income from agricultural, tourism and local non-farm jobs accounts for 97.7%, 70.8% and 17.8% of the total household incomes (Zhang e*t al*., 2019).

The maximum net return of ₹ 60785.07 with a benefit-cost ratio of 2.9 was obtained with the application of 100% RDF, followed by 100% vermicompost. This trend in economic return is mainly due to the higher cost and treatment effect on the seed and haulm yield of soybean (Yadav *et al*., 2020b).

Sindhuja *et al.* (2021) conducted a thorough investigation on the impact of different nutrient sources on the economics of yardlong bean (*Vignaunguiculata* ssp. *sesquipedalis*) cv. ArkaMangala. Plots with 75% RDN through inorganic + 25% RDN through vermicompost + biofertilizers (*Rhizobium* + PSB) were reported with the maximum gross returns (Rs 2,85,200 ha^{-1}), net returns (Rs. 2,14,097.50 ha^{-1}) and B: C ratio (4.01) due to the considerable reduction on the reliance of expensive inorganic fertilizers coupled with a higher yield. The study further states that the addition of biofertilizers and organic manures could replace a significant portion of inorganic nitrogenous fertilizers (25%) without compromising the yield, thereby contributing to reduced production costs, soil health and overall sustainability.

The economics data for the soybean crop exhibited the highest net return (Rs 48549 ha^{-1}), B: C ratio (3.30) in Conservation chemicals due to better crop management practices, which produce maximum economic yield, net return and B: C ratio of soybean as compared to other crop management practices (Meena *et al.,* 2022a).

Meena *et al.* (2023b) concluded that the application of 75% RDF + Vermicompost (1.0 t ha^{-1}) + *Rhizobium* (T_8) reported a considerably maximum gross return (53042.71 Rs ha^{-1}), net return (28980.71 Rs ha^{-1}) and B: C ratio (2.20) when compared to other treatment in the soybean crop followed by treatment (T_4) - 75% RDF + FYM (2.0 t ha^{-1}) + *Rhizobium* and these higher net return and B: C ratio were associated with its higher grain and haulm yield per unit of added cost.

Increased yield of soybean under ZT in conjunction with residue integration created an upsurge in the system economics whereby the gross return, net return and benefit: cost ratio was 11.0%, 23.6% and 30.8% greater when compared with CT – R. Similarly, the gross return, net return and B: C ratio of organic nutrient management practices (ONMPs) was greater over N_1 (Recommended dose of fertilizer) owing to better soybean productivity and minimum support price at these levels (Verma *et al*., 2023).

Chen *et al.* (2024) comprehensively analysed the spatial distribution, change characteristics, and ecosystem service benefits associated with terraces from 1990 to 2020 in Gansu Province, China, whereby notable environmental and economic improvements were observed with the conversion of sloping farmland to terraces. Terraces exhibited a 2.69-fold increase in the grain yield and economic output, which increased from 1.29×10^6 t and 3.88×10^8 \$ to 3.48×10^6 t and 1.04×10^9 \$, respectively, thereby contributing 8.08×10^7 t and 2.42×10^{10} \$ to Gansu Province. On average, annual yields reached 2.6×10^6 t, and economic benefits amounted to 7.82×10^8 \$, with growth rates of 0.72×10^5 t and 2.18×10^7 \$ per year, respectively.

The overall increase in the growth and yield attributes of the groundnut crop with the application of 5 t ha^{-1} Vermicompost + 1.5 kg ha^{-1} Mo significantly increased the gross return (1,61,090.00 Rs ha^{-1}), net return (100505.80 Rs ha^{-1}) and benefit-cost ratio (1.7) (Keerthana *et al.,* 2024).

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

This chapter describes the details of the experiment, the materials used and the research methodology adopted during the entire course of experimentation to study the "**Effect of conservation practice and organic manures on soil properties and performance of soybean (*Glycine max* L.)**".

3.1 General information

3.1.1 Site of experiment

The experiment was carried out in the experimental farm of a newly cleared forest area having a slope of 15 – 20% in the School of Agricultural Sciences (SAS), Medziphema Campus, Nagaland University during the *kharif* season of 2021 and 2022. The experimental farm is located at the foothill of Nagaland at an elevation of 310 meters above mean sea level (MSL) with a geographical location of 20˚45'43" North latitude and 93˚53'04" East longitude.

3.1.2 Climatic and weather conditions

The experimental farm lies in the humid sub-tropical zone characterized by high humidity, and moderate temperature with medium to high annual rainfall. The monsoon period starts from the first week of June and extends to September with an average rainfall ranging from 2000-2500 mm annually, which then gradually decreases from October. The mean temperature ranges from 21ºC to 32ºC during summer and rarely goes below 8ºC in winter due to high atmospheric humidity. The detailed information on meteorological data recorded during the period of experimentation has been presented in Table 3.1 and Table 3.2 and illustrated in Figure 3.1 and Figure 3.2, respectively.

Table 3.1: Mean weekly meteorological data recorded during the cropping season (*kharif* 2021)

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine hours
	Max (˚C)	Min (˚C)	Max (%)	Min (%)			
22	33.11	22.94	91.29	61.00	17.40	1	4.40
23	33.56	23.63	91.71	63.14	39.10	1	2.80
24	33.00	24.79	93.29	75.29	19.50	3	3.80
25	33.01	24.51	93.29	67.43	43.40	4	4.30
26	33.00	25.00	92.57	69.14	37.60	1	1.90
27	33.17	24.73	88.86	73.43	19.20	2	2.50
28	32.41	24.69	92.71	70.43	105.70	5	3.90
29	33.69	24.66	94.57	69.57	53.30	2	3.90
30	34.49	24.89	89.57	70.43	74.90	2	6.60
31	32.27	25.10	91.57	78.43	34.00	3	3.90
32	33.20	24.53	92.86	67.86	25.20	3	3.40
33	32.47	24.93	95.57	77.00	41.80	2	1.60
34	32.37	24.29	91.86	67.71	7.00	0	3.20
35	32.31	24.29	92.86	72.86	52.90	4	3.00
36	33.19	24.01	94.57	68.43	49.10	3	6.50
37	33.79	23.94	93.57	67.71	42.20	1	5.80
38	32.11	23.31	94.00	67.71	13.10	2	5.00
39	33.70	23.77	93.14	66.00	8.10	2	7.10
40	32.29	23.06	94.29	71.14	5.00	1	5.00
41	33.89	23.57	91.86	62.86	53.80	2	7.80
42	33.30	23.60	95.43	70.14	69.10	3	5.40
43	29.99	18.97	96.86	71.86	2.10	0	7.20
44	30.03	19.07	95.14	57.86	0.00	0	7.50
45	29.46	15.24	96.00	49.14	0.00	0	8.40
46	28.64	16.39	94.86	54.71	0.00	0	7.50
47	27.76	13.33	96.43	49.29	0.00	0	8.00
48	26.90	11.40	95.86	45.71	0.00	0	7.90
49	26.43	15.24	95.14	57.71	8.50	1	5.00
50	25.33	11.60	94.86	51.71	0.00	0	6.70
51	24.91	8.93	95.43	46.71	4.70	1	6.70

Source: ICAR Research Centre for NEH Region, Nagaland Centre, Medziphema

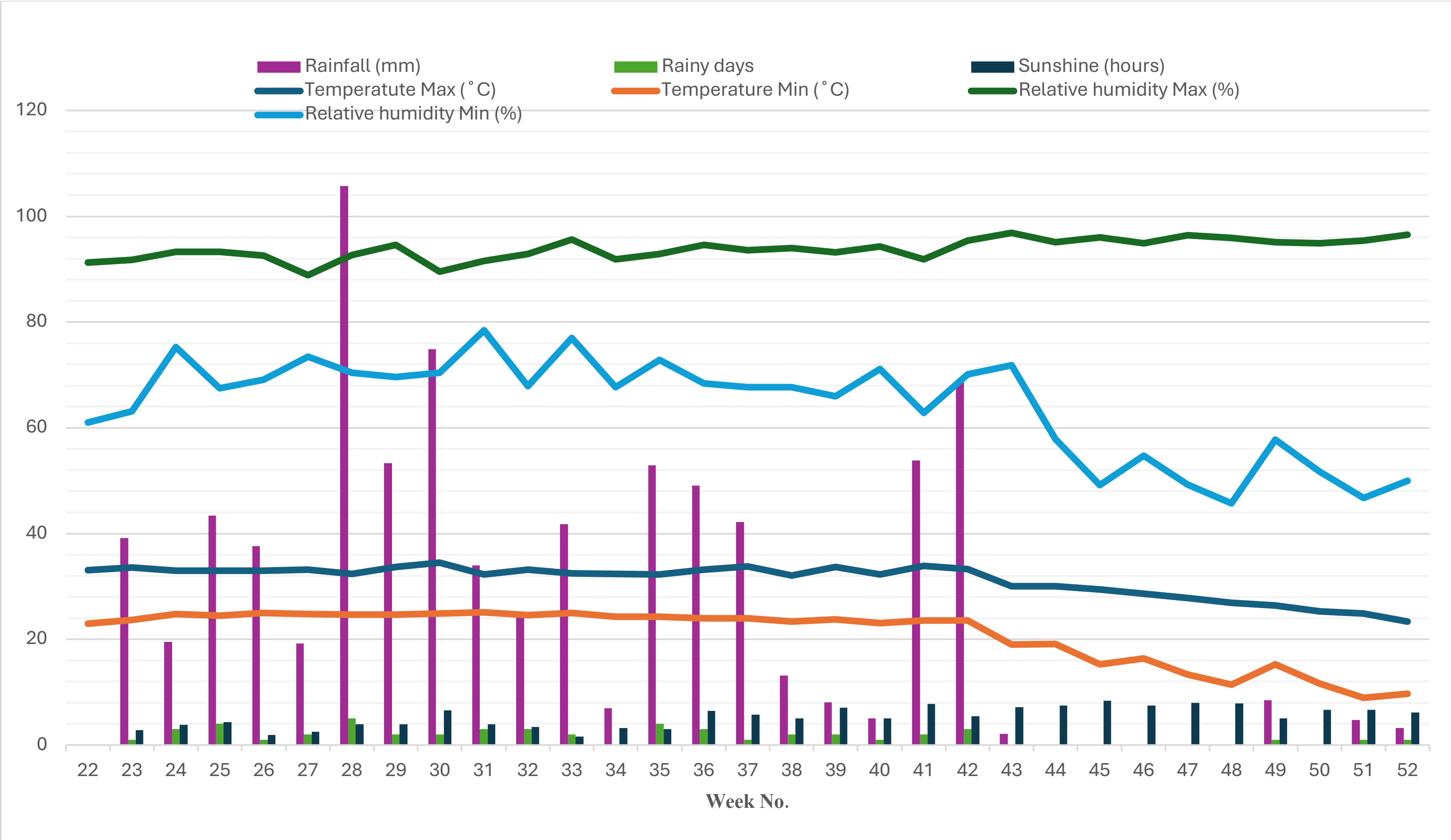

Fig. 3.1: Graphical representation of meteorological data during crop growing season (*kharif* 2021)

Table 3.2: Mean weekly meteorological data recorded during the cropping season (*kharif* 2022)

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine hours
	Max (˚C)	Min (˚C)	Max (%)	Min (%)			
22	33.3	23.3	93.0	65.0	22.5	2	4.8
23	33.0	24.0	94.0	74.0	51.1	4	2.9
24	30.3	23.3	95.0	74.0	46.7	4	1.3
25	31.2	23.4	95.0	75.0	34.8	3	1.8
26	33.3	24.9	93.0	68.0	9.9	2	4.5
27	34.2	24.7	91.0	66.0	77.1	3	7.2
28	34.1	24.5	90.0	69.0	22.9	3	6.9
29	33.9	24.5	92.0	75.0	135.3	4	3.4
30	31.8	23.2	96.0	70.0	135.3	5	3.6
31	33.6	23.9	93.0	68.0	48.8	2	3.1
32	33.3	23.9	96.0	71.0	114.7	5	5.1
33	33.6	24.2	91.0	72.0	27.5	2	6.1
34	34.1	24.5	94.0	68.0	64.2	1	4.1
35	32.7	24.3	93.0	68.0	9.0	1	4.6
36	33.4	24.4	89.0	67.0	21.7	2	4.9
37	31.9	23.5	91.0	72.0	42.8	3	4.1
38	33.5	24.0	91.0	65.0	15.3	2	5.6
39	32.8	23.2	91.0	70.0	81.2	2	6.3
40	31.9	23.5	95.0	74.0	31.0	3	4.4
41	31.8	22.7	91.0	71.0	2.9	1	5.0
42	30.9	20.6	94.0	65.0	19.7	3	5.9
43	28.1	19.9	95.0	71.0	41.0	2	4.7
44	29.8	17.1	96.0	60.0	0.0	0	8.0
45	29.3	16.7	96.0	57.0	0.0	0	8.2
46	27.9	14.6	98.0	56.0	0.0	0	8.2
47	27.7	12.8	96.0	52.0	0.0	0	8.0
48	27.8	14.3	96.0	67.0	0.0	0	7.4
49	27.6	12.0	95.0	49.0	0.0	0	8.0
50	26.4	11.3	96.0	50.0	0.0	0	7.0
51	25.7	11.0	96.0	51.0	0.2	0	6.4
52	33.3	23.3	93.0	65.0	22.5	1	3.9

Source: ICAR Research Centre for NEH Region, Nagaland Centre, Medziphema

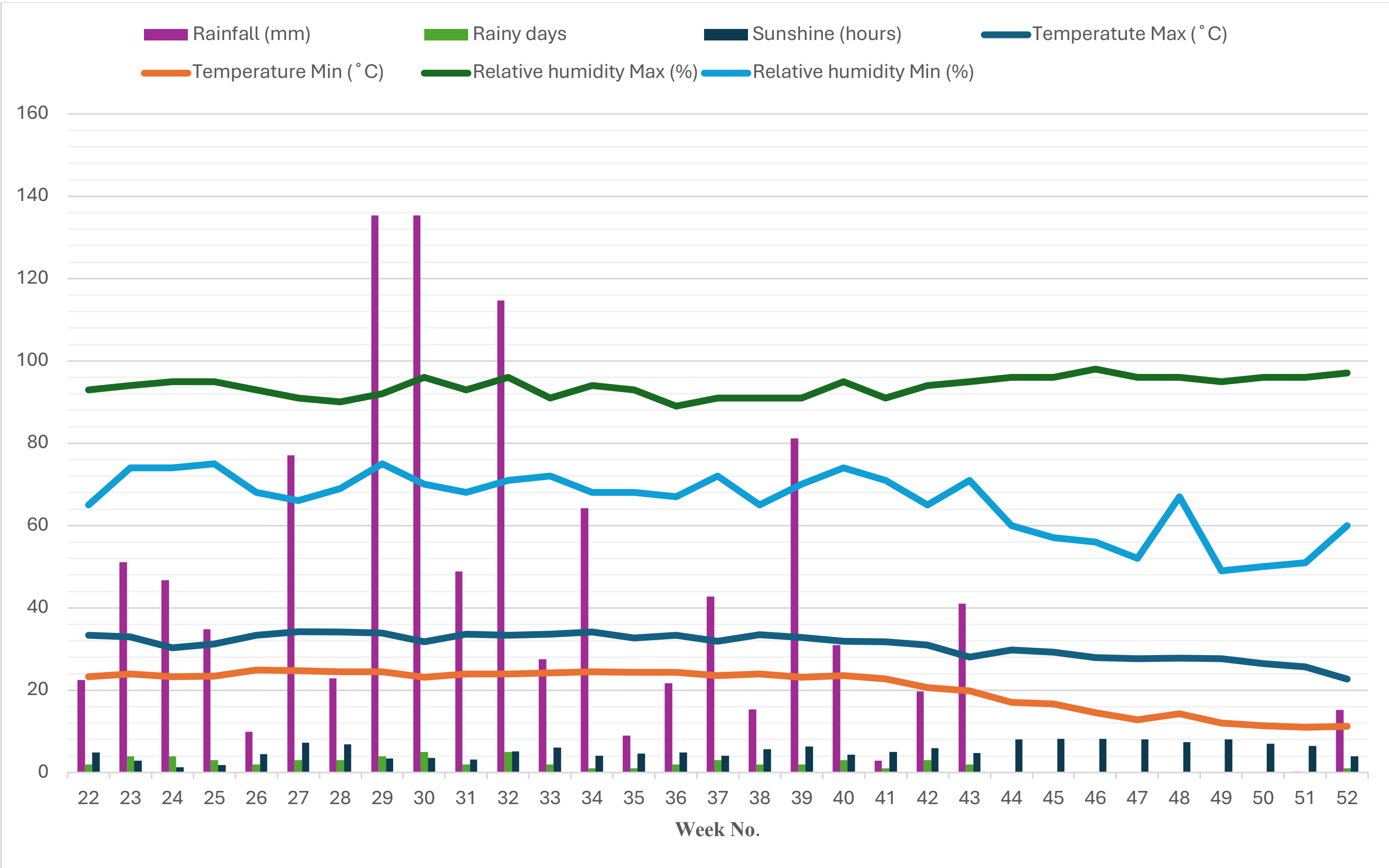

Fig. 3.2: Graphical representation of meteorological data during crop growing season (*kharif* 2022)

3.1.3 Soil condition

The soil condition of the experimental plot was noted to be well drained and sandy loam in texture having a sand percent of 56.80, silt percent of 28.20 and clay percent of 17.00. To ascertain the texture and fertility status of the soil, soil samples were taken from a depth of 0-15 cm from different locations of the experimental plots with the help of soil auger. The soil samples collected were then mixed, air dried, grinded and sieved for analysis of different parameters following standard procedures as mentioned in Table 3.3.

Table 3.3: Initial soil properties of the experimental field

Characteristics	Methods employed	Initial	
		Content	Inference
Soil pH	Glass electrode pH meter (1:2.5 soil and water ratio) (Jackson, 1973)	**5.21**	**Acidic**
Soil organic carbon (%)	Walkley and Black method (Walkley and Black, 1934)	**1.63**	**High**
Cation exchange capacity [c mol (p^+) kg^{-1}]	NH_4OAc procedure (Sumner and Miller, 1996)	**15.63**	**Moderate**
Available N (kg ha^{-1})	Alkaline Potassium Permanganate method (Subbiah and Asijia, 1956)	**485**	**Medium**
Available P_2O_5 (kg ha^{-1})	Bray's No. 1 method (Bray and Krutz, 1945)	**11.85**	**Low**
Available K_2O (kg ha^{-1})	Neutral Normal Ammonium Acetate Method (Hanway and Heidal, 1952)	**147.33**	**Medium**
Available S (kg ha^{-1})	Turbidimetric determination (Chesnin and Yein, 1951)	**14.21**	**Sufficient**
Bulk density (g cm^{-3})	Pycnometer method (Majumdar and Singh, 2000)	**1.30**	**Ideal**
Particle density (g cm^{-3})	Pycnometer method (Baruah and Barthakur, 1997)	**2.55**	**-**
Hydraulic conductivity (cm hr^{-1})	Constant head method (Klute, 1965)	**8.62**	**Moderate**
Water holding capacity (%)	Keen Rackzowski boxes (Piper, 1966)	**58.32**	**-**
Mean weight diameter (mm)	Yoder's apparatus (Van Bavel, 1950)	**1.30**	**-**
Soil microbial biomass carbon (μg g^{-1} soil)	Fumigation extraction method (Vance *et al.,* 1987)	**207.57**	**-**

3.2 Details of experimental techniques

3.2.1 Design and experimental layout

The field experiment was laid out in split plot design (SPD) with fifty-four treatment combinations consisting of two forms of conservation practice treatments in the main plot and nine organic sources treatments in the sub-plot, which were replicated thrice. The whole experimental field was divided into two equal blocks and each block was again divided into twenty-seven equal-sized subplots measuring 2.5m x 1.5m to accommodate the treatments. The treatments were randomly allocated within the plots of a block. The details of the plan and layout of the experimental field have been presented in Figure 3.3.

3.2.2 Experimental details

The experiment which was conducted consisted of the following components:

a)	Crop	Soybean (*Glycine max* L.)
b)	Variety	DSB 19
c)	Design of the experiment	Split Plot Design (SPD)
d)	Number of replications	3
e)	Number of treatments in main plot	2
f)	Number of treatments in sub plot	9
g)	Number of treatment combinations	18
h)	Total number of plots	54
i)	Spacing	45 cm x 10 cm
j)	Plot size	2.5 m x 1.5 m
k)	Distance between the main plots	1 m
l)	Distance between each plot	0.5 m

m)	Method of sowing	Line sowing
o)	Fertilizer doses	20 kg N ha^{-1}
		80 kg P_2O_5 ha^{-1}
		40 kg K_2O ha^{-1}
		40 kg S ha^{-1}

3.2.3 Treatment details

3.2.3.1 Main plot

The two forms of conservation practices allotted in the main plots are described below-

1) C_1: Bench terrace
2) C_2: Non-terrace

3.2.3.2 Sub-plot

Nine organic sources allotted in the sub-plots are described below-

1) O_1: Control
2) O_2: FYM @ 5 t ha^{-1}
3) O_3: FYM @ 10 t ha^{-1}
4) O_4: Poultry manure @ 2.5 t ha^{-1}
5) O_5: Poultry manure @ 5 t ha^{-1}
6) O_6: Vermicompost @ 2.5 t ha^{-1}
7) O_7: Vermicompost @ 5 t ha^{-1}
8) O_8: Enriched compost @ 2.5 t ha^{-1}
9) O_9: Enriched compost @ 5 t ha^{-1}

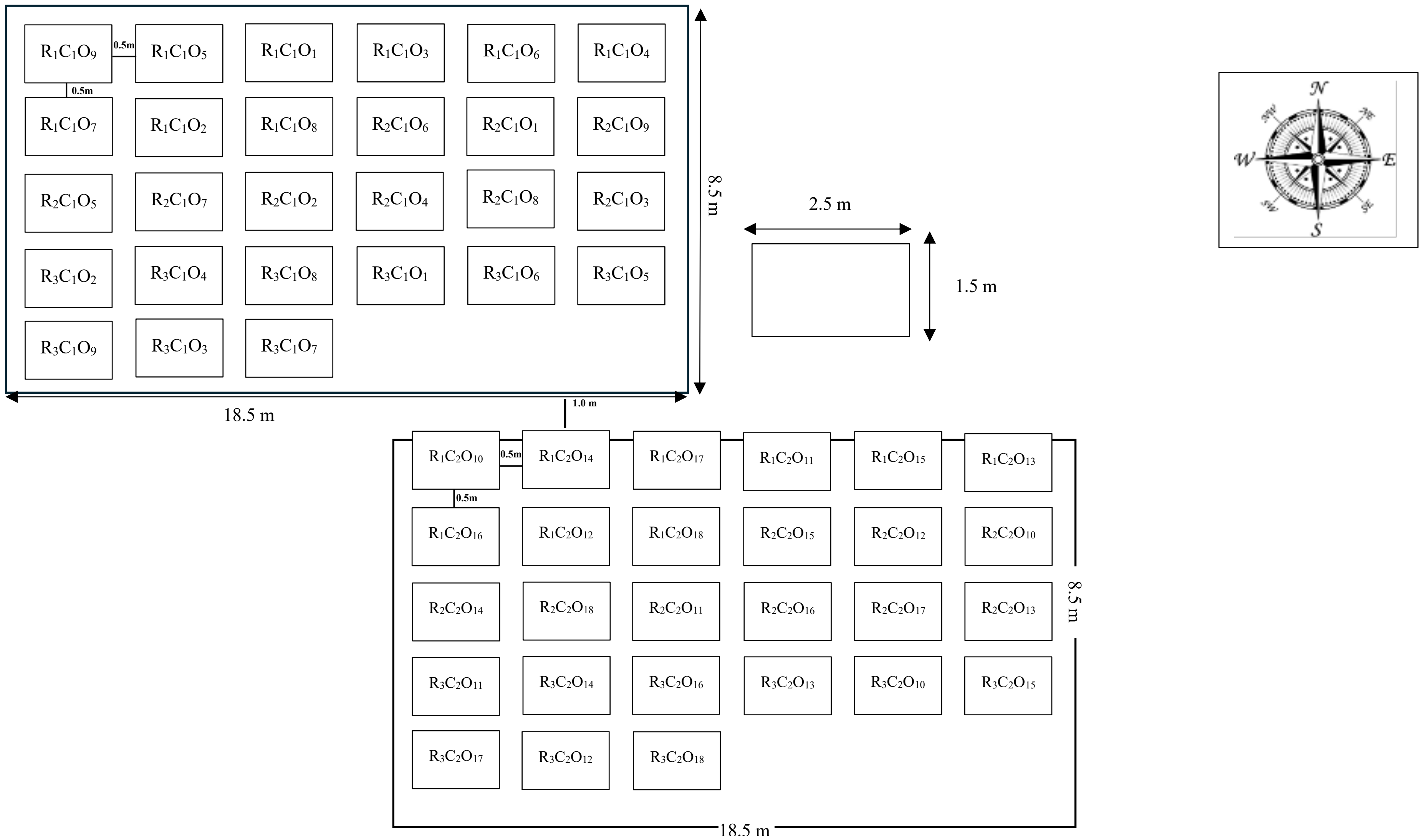

Fig. 3.3: Field layout of the experiment in Split Plot Design (SPD)

3.2.3.3 Treatment combinations

A total of 18 treatment combinations were obtained from the multiplication of two main factors and nine sub-factors.

Treatment combinations	Symbols
Control	C_1O_1
Bench terrace + FYM @ 5 t ha^{-1}	C_1O_2
Bench terrace + FYM @ 10 t ha^{-1}	C_1O_3
Bench terrace + Poultry manure @ 2.5 t ha^{-1}	C_1O_4
Bench terrace + Poultry manure @ 5 t ha^{-1}	C_1O_5
Bench terrace + Vermicompost @ 2.5 t ha^{-1}	C_1O_6
Bench terrace + Vermicompost @ 5 t ha^{-1}	C_1O_7
Bench terrace + Enriched compost @ 2.5 t ha^{-1}	C_1O_8
Bench terrace + Enriched compost @ 5 t ha^{-1}	C_1O_9
Control	C_2O_1
Non-terrace + FYM @ 5 t ha^{-1}	C_2O_2
Non-terrace + FYM @ 10 t ha^{-1}	C_2O_3
Non-terrace + Poultry manure @ 2.5 t ha^{-1}	C_2O_4
Non-terrace + Poultry manure @ 5 t ha^{-1}	C_2O_5
Non-terrace + Vermicompost @ 2.5 t ha^{-1}	C_2O_6
Non-terrace + Vermicompost @ 5 t ha^{-1}	C_2O_7
Non-terrace + Enriched compost @ 2.5 t ha^{-1}	C_2O_8
Non-terrace + Enriched compost @ 5 t ha^{-1}	C_2O_9

3.3 Agronomic practices

The details of various agronomic practices carried out during the research are presented below.

3.3.1 Selection and preparation of field

A newly cleared forest area which was well-drained with a slope per cent of 15 to 20 was selected for carrying out the research work in the experimental farm of the Department of Soil and Water Conservation. Half of the selected area was converted to bench terraces, representing the conserved plots while the remaining half was converted into a normal non-conserved plot. Before converting the forest land into a bench terrace, the topsoil (10 cm) was carefully removed and later spread over the constructed bench terrace plots to maintain soil fertility. The terrace length and terrace width of the constructed bench terraces were 18.5 m and 10.5 m, respectively. Stumps and roots of trees were removed before ploughing. Light ploughing was done to remove stubbles and weeds with the help of spades, rakes and hand-hoes, and care was taken for minimum disturbance of the soil.

3.3.2 Design and layout

After planking, with the help of measuring tape, pegs and ropes, the field plots were laid out in the field as per the statistical design (Split plot design). There were two main plots and nine subplots. The first main plot was converted to a bench terrace while the second main plot was converted into normal plots, all of the same size. A total of 54 plots were obtained with 27 subplots in each main plot having a gross plot size of 18.5 m × 10.5 m, and the subplot was 2.5 m x 1.5 m each. The distance between the two main plots was kept at 1 m. Bunds were constructed subsequently so that loss of water could be avoided and rainwater could be accumulated and also for good drainage. The field was levelled accordingly to reduce erosion. The layout of the experiment has been presented in Fig 3.3.

3.3.3 Manures and fertilizers application

Well-decomposed farmyard manure @ 5 and 10 t ha^{-1}, poultry manures @ 2.5 and 5 t ha^{-1}, vermicompost @ 2.5 and 5 t ha^{-1}, and enriched compost @ 2.5 and 5 t ha^{-1} along with the recommended dose of nitrogen, phosphorus, potassium and sulphur at 20:80:40:40 kg ha^{-1} through Urea (46.6% N), SSP (16% P_2O_5), MOP (60% K_2O), and gypsum (23.5% S), respectively were applied to each plot as basal dose and mixed with the soil. The organic manures were applied one month before sowing for even decomposition.

3.3.4 Seed rate, seed treatment and method of sowing

Healthy seeds @ 60 kg ha^{-1} were sown on July 8, 2021, and July 11, 2022, respectively. The seeds were first treated with fungicide Bavistin @ 2 g L^{-1} of water and *Rhizobium japonicum* @ 20 g kg^{-1} seed and dried in the shade for an hour before sowing. The seeds were then sown in line at a depth of 1.5 cm - 2 cm maintaining a row-to-row distance of 45 cm and plant-to-plant distance of 10 cm. The spacing was maintained by thinning out the plants after 15 DAS.

3.3.5 Irrigation

Irrigation was provided after sowing to obtain proper moisture of the soil for germination and establishment of the crops. Thereafter, irrigation was given as and when required depending on rainfall.

3.3.6 Intercultural operations

For maintaining optimum and uniform plant population, various operations after sowing such as thinning and gap-filling at 15 DAS were carried out. Hand weeding was first done at 20 DAS and later at every emergence of weeds *i.e.,* at every 15-day interval, to control the weeds. To control the insect pests, hand-picking was done to monitor them.

3.3.7 Harvesting and threshing

The soybean crop was harvested plot-wise when more than 80% of the pods turned dark brownish and were brittle on slight pressure with fingers and all the leaves turned yellow. Two to three pickings were done and the stover was left to be sun-dried for some days. With the help of a sickle, the stalks were cut on the ground level and threshing was done manually to collect the remaining seeds. The seeds were weighed with the help of a weighing balance and recorded for each plot after cleaning by winnowing. The stover, bundle for each individual plot were also weighed separately.

3.4 Soil analysis

Initial soil samples (one sample from each strip) and the final soil samples collected from individual plots after harvest of crops were analysed for the following properties

- pH
- Soil organic carbon
- Cation exchange capacity
- Bulk density
- Particle density
- Hydraulic conductivity
- Water holding capacity
- Mean weight diameter

- Available N, P, K and S
- Soil microbial biomass carbon

Soil samples from individual plots were collected before and after the harvest of the crop and air-dried, to evaluate the change in the physio-chemical properties of the soil. Soil samples at a depth of 15 cm from each sub-plot were collected, mixed thoroughly and composited to retain about 500 g of representative soil using the quadrate method. Two-thirds of each sample was ground to pass through a 2 mm sieve and kept in polythene bags for laboratory analysis. The remaining portion of soil samples was preserved for analysis of mean weight diameter (Van Bavel, 1950).

3.4.1 Soil sample collection and preparation for analysis

The soil samples were collected in a random zig-zag manner from the surface of the plough up to 0-15 cm (generally expressed as the plough layer) after harvest to assess the change in the soil properties. The collected soil samples were quartered until 500 g composite samples were obtained. The air-dried soil samples were then passed through a 2 mm sieve for further analysis. Clod samples were also preserved for analysing the mean weight diameter of the soil (Van Bavel, 1950).

3.4.1.1 Soil pH

The soil pH was determined in soil: water (1:2.5) suspension, using a Glass Electrode pH meter (Jackson, 1973).

3.4.1.2 Organic carbon (%)

The rapid titration method outlined by Walkley and Black (1934) was used to determine the organic carbon content of the soil. It was expressed in percentage as described by Jackson (1973).

3.4.1.3 Cation exchange capacity (CEC) [c mol (p^+) kg $^{-1}$]

The cation exchange capacity (CEC) of the soil was determined using the NH_4OAc procedure, performed by saturating soil samples (0.5 – 10 g) with 25 mL NH_4OAc (1 M, pH 7) solution, as described by Sumner and Miller (1996).

3.4.1.4 Bulk density (g cm^{-3})

The bulk density of soil was determined using the core method as described by Majumdar and Singh (2000). The density of the soil was expressed in g cm^{-3}.

$$\textbf{Bulk density (g cm}^{-3}\textbf{)} = \frac{\textbf{Oven dry weight of soil (g)}}{\textbf{Volume of soil}(cm^3)}$$

3.4.1.5 Particle density (g cm^{-3})

The particle density of soil was determined using the pycnometer method as described by Baruah and Barthakur (1997). It was expressed in g cm^{-3}.

$$\textbf{Particle density (g cm}^{-3}\textbf{)} = \frac{\textbf{weight of soil solids (g)}}{\textbf{volume of soil solids (cm}^3\textbf{)}}$$

3.4.1.6 Hydraulic conductivity (cm hr^{-1})

To determine hydraulic conductivity, soil samples were collected in brass cylindrical rings with the help of a core sampler (0.08 m diameter ring). It was determined as per the constant head method (Klute, 1965) by using the following equation:

$$K_s = \frac{\mathbf{Vx}}{\mathbf{At\ (\Delta H + x)}}$$

Where,

Ks = saturated hydraulic conductivity (cm sec^{-1})

V = Volume of water collected (cm^3)

A = Cross-sectional area (cm^2)

($\Delta H + x$) = Difference in head at inlet and outlet (cm)

t = time (hr)

3.4.1.7 Water holding capacity (%)

The water holding capacity was determined using Keen Raczkowski boxes as described by Piper (1966). The soil samples were kept in Keen Raczkowski boxes with uniform tapping and saturated overnight. After saturation, the samples are weighed and kept in the oven for 48 hours at an equilibrium temperature of 105°C. The samples were then cooled and weighed. The water holding capacity was calculated by the weight difference and expressed in percentage (%).

3.4.1.8 Mean weight diameter (mm)

Mean weight diameter (MWD) is determined by breaking the air-dried natural clod samples with gentle pressure. It was passed through an 8 mm mesh sieve and retained on a 5 mm sieve. Fifty grams of soil retained on a 5 mm mesh sieve were transferred to the topmost sieve of the nest of the sieves arranged in the order of 5 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm. The arranged sieves were then immersed underwater for 30 minutes and shaken in Yoder's apparatus for 30 minutes. Fractions retained in each sieve were collected, oven-dried at equilibrium temperature for 24 hours, weighed and per cent aggregation (of various sizes) was calculated. MWD was then calculated from the equation given by Van Bavel (1950) as follows:

$$\mathbf{MWD} = \sum_{i=1}^{N} x_i d_i$$

Where,

xi = Mean diameter of each size fraction, and

di = Proportion by weight of each size fraction

Summation of all the fractions > 0.25 mm in wet sieving gave per cent macro-aggregates.

3.4.1.9 Available nitrogen (kg ha^{-1})

The available nitrogen content in the soil was determined using the alkaline potassium permanganate ($KMnO_4$) method as outlined by Subbiah and Asija (1956) with the help of 'Kel Plus' nitrogen distillation machine. The results were calculated in terms of kg ha^{-1}. The procedure involves the distillation of soil alkaline potassium permanganate solution determining the ammonia liberated and it serves as an index of the available (mineralization) N status of the soil.

3.4.1.10 Available phosphorus (kg ha^{-1})

The available soil phosphorus was determined by Bray's No. 1 method as illustrated by Bray and Kurtz (1945) using 0.03 N NH_4F + 0.025 N HCL (pH 3.5) as the extracting solution. In the filtered extract, phosphorus was estimated colorimetrically by adding ammonium molybdate and stannous chloride. The intensity (% transmittance) of characteristics blue colour in the solution gives the measure for the concentration of P in the test solution, which was read in the spectrometer at 660 nm wavelength. After getting the % transmittance of the P in the test solution, the concentration of P was read from the standard curve. This method is primarily meant for soils that have moderate to strong acids with a pH of around 5.5 or less. The results were then expressed as P_2O_5 kg ha^{-1}.

3.4.1.11 Available potassium (kg ha^{-1})

Available potassium content in soil was determined by the neutral normal ammonium acetate method (Jackson, 1973). Neutral normal NH_4OAc (pH= 7.0) was used as an equilibrium solution to exchange the exchangeable K ions of the soil. In the filtered extract, K was determined using a flame photometer (Hanway and Heidal, 1952). Available potassium content in the soil solution was converted to available K_2O and expressed in terms of kg ha^{-1}.

3.4.1.12 Available sulphur (kg ha^{-1})

Available sulphur was determined using the turbidimetric method as illustrated by Chesnin and Yien (1951). Sulphate was extracted from the soil sample by monocalcium phosphate solution. In the filtered extract, after adding 25% HNO, and acetic phosphoric acid, sulphur was determined by adding barium sulphate seed suspension, barium chloride crystals and gum acacia. The intensity of turbidity produced in the sample solution was measured by spectrophotometer at 440 nm wavelength. Available sulphur content in soil was expressed in kg ha^{-1}.

3.4.1.13 Soil microbial biomass carbon (SMBC) (µg g^{-1} soil)

Soil microbial biomass carbon (SMBC) was determined by the fumigation extraction method as described by Vance *et al.* (1987). Ethanol-free chloroform was used to fumigate the fresh soil samples in a vacuum desiccator. After 24 hrs, the vacuum was released and fumigated soil samples along with their non-fumigated counterparts were extracted with 0.5 M K_2SO_4. The filtered extract was titrated against 0.005 N ferrous ammonium sulphate after adding $K_2Cr_2O_7$, conc. H_2SO_4 and conc. H_3PO_4 in the presence of diphenylamine indicator. Thereafter, the total weight of extractable carbon in fumigated and non-fumigated soil samples was calculated. SMBC was calculated by using the following formula:

$$\textbf{SMBC } (\mu g\ g^{-1}\ \textbf{soil}) = E_{CF} - EC_{NF} / K_{EC}$$

Where,

E_{CF} = Total weight of extractable C in fumigated soil sample

EC_{NF} = Total weight of extractable C in non-fumigated soil sample

K_{EC} = Calibration factor ~ 0.38

3.5. Observation of crop

3.5.1 Growth attributes

Five healthy plants were randomly selected from each plot excluding the border row plants and tagged. Their growth attributes were thereby recorded. Periodic plant sampling was done in both years to monitor plant growth attributes.

3.5.1.1 Plant height (cm)

Plant height on different days after sowing was recorded by taking the readings of the five healthy tagged plants. The height was measured by linear scale from the base of the plant to the apical portion of the main shoot after emergence in centimetres (cm) at an interval of 35 DAS, 70 DAS and at harvest. The mean plant height for each treatment was calculated as the average of five plants.

3.5.1.2 Number of nodules per plant

The nodule count was obtained during the flowering stage by carefully uprooting the selected sample plants with the help of a shovel from each plot. The roots and nodules were then gently washed and separated from the plant, followed by a careful detachment of nodules from the roots. The nodules were counted and the average value of each treatment was calculated and recorded.

3.5.1.3 Nodule weight per plant (g)

From the collected root nodules, the nodules were dried to remove the moisture content and then weighed to obtain the nodule dry weight. This was done at the flowering stage and average nodule weight per plant was calculated for each treatment and expressed in grams.

3.5.1.4 Diameter of nodules (mm)

The diameters of the horizontal axis of individual nodules were measured using a slide calliper.

3.5.2 Yield attributes and yield

3.5.2.1 Number of pods per plant

At harvest, the pods were collected from the tagged plants separately from each plot and the average was recorded.

3.5.2.2 Number of seeds per pod

After the pods were counted from the five randomly selected plants, the seeds were further counted and recorded. This was done for all the treatments and the average was noted.

3.5.2.3 Test weight (g)

From each treatment, one thousand seeds were counted and weighed. The average weight was then calculated giving the test weight and expressed in grams.

3.5.2.4 Seed yield (kg ha^{-1})

The harvested pods from each treatment were sun-dried, threshed and the seeds were separated and properly sundried to bring down the moisture content. The seed weight of each plot was taken on a treatment basis and then expressed in terms of kg ha^{-1} using the formula:

$$\textbf{Seed yield (kg ha}^{-1}\textbf{)} = \frac{\text{Weight of the seed per plot (kg)}}{\text{Size of the plot } (m^2)} \times 10000$$

3.5.2.5 Stover yield (kg ha^{-1})

The produce collected from each net plot after harvesting and threshing was allowed to be sundried for some days and was tied in bundles separately for each treatment. The stover yield of each plot was calculated after subtraction of seed yield from bundle weight. The bundle weight was recorded with the help of spring balance and converted into kg ha^{-1} using the formula:

$$\textbf{Stover yield (kg ha}^{-1}\textbf{)} = \frac{\text{Weight of the stover per plot (kg)}}{\text{Size of the plot } (m^2)} \times 10000$$

3.5.2.6 Biological yield (kg ha^{-1})

The biological yield was calculated using the formula:

$$\textbf{Biological yield (kg ha}^{-1}\textbf{)} = \frac{\text{Weight of the seed + stover per plot (kg)}}{\text{Size of the plot } (m^2)} \times 10000$$

3.5.2.7 Harvest index (%)

Harvest index (HI) is the ratio of economic yield to biological yield. It was calculated using the formula given by Donald (1962) *i.e.,* dividing the economic yield (seed yield) by the biological yield (seed yield and stover yield) multiplied by 100.

$$\textbf{Harvest index (\%)} = \frac{\text{Economic yield (seed yield)}}{\text{Biological yield (seed + stover yield)}} \times 100$$

3.5.3 Quality parameters

3.5.3.1 Estimation of protein content in seed

The nitrogen content value of the seed was multiplied by 6.25 to get the crude protein content, which also includes non-protein nitrogen. The crude protein content (%) of soybean seed was worked out by the following formula (A.O.A.C., 1965):

Crude protein (%) = N content (%) x 6.25 (as a constant factor)

3.5.3.2 Determination of oil content in seed

The oil content (%) in the seed was determined by adopting the Soxhlet ether extraction method (A.O.A.C., 1960). Seed samples of 5g each from all the treatments (plot-wise) were taken and further crushed to powder in a mortar for extraction of oil. The samples were transferred in a thimble pre-weighed oil flask which was attached to the Soxhlet assembly and extracted with light petroleum ether (A.R. Grade 60ºC – 80ºC) for 6 hours in a Soxhlet extraction unit as per the method described by the Association of Official Analytical Chemists (1960). After extraction, the extract was transferred to a weight flask kept in a hot air oven at 80°C for half an hour or till the last traces of solvent and moisture were removed. The flask was then cooled in desiccators and the weight of the oil was recorded after a constant weight was obtained. From the weight of the oil, the oil content percentage in the seed was calculated using the following formula:

$$\textbf{Per cent oil} = \frac{(W_2 - W_1) \times 100}{W}$$

Where,

W_2 = weight of the empty flask (g)

W_1 = weight of the empty flask + weight of oil (g)

W = weight of sample taken for extraction (g)

3.6 Chemical analysis of plant materials

3.6.1 Collection and preparation of plant samples

The plant samples were randomly collected from each plot at the harvest stage. The plant materials *i.e.*, seeds and stover were separated, and air-dried followed by oven drying at a temperature of 65°C. It was further powdered using the Wiley Mill and passed through a 30-mesh sieve. Finally, it was kept in polythene bags and labelled for further chemical analysis of N, P, K, and S.

3.6.2 Digestion of plant samples

The powdered plant samples were pre-digested separately in HNO_3. The pre-digested samples were digested with di acid (HNO_3: $HClO_4$) mixture at a 10:4 ratio till a clear solution was observed, cooled and diluted in HCl. The content was made up to a known volume by using double distilled water. A known quantity of liquid was used for analysis of N, P, K, and S.

3.6.3 N, P, K and S content (%) in seed and stover

After threshing, the seed and stover samples were collected separately from each plot. The samples were ground to powder and subjected to chemical analysis for N, P, K and S content.

Nutrient	Method
Nitrogen	Modified Kjeldhal method as described by (Black, 1965)
Phosphorus	Vanado-molybdate-phosphoric acid method (Jackson, 1973)
Potassium	Flame photometer (Chapman and Pratt, 1961)
Sulphur	Turbidimetric method (Chesnin and Yien, 1951)

3.6.4 N, P, K and S uptake (kg ha^{-1}) in seed and stover

Nutrient uptake is the amount of nutrients taken up by the crop. The percentage of nutrients was multiplied with seed or stover yield to obtain uptake by seed and stover. The uptake of nutrients was computed as follows:

$$\textbf{Nutrient uptake (kg ha}^{-1}\textbf{)} = \frac{\textbf{Nutrient content (\%) in seed or stover x seed or stover yield (kg ha}^{-1}\textbf{)}}{\textbf{100}}$$

3.7 Economics

To evaluate the economic feasibility of different treatments, the economics of each treatment was worked out as per existing market prices.

3.7.1 Total cost of cultivation (₹ ha^{-1})

The total cost of cultivation was calculated separately by taking into account all investments (prices of produce, inputs and labour rates used) incurred in each treatment.

3.7.2 Gross return (₹ ha^{-1})

The gross return for each treatment was calculated by multiplying the values of economic produce with the prevailing support prices of output.

3.7.3 Net return (₹ ha^{-1})

To evaluate the profitability of different treatments, net returns for each treatment were estimated by subtracting the total cost of cultivation from the corresponding gross return and expressed in ₹ ha^{-1}.

Net return = Gross return - Total cost of cultivation

3.7.4 Benefit: Cost Ratio

Benefit: Cost Ratio (B: C Ratio) was calculated by using the following formula:

$$\textbf{B: C Ratio} = \frac{\textbf{Net returns}}{\textbf{Total cost of cultivation}} \times 100$$

3.8 Statistical analysis

The data recorded during the study were statistically analysed and computed in a split plot design (SPD) using the technique of Analysis of Variance as described by Gomez and Gomez (1984). The significance differences were tested by the 'F' test. Critical difference (CD) of different groups of treatments and their interactions at a 5% probability level were calculated whenever the 'F' test was significant.

Plate No. 1: Field layout

Plate No. 2: Field preparation and application of organic sources

Plate No.3: Seedling emergence

Plate No. 4: General view of the experimental plot

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSIONS

In this chapter, generalised and classified results are presented along with tables and graphs. The results obtained through the experiment are also discussed along with suitable evidence based on the experiments carried out elsewhere to draw valid conclusions for scientific and practical utility. Interaction effects of treatments on observed parameters are presented only whenever found significant. The salient research findings obtained from this study are discussed in detail.

4.1. Effect of conservation practice and organic manures on the soil properties

The results of the important soil physicochemical and biological properties as influenced by conservation practices under different sources of organic manures *viz*., soil pH, organic carbon, cation exchange capacity (CEC), bulk density, particle density, hydraulic conductivity, water holding capacity, mean weight diameter, available N, P, K, S and soil microbial biomass carbon (SMBC) are discussed and presented under the following headings.

4.1.1. Soil pH

The two-year experimental data and pooled average on the impact of conservation practices and organic manures on soil pH after harvest, including their interaction effect, are presented in Tables 4.1(a) and 4.1(b) and illustrated in Figures 4.1(a) and 4.1(b).

4.1.1.1. Effect of conservation practice on soil pH

The data from Table 4.1(a) showed that in both years of the experiment, the highest soil pH of 5.61 and 5.74 was found in C_2 (Non-terrace) with a pooled average of 5.67. Meanwhile, the lowest soil pH of 5.17 and 5.22 was observed in C_1 (Bench terrace), along with a pooled average of 5.19.

These reports conform with the findings of Chen *et al.* (2021) whereby the average soil pH for the entire soil depth of the terraced fields in Yunnan and Gansu was lower than those of the sloped lands.

4.1.1.2. Effect of organic sources on soil pH

The effect of different organic sources on soil pH is presented in Table 4.1(a). Usages of different organic sources significantly decreased the soil pH during the whole experimental period. In the year 2021, the recorded pH values ranged from 5.18 to 5.73 with a mean of 5.45, while in the year 2021, the pH values varied from 5.24 to 5.83 with a mean value of 5.53. In both years, the significantly lowest and the highest pH values were recorded from treatments O_7 (Vermicompost @ 5 t ha^{-1}) and O_1 (Control), respectively. Similarly, the highest pooled average pH of 5.78 was recorded in O_1 (Control) and the lowest pooled average pH of 5.21 was recorded in O_7 (Vermicompost @ 5 t ha^{-1}).

Critical analysis of the pooled pH data recorded the highest significant reduction of 10.94% with the application of vermicompost @ 5 t ha^{-1}, followed by a decrease of 10.31% with the application of FYM @ 10 t ha^{-1} over control. The remarkable reduction in pH might be because of the incorporation of organic amendments, which led to an increase in soil EC. The addition of organic sources had a positive effect and ascribed the formation of CO_2 and the organic acids during the process of microbial decomposition towards the counteraction of the negative effects of soil pH. The microbial growth reflected microbial activation, which occurs due to the addition of a substrate amount in the form of organic amendments. This study is in line with other published works indicating the reductions of pH due to the organic sources by Singh *et al.* (2016) and Yadav *et al*. (2024).

4.1.1.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on soil pH is presented in Table 4.1(b). Here, a significant reduction of soil pH was observed with values ranging from 4.86 to 5.59 in 2021, 4.87 to 5.91 in 2022 and 4.87 to 5.86 in pooled, respectively. The highest soil pH in 2021 was found in treatment C_2O_1 (Control) with a maximum pH of 5.81 and was observed to be significantly at par with C_2O_5 (Non-terrace + Poultry manure @ 5 t ha^{-1}) (5.67), followed by C_1O_1 (Control) (5.66) and C_2O_4 (Non-terrace + Poultry manure @ 2.5 t ha^{-1}) (5.64). In the succeeding year, the highest pH was observed in C_2O_1 (Control) with the maximum pH value of 5.91 and was observed to be significantly at par with C_2O_4 (Non-terrace + Poultry manure @ 2.5 t ha^{-1}) (5.78), followed by C_2O_2 (Non-terrace + FYM @ 5 t ha^{-1}) (5.77), C_2O_8 (Non-terrace + Enriched compost @ 2.5 t ha^{-1}) (5.75), C_1O_1 (Control) (5.75), C_2O_5 (Non-terrace + Poultry manure @ 5 t ha^{-1}) (5.73) and C_2O_6 (Non-terrace + Vermicompost @ 2.5 t ha^{-1}) (5.73). For the pooled average, the highest pH was seen in C_2O_1 (Control) with the maximum recorded pH of 5.86, and was deemed statistically superior over the rest.

In the initial experimental year, the lowest soil pH was recorded from C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with the lowest pH value of 4.86, and was found to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (4.87) followed by C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (4.92) and C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}) (4.92). From the succeeding year, the lowest soil pH was recorded from C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with the minimum pH value of 4.87, which was statistically at par with C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (4.89), C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}) (4.93) and C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (4.95), respectively. Likewise, in the pooled average the lowest soil pH was observed in both C_1O_7 and C_1O_3 with a minimum pH of 4.87 and 4.87, respectively followed by C_1O_2 (4.93) and C_1O_6 (4.93), which was observed to be significantly at par with C_1O_7 and C_1O_3. Critical analysis of the pooled pH data recorded the highest significant reduction of 20.32% with treatments C_1O_7 and C_1O_3, followed by a reduction of 18.86% from the application of C_1O_2 and C_1O_6 over control.

Soil pH is related to the types of parent materials, soil weathering and the degree of erosion. Alteration in soil pH affects the community structure of soil microorganisms and the exchange, transport, and transformation of nutrient ions in the soil, and thus affects the content and availability of soluble nutrients in the soil (Zhang *et al.,* 2019). The soil pH was significantly decreased in the treatments with conservation and organic manure practices because of the uptake of exchangeable cations by soybean plants, leaching and decomposition of organic matter including root biomass and release of several organic acids and increase in Al ions. The findings conform with those of Chen *et al.* (2021), Mohan *et al*. (2023) and Meena *et al.* (2024).

4.1.2. Organic carbon

The two-year experimental data and the pooled average on the impact of conservation practices and organic manures on soil organic carbon after harvest, including their interaction effect, are presented in Tables 4.1(a) and 4.1(b) and illustrated in Figures 4.2(a) and 4.2(b).

4.1.2.1. Effect of conservation practice on organic carbon

As was apparent from Table 4.1(a), the maximum organic carbon in the soil during both the years of experimentation was found under C_1 (Bench terrace) with recorded values of 2.27% and 2.37%, respectively along with the pooled average of 2.32%. The lowest organic carbon was recorded in C_2 (Non-terrace) with a minimum organic carbon value of 2.11% and 2.17%, respectively along with a pooled average of 2.14%. From this data, an upsurge of 8.41% was observed in the pooled organic carbon content with the use of bench terraces as a form of conservation practices over non-conservation practice.

By changing microtopography, terraces can effectively minimize soil loss and thus preserve the soil organic carbon (Shi *et al.,* 2019 and Chen *et al.,* 2020b). The organic carbon sequestration not only reduces atmospheric CO_2 and global warming but also increases the soil organic matter and improves soil and water conservation, thus boosting crop production (Mirchooli *et al.,* 2020). Further, the increased soil organic carbon levels in terraced fields facilitate soil aggregate production and stability, which significantly affects soil structure (Deng *et al*., 2018).

4.1.2.2. Effect of organic sources on organic carbon

The effect of different organic sources on the soil organic carbon is presented in Table 4.1(a). During the year 2021, the highest organic carbon was observed in sources O_3 (FYM @ 10 t ha^{-1}) and O_7 (Vermicompost @ 5 t ha^{-1}) with a maximum recorded value of 2.31% each, respectively. They were observed to be at par with sources O_5 (Poultry manure @ 5 t ha^{-1}) (2.27%), O_6 (Vermicompost @ 2.5 t ha^{-1}) (2.26%) and O_9 (Enriched compost @ 5 t ha^{-1}) (2.26%), respectively. However, in the succeeding year, the highest soil organic carbon was observed in O_7 (Vermicompost @ 5 t ha^{-1}) with a maximum value of 2.43%, and was observed to be significantly at par with O_3 (FYM @ 10 t ha^{-1}) (2.41%), O_6 (Vermicompost @ 2.5 t ha^{-1}) (2.38%) and O_2 (FYM @ 5 t ha^{-1}) (2.36%). For the pooled average, the highest soil organic carbon of 2.37% was recorded from source O_7 (Vermicompost @ 5 t ha^{-1}), which was significantly at par with O_3 (FYM @ 10 t ha^{-1}) (2.36%). The lowest organic carbon in both years was noted from O_1 (Control) with values recorded at 1.73% and 1.74%, respectively along with the pooled average of 1.73%. Further analysis of the pooled organic carbon recorded an augmented value of 36.99% over control with the application of Vermicompost @ 5 t ha^{-1}.

An inquisition of the data showed that there were significant variations in the soil organic carbon with the application of organic amendments used in both years. This may be attributed to the bulk posting of organic sources rich in nitrogen which enhanced microbial activity in the soil and thereby greater conversion of organically bound nitrogen to inorganic form by the activities of microbes. Shen *et al.* (2022) also reported that manures add more organic carbon in the soil which could be attributed to the presence of more humified, less labile, and labile forms of carbon in decomposed organic sources. A significant increase in the soil organic carbon with the application of organic amendments was also reported by Ghosh *et al*. (2017) and Yadav *et al.* (2020a).

4.1.2.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on soil organic carbon is presented in Table 4.1(b). The results showed significant variations in the organic carbon content under different treatments during the period of study, with values ranging from 1.71% to 2.41% in 2021, 1.73% to 2.57% in 2022 and 1.72% to 2.49% in pooled. The highest soil organic carbon during the year 2021 was found in C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with a maximum value of 2.41% closely followed by C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (2.40%). It was also significantly at par with C_1O_5 (Bench terrace + Poultry manure @ 5 t ha^{-1}) (2.37%) and C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (2.35%). However, in the year 2022, the highest soil organic carbon was observed from C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a value of 2.57%, which was significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (2.53%) and C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (2.50%), respectively. In the case of pooled, the highest soil organic carbon (2.49%) was perceived in

C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) and was observed to be significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (2.47%). The lowest soil organic carbon was recorded from C_2O_1 (Control) with the minimum recorded value of 1.71%, 1.73% and 1.72%, which was significantly at par with C_1O_1 (Control) (1.75%, 1.76% and 1.75%). Critical examination of the pooled average showed an upsurged in the organic carbon content from 32.56% to 44.77% over C_2O_1 and 30.29% to 42.29% over C_1O_1 in plots with treatments C_1O_2 to C_2O_9, thereby showing that application of organic manures in conjunction to conservation practice: bench terrace greatly increased the organic carbon content.

Higher soil organic carbon in bench terrace compared to that of the sloped land was associated with the reduced degree of soil erosion after terracing and the accumulated biomass (Chaplot *et al.*, 2009 and Mesfin *et al.*, 2018). According to Zhao *et al.* (2023), organic carbon in soil is important for maintaining soil structure and fertility as it promotes the formation of soil aggregates, refines the soil structure, and improves crop yields and thereby food security. Also, the addition of organic nutrient sources created an environment conducive to the formation of humic acid which stimulates the activity of soil microorganisms, biological immobilization, and continuous mineralization of FYM and vermicompost on the surface soil layer increasing the organic carbon content and decreasing bulk density of the soil. The result of the present investigation is in harmony with the findings of Aher *et al.* (2015), Mirchooli *et al.* (2020), Shi *et al*. (2022), Meena *et al*. (2023a) and Yadav *et al*. (2024).

Table 4.1(a): Effect of conservation practice and organic manures on soil pH and organic carbon of soil after harvest

TREATMENT	pH			Organic carbon (%)		
FORMS OF CONSERVATION PRACTICE	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	5.17	5.22	5.19	2.27	2.37	2.32
C_2 - Non-terrace	5.61	5.74	5.67	2.11	2.17	2.14
SEm±	0.04	0.04	0.03	0.01	0.01	0.01
CD (P=0.05)	0.23	0.22	0.10	0.08	0.05	0.03
CV	3.63	3.43	3.53	3.06	1.91	2.53
ORGANIC SOURCES						
O_1 - Control	5.73	5.83	5.78	1.73	1.74	1.74
O_2 - FYM @ 5 t ha^{-1}	5.26	5.35	5.30	2.22	2.36	2.29
O_3 - FYM @ 10 t ha^{-1}	5.20	5.27	5.24	2.31	2.41	2.36
O_4 - Poultry manure @ 2.5 t ha^{-1}	5.48	5.67	5.57	2.18	2.23	2.20
O_5 - Poultry manure @ 5 t ha^{-1}	5.46	5.49	5.48	2.27	2.32	2.29
O_6 - Vermicompost @ 2.5 t ha^{-1}	5.24	5.34	5.29	2.26	2.38	2.32
O_7 - Vermicompost @ 5 t ha^{-1}	5.18	5.24	5.21	2.31	2.43	2.37
O_8 - Enriched compost @ 2.5 t ha^{-1}	5.50	5.61	5.55	2.18	2.24	2.21
O_9 - Enriched compost @ 5 t ha^{-1}	5.44	5.51	5.47	2.26	2.32	2.29
SEm±	0.04	0.05	0.03	0.02	0.02	0.01
CD (P=0.05)	0.13	0.14	0.09	0.05	0.07	0.04
CV	2.04	2.18	2.11	1.88	2.45	2.19

Table 4.1(b): Interaction effect of conservation practice and organic manures on soil pH and organic carbon of soil after harvest

TREATMENTS	pH			Organic carbon (%)		
	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	5.66	5.75	5.71	1.75	1.76	1.75
C_1O_2	4.92	4.93	4.93	2.30	2.46	2.38
C_1O_3	4.87	4.87	4.87	2.41	2.53	2.47
C_1O_4	5.32	5.55	5.44	2.25	2.31	2.28
C_1O_5	5.25	5.25	5.25	2.37	2.42	2.39
C_1O_6	4.92	4.95	4.93	2.35	2.50	2.42
C_1O_7	4.86	4.89	4.87	2.40	2.57	2.49
C_1O_8	5.39	5.46	5.43	2.25	2.33	2.29
C_1O_9	5.30	5.31	5.31	2.35	2.42	2.38
C_2O_1	5.81	5.91	5.86	1.71	1.73	1.72
C_2O_2	5.59	5.77	5.68	2.15	2.26	2.20
C_2O_3	5.54	5.67	5.60	2.21	2.29	2.25
C_2O_4	5.64	5.78	5.71	2.11	2.14	2.13
C_2O_5	5.67	5.73	5.70	2.18	2.21	2.19
C_2O_6	5.56	5.73	5.65	2.18	2.27	2.22
C_2O_7	5.51	5.60	5.55	2.23	2.29	2.26
C_2O_8	5.61	5.75	5.68	2.10	2.15	2.12
C_2O_9	5.58	5.70	5.64	2.17	2.23	2.20
SEm±	0.06	0.07	0.05	0.02	0.03	0.02
CD (P=0.05)	0.18	0.20	0.13	0.07	0.09	0.06

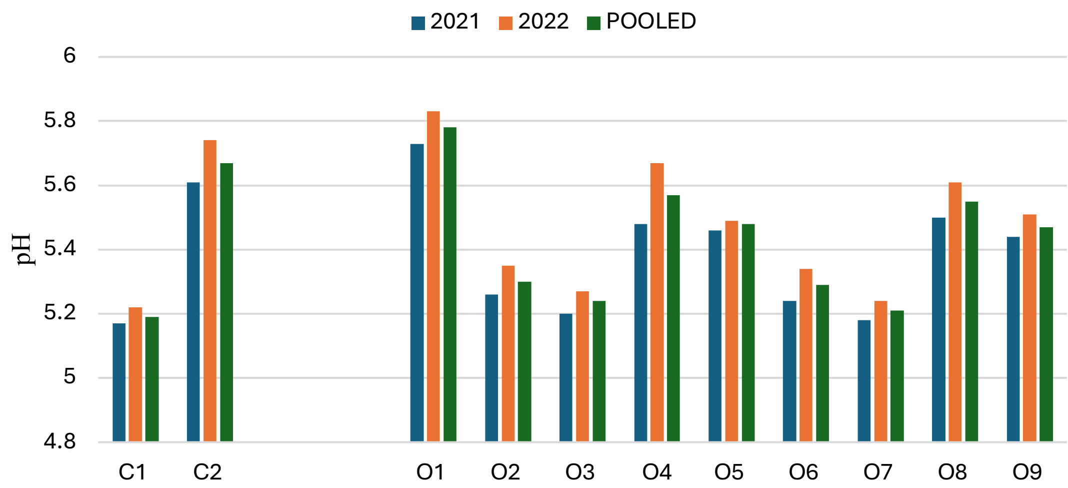

Fig. 4.1(a): Effect of conservation practice and organic manures on soil pH

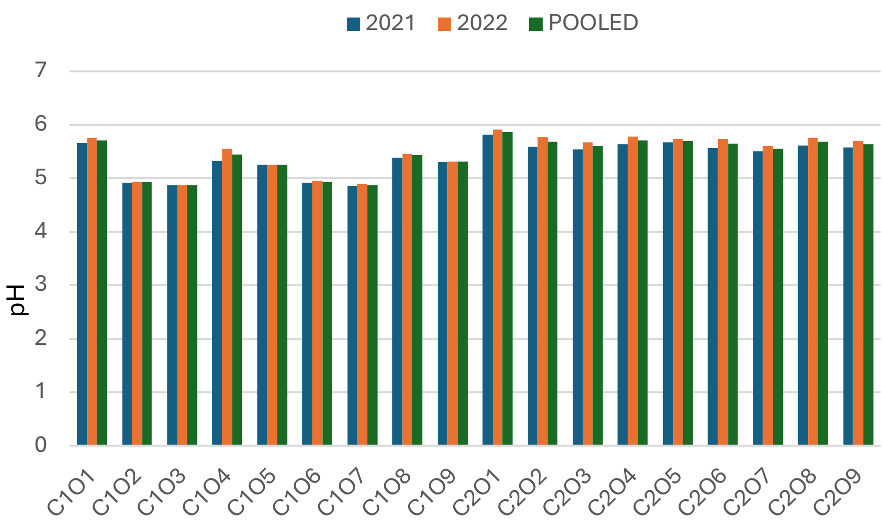

Fig. 4.1(b): Interaction effect of conservation practice and organic manures on soil pH

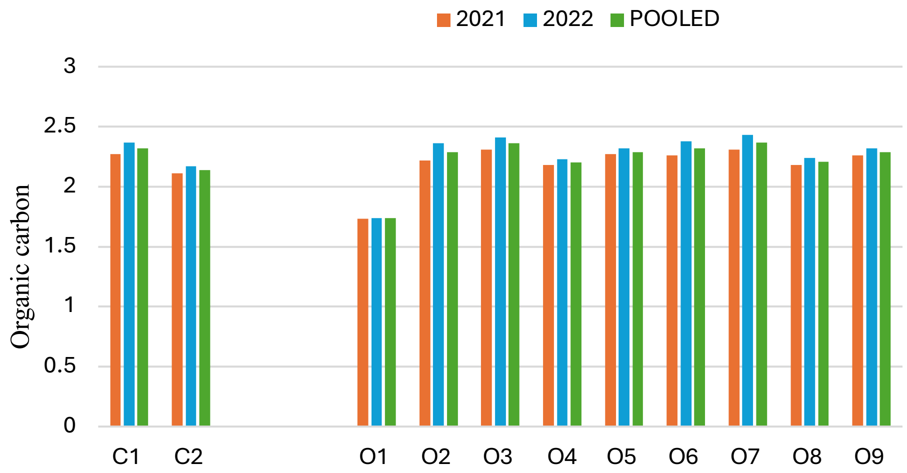

Fig. 4.2(a): Effect of conservation practice and organic manures on organic carbon of soil after harvest

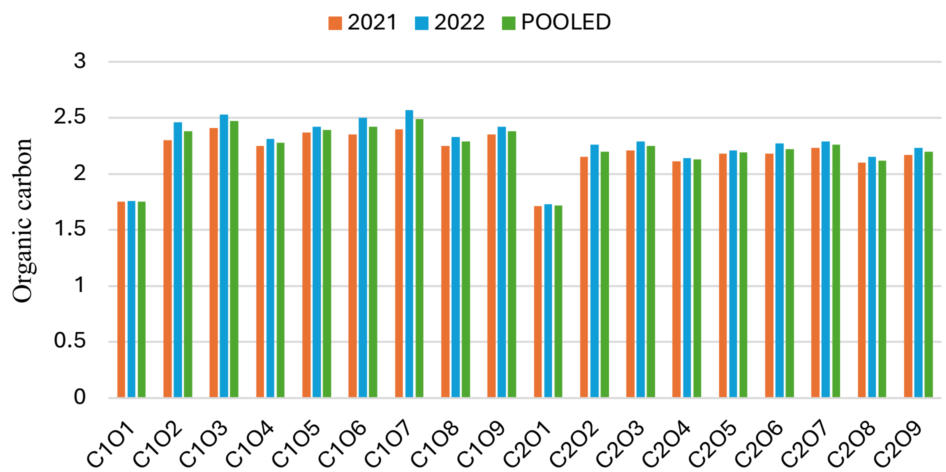

Fig. 4.2(b): Interaction effect of conservation practice and organic manures on organic carbon of soil after harvest

4.1.3. Cation exchange capacity (CEC)

The two-year experimental data and pooled average on the impact of conservation practices and organic manures on the cation exchange capacity (CEC) of the soil after harvest, including their interaction effect, are presented in Table 4.2(a) and 4.2(b) and illustrated graphically in Figure 4.3(a) and 4.3(b).

4.1.3.1. Effect of conservation practice on CEC

As was apparent from Table 4.2(a), the maximum CEC of the soil after harvest was recorded under C_1 (Bench terrace) with values logged at 19.50 [c mol (p^+) kg^{-1}] and 20.27 [c mol (p^+) kg^{-1}] during 2021 and 2022, respectively along with the pooled average of 19.88 [c mol (p^+) kg^{-1}]. The lowest CEC for both the experimental years were recorded in C_2 (Non-terrace) with the minimum CEC values of 19.12 [c mol (p^+) kg^{-1}] and 19.44 [c mol (p^+) kg^{-1}], respectively, along with a recorded pooled average of 19.28 [c mol (p^+) kg^{-1}]. An augmented 3.11% of the pooled CEC was observed with the utilization of conservation practice over non-conservation practice.

The result agrees with Degu *et al*. (2019) and Atinafu *et al.* (2024) who stated that CEC was higher under land treated with conservation practices than untreated land due to reduced soil erosion and increased clay content.

4.1.3.2. Effect of organic sources on CEC

The effect of different organic sources on the CEC of the soil is presented in Table 4.2(a). It was apparent from the data that the CEC of the soil on different organic sources showed significant variations during the study period. The CEC was observed to increase from 15.09% to 26.42% in 2021, 19.2% to 30.52% in 2022 and 17.18% to 28.51% in pooled over control. During 2021 the highest CEC was perceived in O_7 (Vermicompost @ 5 t ha^{-1}) with a maximum value of 20.53 [c mol (p^+) kg^{-1}] and was observed to be statistically superior over the rest.

Similarly in 2022 and in pooled, the highest CEC was reported in O_7 (Vermicompost @ 5 t ha^{-1}) with a maximum CEC of 21.21 [c mol (p^+) kg^{-1}] and 20.87 [c mol (p^+) kg^{-1}], respectively and was observed to be significantly at par with O_3 (FYM @ 10 t ha^{-1}) with CEC value of 21.12 [c mol (p^+) kg^{-1}] and 20.70 [c mol (p^+) kg^{-1}]. Moreover, CEC was reported significantly lowest in O_1 (Control) with values recorded at 16.24 [c mol (p^+) kg^{-1}] and 16.25 [c mol (p^+) kg^{-1}], respectively along with the pooled average of 16.24 [c mol (p^+) kg^{-1}].

Further analysis of the pooled CEC recorded an augmented value of 28.51% and 27.46% over control with the application of Vermicompost @ 5 t ha^{-1} and FYM @ 10 t ha^{-1}, respectively. Organic manure application enhances soil CEC by adding organic matter and clay-humus complexes. The organic matter improves soil structure and aggregation, increasing the surface area for cation exchange reactions. The enhanced CEC promotes soil fertility, nutrient retention, and buffering capacity, reducing nutrient leaching and runoff, and improving overall soil health (Chen *et al*., 2020a). The result corroborates with the findings of Singh *et al.* (2022) and Verma *et al*. (2024).

4.1.3.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on CEC is presented in Table 4.2(b). The CEC was significantly influenced in plots where conservation practice and organic manures were employed. In 2021, the CEC was detected significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a value of 20.84 [c mol (p^+) kg^{-1}]. Meanwhile, in 2022 and in pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was perceived as highest with a maximum CEC of 21.97 [c mol (p^+) kg^{-1}] and 21.40 [c mol (p^+) kg^{-1}], respectively and was observed to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with a value of 21.83 [c mol (p^+) kg^{-1}] and 21.17 [c mol (p^+) kg^{-1}]. Moreover, it was reported that an increase of 17.08% to 28.48% in 2021, 22.67 % to 35.37% in

2022 and 19.91% to 31.94% in pooled over control was observed in plots with treatments of conservation practice plus organic sources.

The lowest CEC was noted in C_2O_1 (Control) with values recorded at 16.22 [c mol (p^+) kg^{-1}] and 16.23 [c mol (p^+) kg^{-1}] in 2021 and 2022, respectively, along with the pooled average of 16.22 [c mol (p^+) kg^{-1}].

A parallel relation was observed with an increase in the dose of organic sources and a higher amount of cation exchange capacity (CEC) in the soil as an outcome of the influence of higher organic carbon content, clay, and organic matter in terrace areas. Through the application of organic manures into the soil, the release of organic matter takes place which brings about an increase in the cation exchange capacity, water holding capacity, and chelating ability ensuring improved soil stability. These findings were similar to the findings of Kassa *et al*. (2017), Singh *et al.* (2020), Meena *et al.* (2023a), Meena *et al.* (2023b) and Atinafu *et al.* (2024).

Table 4.2(a): Effect of conservation practice and organic manures on CEC of soil after harvest

TREATMENT	CEC [c mol (p^+) kg $^{-1}$]		
FORMS OF CONSERVATION PRACTICE	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	19.50	20.27	19.88
C_2 - Non-terrace	19.12	19.44	19.28
SEm±	0.03	0.04	0.02
CD (P=0.05)	0.18	0.23	0.10
CV	0.82	0.99	0.91
ORGANIC SOURCES			
O_1 - Control	16.24	16.25	16.24
O_2 - FYM @ 5 t ha^{-1}	19.93	20.59	20.26
O_3 - FYM @ 10 t ha^{-1}	20.28	21.12	20.70
O_4 - Poultry manure @ 2.5 t ha^{-1}	19.33	19.68	19.50
O_5 - Poultry manure @ 5 t ha^{-1}	19.59	19.97	19.78
O_6 - Vermicompost @ 2.5 t ha^{-1}	20.12	20.73	20.43
O_7 - Vermicompost @ 5 t ha^{-1}	20.53	21.21	20.87
O_8 - Enriched compost @ 2.5 t ha^{-1}	18.69	19.37	19.03
O_9 - Enriched compost @ 5 t ha^{-1}	19.10	19.79	19.44
SEm±	0.04	0.14	0.07
CD (P=0.05)	0.13	0.39	0.20
CV	0.56	1.69	1.27

Table 4.2(b): Interaction effect of conservation practice and organic manures on CEC of soil after harvest

TREATMENTS	CEC [c mol (p^+) kg $^{-1}$]		
	2021	**2022**	**POOLED**
C_1O_1	16.26	16.27	16.26
C_1O_2	20.01	20.97	20.49
C_1O_3	20.52	21.83	21.17
C_1O_4	19.59	19.97	19.78
C_1O_5	19.85	20.22	20.03
C_1O_6	20.26	21.23	20.75
C_1O_7	20.84	21.97	21.40
C_1O_8	18.99	19.91	19.45
C_1O_9	19.17	20.07	19.62
C_2O_1	16.22	16.23	16.22
C_2O_2	19.85	20.21	20.03
C_2O_3	20.03	20.42	20.23
C_2O_4	19.06	19.38	19.22
C_2O_5	19.34	19.73	19.53
C_2O_6	19.98	20.23	20.11
C_2O_7	20.22	20.45	20.34
C_2O_8	18.39	18.84	18.61
C_2O_9	19.02	19.50	19.26
SEm±	0.06	0.19	0.10
CD (P=0.05)	0.18	0.56	0.29

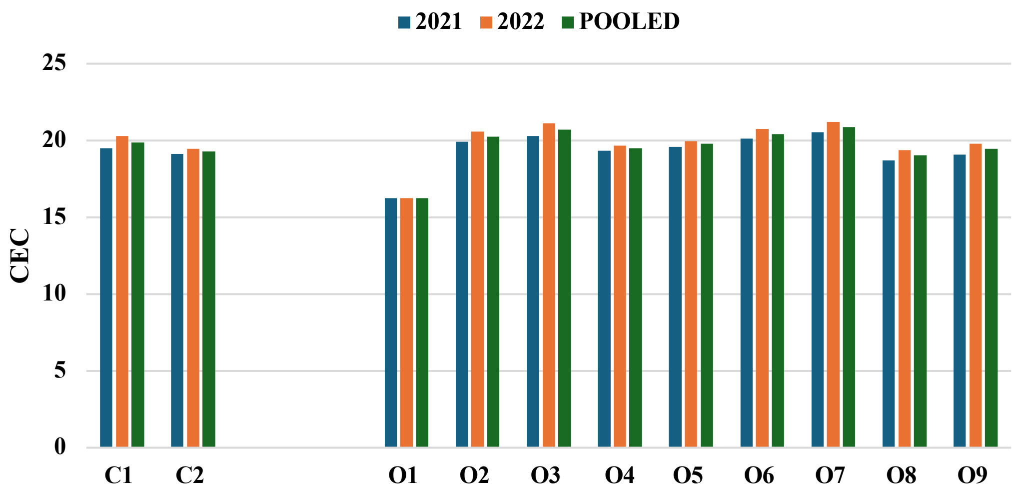

Fig. 4.3(a): Effect of conservation practice and organic manures on CEC of soil after harvest

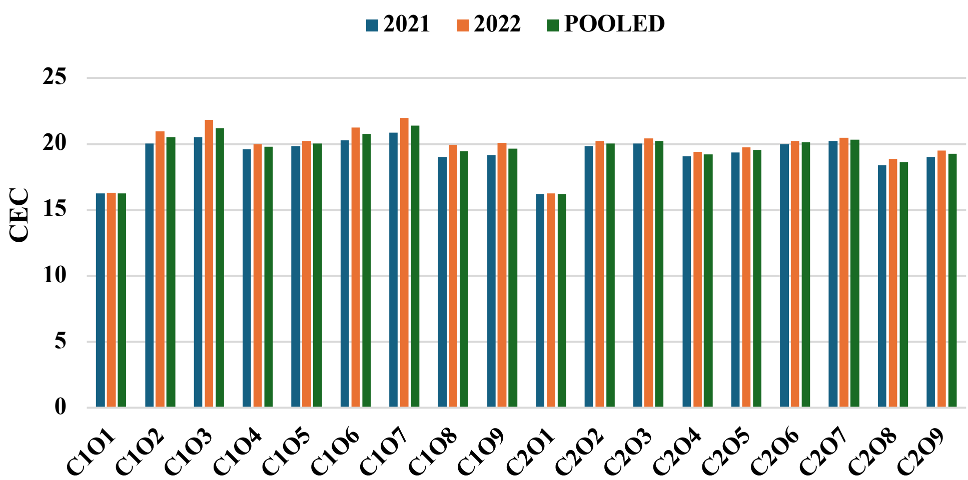

Fig. 4.3(b): Interaction effect of conservation practice and organic manures on CEC of soil after harvest

4.1.4. Bulk density

The data perceived from the two-year experimentation along with the pooled average on the impact of conservation practice and organic manures on the bulk density of the soil after harvest, including their interaction are presented in Tables 4.3(a) and 4.3(b), respectively.

4.1.4.1. Effect of conservation practice on bulk density

From the documented Table 4.3(a), it was observed that during the first and second trials, the maximum bulk density in the soil after harvest was recorded under C_2 (Non-terrace) with values of 1.24 g cm^{-3} and 1.27 g cm^{-3}, respectively along with the pooled average recorded at 1.26 g cm^{-3}. The lowest bulk density was recorded in C_1 (Bench terrace) for both years with values noted at 1.08 g cm^{-3} and 1.10 g cm^{-3}, respectively, along with a recorded pooled average of 1.09 g cm^{-3}.

The above results agree with the study of Wubie and Assen (2020) whereby they concluded that conservation practice results in lower bulk density due to the presence of relatively higher clay fraction and soil organic carbon (Brar *et al*., 2013 and Kumar *et al*., 2022).

4.1.4.2. Effect of organic sources on bulk density

The effect of different organic sources on the soil organic carbon is presented in Table 4.3(a). Here, the bulk density of the soil was observed to vary from 1.11 g cm^{-3} to 1.30 g cm^{-3} in the initial year, 1.11 g cm^{-3} to 1.31 g cm^{-3} in the succeeding year and 1.11 cm^{-3} to 1.30 cm^{-3} in the pooled. In both the experimental years, the highest bulk density of the soil was observed in O_1 (Control) with values recorded at 1.30 g cm^{-3} and 1.31 g cm^{-3}, respectively along with the pooled average recorded at 1.30 g cm^{-3}. The lowest bulk density of 1.11 g cm^{-3} each was observed in both treatments O_6 (Vermicompost @ 2.5 t ha^{-1}) and

O_7 (Vermicompost @ 5 t ha^{-1}) in the year 2021, and they were found to be at par with treatments O_3 (FYM @ 10 t ha^{-1}) (1.12 g cm^{-3}), O_2 (FYM @ 5 t ha^{-1}) (1.15 g cm^{-3}), O_4 (Poultry manure @ 2.5 t ha^{-1}) (1.16 g cm^{-3}), O_5 (Poultry manure @ 5 t ha^{-1}) (1.17 g cm^{-3}), O_8 (Enriched compost @ 2.5 t ha^{-1}) (1.17 g cm^{-3}) and O_9 (Enriched compost @ 5 t ha^{-1}) (1.17 g cm^{-3}), respectively. Similarly in the subsequent year 2022, the lowest bulk density of 1.11 g cm^{-3} was observed in treatment $O_{7,}$ and it was found to be at par with treatments O_3 (FYM @ 10 t ha^{-1}) (1.13 g cm^{-3}), O_6 (Vermicompost @ 2.5 t ha^{-1}) (1.13 g cm^{-3}), O_2 (FYM @ 5 t ha^{-1}) (1.14 g cm^{-3}) and O_9 (Enriched compost @ 5 t ha^{-1}) (1.19 g cm^{-3}). Likewise in pooled, the lowest bulk density of 1.11 g cm^{-3} was observed from treatment O_7, and it was found to be at par with treatments O_3 (FYM @ 10 t ha^{-1}) (1.12 g cm^{-3}), O_6 (Vermicompost @ 2.5 t ha^{-1}) (1.12 g cm^{-3}) and O_2 (FYM @ 5 t ha^{-1}) (1.15 g cm^{-3}). The decreased bulk density in conserved organic added plots may be due to an increase in aggregation and pore space by the addition of organic matter (Ronanki and Behera, 2019 and Singh *et al*., 2021).

4.1.4.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on bulk density is presented in Table 4.3(b). Here, the soil bulk density was significantly reduced in both years with values ranging from 1.03 to 1.30 in 2021, 0.99 to 1.32 in 2022 and 1.01 to 1.31 in pooled, respectively. In 2021, the highest soil bulk density was found in both treatment Control (C_1O_1) and C_2O_9 (Non-terrace + Enriched compost @ 5 t ha^{-1}) with a recorded value of 1.30 g cm^{-3}, which was found to be significantly at par with C_2O_1 (Control) (1.29 g cm^{-3}), followed by C_2O_5 (Non-terrace + Poultry manure @ 5 t ha^{-1}) (1.28 g cm^{-3}), C_2O_8 (Non-terrace + Enriched compost @ 2.5 t ha^{-1}) (1.27 g cm^{-3}), C_2O_4 (Non-terrace + Poultry manure @ 2.5 t ha^{-1}) (1.26 g cm^{-3}) and C_2O_2 (Non-terrace + FYM @ 5 t ha^{-1}) (1.24 g cm^{-3}). However, in 2022, the highest soil bulk density was observed in C_2O_4 (Non-terrace + Poultry manure

@ 2.5 t ha^{-1}) with the maximum recorded value of 1.34 g cm^{-3}, which was further observed to be significantly at par with C_2O_1 (Control) (1.32 g cm^{-3}), C_1O_1 (Control) (1.31 g cm^{-3}), C_2O_5 (Non-terrace + Poultry manure @ 5 t ha^{-1}) (1.29 g cm^{-3}), C_2O_8 (Non-terrace + Enriched compost @ 2.5 t ha^{-1}) (1.28 g cm^{-3}), C_2O_2 (Non-terrace + FYM @ 5 t ha^{-1}) (1.26 g cm^{-3}), C_2O_3 (Non-terrace + FYM @ 10 t ha^{-1}) (1.26 g cm^{-3}), C_2O_6 (Non-terrace + Vermicompost @ 2.5 t ha^{-1}) (1.24 g cm^{-3}), C_2O_9 (Non-terrace + Enriched compost @ 5 t ha^{-1}) (1.24 g cm^{-3}) and C_2O_7 (Non- terrace + Vermicompost @ 5 t ha^{-1}) (1.22 g cm^{-3}). For the pooled average, the highest bulk density was seen in C_1O_1 (Control) with the maximum recorded value of 1.31 g cm^{-3}. It was further found to be significantly at par with C_2O_1 (Control) (1.30 g cm^{-3}), C_2O_4 (Non-terrace + Poultry manure @ 2.5 t ha^{-1}) (1.30 g cm^{-3}), C_2O_5 (Non-terrace + Poultry manure @ 5 t ha^{-1}) (1.29 g cm^{-3}), C_2O_8 (Non-terrace + Enriched compost @ 2.5 t ha^{-1}) (1.27 g cm^{-3}), C_2O_9 (Non-terrace + Enriched compost @ 5 t ha^{-1}) (1.27 g cm^{-3}), C_2O_2 (Non-terrace + FYM @ 5 t ha^{-1}) (1.25 g cm^{-3}) and C_2O_3 (Non-terrace + FYM @ 10 t ha^{-1}) (1.23 g cm^{-3}), respectively.

In the initial year, the lowest bulk density was recorded from C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a recorded value of 1.03 g cm^{-3}, which was significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (1.04 g cm^{-3}), followed by C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (1.04 g cm^{-3}), C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}) (1.05 g cm^{-3}), C_1O_5 (Bench terrace + Poultry manure @ 5 t ha^{-1}) (1.05 g cm^{-3}), C_1O_4 (Bench terrace + Poultry manure @ 2.5 t ha^{-1}) (1.07 g cm^{-3}) and C_1O_8 (Bench terrace + Enriched compost @ 2.5 t ha^{-1}) (1.07 g cm^{-3}), respectively. Correspondingly, in the succeeding year, the lowest bulk density was recorded from C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with recorded values of 0.99 g cm^{-3} and was found to be significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (1.00 g cm^{-3}) followed by C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (1.03 g cm^{-3}), C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}) (1.03 g cm^{-3}), C_1O_5 (Bench terrace +

Poultry manure @ 5 t ha^{-1}) (1.11 g cm^{-3}) and C_1O_4 (Bench terrace + Poultry manure @ 2.5 t ha^{-1}) (1.13 g cm^{-3}). Likewise in pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was recorded with the lowest bulk density of 1.01 g cm^{-3}, C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (1.04 g cm^{-3}) followed by C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (1.03 g cm^{-3}), C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}) (1.04 g cm^{-3}) and C_1O_5 (Bench terrace + Poultry manure @ 5 t ha^{-1}) (1.09 g cm^{-3}). This might be due to variations of organic residue added in various treatments.

It is a well-documented and scientifically proven fact that the addition of organic sources improves the soil's physical properties and any significant changes in the soil's physical properties can be recorded only on long-term application of organic manure. Similar, results were reported by Dugan *et al.* (2024). In addition to the dilution effect of organic matter enrichment at the soil surface, soil tillage is also effective in lowering the bulk density at the upper portion of the soil profile. The increase in organic matter content results in greater total porosity and lowers soil bulk density (Tejada *et al.,* 2008).

4.1.5. Particle density

The two-year experimental data and pooled average on the impact of conservation practices and organic manures on the particle density of soil after harvest, including their interaction effect, are presented in Tables 4.3(a) and 4.3(b), respectively.

4.1.5.1. Effect of conservation practice on particle density

As perceived from Table 4.3(a), the highest particle density of the soil for both years was observed in C_2 (Non-terrace) with values of 2.41 g cm^{-3} and 2.46 g cm^{-3}, respectively, along with the pooled average of 2.43 g cm^{-3} whereas the lowest particle density was observed in C_1 (Bench terrace) with values of 2.30 g cm^{-3} and 2.33 g cm^{-3}, respectively, along with the pooled average recorded at

2.32 g cm^{-3}. Further inquisition of the data, showed that the bulk density was not significantly influenced by the conservation practice.

4.1.5.2. Effect of organic sources on particle density

The effect of different organic sources on the particle density of the soil is presented in Table 4.3(a). Here, the particle density of the soil on different organic sources reported no significant variations during the period of study. The particle density was recorded highest in O_1 (Control) with maximum recorded values of 2.51 g cm^{-3} and 2.58 g cm^{-3}, along with the pooled average at 2.54 g cm^{-3} The lowest for both the years and in pooled was observed in O_7 (Vermicompost @ 5 t ha^{-1}) with the minimum particle density of 2.28 g cm^{-3}, 2.24 g cm^{-3} and 2.26 g cm^{-3}, respectively due to the higher organic carbon content of the soil under the incorporation of organic matter (Tandel *et al.,* 2009 and Meena *et al*., 2022b).

4.1.5.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on bulk density is presented in Table 4.3(b). Here, the maximum particle density of the soil was recorded in Control (C_2O_1) with values of 2.51 g cm^{-3} and 2.59 g cm^{-3}, during the years 2021 and 2022, along with the pooled average recorded at 2.55 g cm^{-3}, respectively and the lowest particle density was found in treatment C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a minimum value of 2.21 g cm^{-3}, 2.15 g cm^{-3} and 2.18 g cm^{-3}, respectively.

Application of organic manures greatly leads to a reduction in particle density as compared to control plots due to increased organic carbon content which helps in the formation of more stable aggregate and macro and micropores. The results of our experiment are in conformity with the findings of Nandapure *et al.* (2014) and Dhaliwal *et al.* (2015). Since there was no significant effect on the soil's particle density by the various treatments therefore no further comparison.

Table 4.3(a): Effect of conservation practice and organic manures on bulk density and particle density of soil after harvest

TREATMENT	Bulk density (g cm^{-3})			Particle density (g cm^{-3})		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	1.08	1.10	1.09	2.30	2.33	2.32
C_2 - Non-terrace	1.24	1.27	1.26	2.41	2.46	2.43
SEm±	0.02	0.01	0.01	0.05	0.08	0.05
CD (P=0.05)	0.09	0.06	0.04	NS	NS	NS
CV	6.92	4.44	5.78	10.53	16.76	14.05
ORGANIC SOURCES						
O_1 - Control	1.30	1.31	1.30	2.51	2.58	2.54
O_2 - FYM @ 5 t ha^{-1}	1.15	1.14	1.15	2.32	2.34	2.33
O_3 - FYM @ 10 t ha^{-1}	1.12	1.13	1.12	2.30	2.31	2.30
O_4 - Poultry manure @ 2.5 t ha^{-1}	1.16	1.24	1.20	2.41	2.46	2.43
O_5 - Poultry manure @ 5 t ha^{-1}	1.17	1.20	1.19	2.35	2.42	2.38
O_6 - Vermicompost @ 2.5 t ha^{-1}	1.11	1.13	1.12	2.31	2.29	2.30
O_7 - Vermicompost @ 5 t ha^{-1}	1.11	1.11	1.11	2.28	2.24	2.26
O_8 - Enriched compost @ 2.5 t ha^{-1}	1.17	1.22	1.20	2.38	2.49	2.43
O_9 - Enriched compost @ 5 t ha^{-1}	1.17	1.19	1.18	2.36	2.43	2.39
SEm±	0.03	0.03	0.02	0.11	0.18	0.10
CD (P=0.05)	0.08	0.08	0.06	NS	NS	NS
CV	5.69	5.89	5.79	11.29	18.26	15.23

Table 4.3(b): Interaction effect of conservation practice and organic manures on bulk density and particle density of soil after harvest

TREATMENTS	Bulk density (g cm^{-3})			Particle density (g cm^{-3})		
	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	1.30	1.31	1.31	2.50	2.57	2.53
C_1O_2	1.05	1.03	1.04	2.27	2.25	2.26
C_1O_3	1.04	1.00	1.02	2.23	2.20	2.22
C_1O_4	1.07	1.13	1.10	2.32	2.41	2.37
C_1O_5	1.06	1.11	1.09	2.29	2.36	2.32
C_1O_6	1.04	1.03	1.03	2.25	2.25	2.25
C_1O_7	1.03	0.99	1.01	2.21	2.15	2.18
C_1O_8	1.07	1.17	1.12	2.35	2.43	2.39
C_1O_9	1.05	1.14	1.09	2.30	2.37	2.33
C_2O_1	1.29	1.32	1.30	2.51	2.59	2.55
C_2O_2	1.24	1.26	1.25	2.37	2.43	2.40
C_2O_3	1.19	1.26	1.23	2.36	2.41	2.39
C_2O_4	1.26	1.34	1.30	2.49	2.51	2.50
C_2O_5	1.28	1.29	1.29	2.42	2.48	2.45
C_2O_6	1.19	1.24	1.21	2.37	2.33	2.35
C_2O_7	1.18	1.22	1.20	2.34	2.32	2.33
C_2O_8	1.27	1.28	1.27	2.40	2.54	2.47
C_2O_9	1.30	1.24	1.27	2.42	2.49	2.45
SEm±	0.04	0.04	0.03	0.15	0.25	0.15
CD (P=0.05)	0.11	0.12	0.08	NS	NS	NS

4.1.6. Hydraulic conductivity

The two-year experimental data and pooled average pertaining to the impact of conservation practice and organic manures on the hydraulic conductivity of the soil after harvest, including their interactions are presented in Tables 4.4(a) and 4.4(b) and graphically depicted in Figures 4.4(a) and 4.4(b).

4.1.6.1. Effect of conservation practice on hydraulic conductivity

As was evident from Table 4.4(a), the hydraulic conductivity of the soil was significantly influenced during the period of study whereby C_1 (Bench terrace) was recorded significantly highest with the maximum hydraulic conductivity of 12.81 cm hr^{-1} and 13.04 cm hr^{-1}, respectively. Moreover, the pooled was also recorded as significantly highest in C_1 with a recorded data of 12.93 cm hr^{-1}. The hydraulic conductivity was noted significantly lowest in C_2 (Non-terrace) with recorded values of 11.51 cm hr^{-1} and 11.72 cm hr^{-1}, respectively along with the pooled average of 11.61 cm hr^{-1}.

4.1.6.2. Effect of organic sources on hydraulic conductivity

The effect of different organic sources on the hydraulic conductivity of the soil is presented in Table 4.4(a). From the critical examination of the data, it was noticed that the hydraulic conductivity was significantly influenced by the organic sources. The values were statistically significant during the period of study with the recorded values varying from 9.48 cm hr^{-1} to 13.24 cm hr^{-1} in 2021, 9.51 cm hr^{-1} to 13.62 cm hr^{-1} in 2022 and 9.50 cm hr^{-1} to 13.43 cm hr^{-1} in pooled, respectively. It was also perceived that a surge in the hydraulic conductivity of 23.52% to 39.66%, 25.24% to 43.22% and 24.32% to 41.37% in 2021, 2022 and in pooled was observed in plots where organic sources were added as compared to control plot. Source O_7 (Vermicompost @ 5 t ha^{-1}) was deemed highest with the maximum hydraulic conductivity of 13.24 cm hr^{-1} in

2021, 13.62 cm hr^{-1} in 2022 and 13.43 cm hr^{-1} in pooled, respectively. It was further observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) (13.15 cm hr^{-1}) and O_6 (Vermicompost @ 2.5 t ha^{-1}) (12.93 cm hr^{-1}) in the initial year and for the succeeding year and in pooled it was reported to be statistically at par only with O_3 (FYM @ 10 t ha^{-1}) (13.37 cm hr^{-1} and 13.26 cm hr^{-1}). Moreover, it was apparent that during 2021 and 2022, O_1 (Control) was deemed significantly lowest in both, with a minimum hydraulic conductivity of 9.48 cm hr^{-1} and 9.51 cm hr^{-1}, respectively along with the pooled average of 9.50 cm hr^{-1}. This increase in the plots with organic sources especially vermicompost and FYM, might be because of the reduction in bulk density and an enhancement in the soil cluster, which results in increased hydraulic conductivity. Similar findings were reported by Margal *et al.* (2021) and Bhanwaria *et al.* (2022).

4.1.6.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the hydraulic conductivity is presented in Table 4.4(b). As perceived from the table, the hydraulic conductivity of the soil was significantly influenced by the interaction effects of the treatments during the experimental period. An upsurge of 29.67% to 50.16%, 29.19% to 54.16% and 29.43% to 52.22% was observed in the plots where conservation practice with organic sources was carried out over the control plot. In 2021, the hydraulic conductivity of the soil was perceived highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with recorded values of 14.22 cm hr^{-1}, which was observed to be significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) and C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) with values of 14.10 cm hr^{-1} and 13.75 cm hr^{-1}. Similarly, in 2022 and in pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was also noted significantly highest with the maximum recorded value of 14.63 cm hr^{-1} and 14.43 cm hr^{-1} and was observed to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (14.38 cm

hr^{-1} and 14.24 cm hr^{-1}), respectively. Meanwhile, the least hydraulic conductivity as per data was noticed in C_2O_1 (Control) with a minimum recorded value of 9.47 cm hr^{-1}, 9.49 cm hr^{-1} and 9.48 cm hr^{-1} in 2021, 2022 and in pooled, respectively, which was observed to be statistically at par with C_1O_1 (Control) with values logged at 9.50 cm hr^{-1}, 9.52 cm hr^{-1} and 9.51 cm hr^{-1}, respectively.

The increase in the conserved plots may have been a result of stable soil structure with greater pore configuration and connectivity (Bhattacharyya *et al.,* 2006 and Eze *et al*., 2020) due to reduced soil disturbance. This optimum hydraulic conductivity indicates adequate water movement within the root zone and ease of nutrient supply to plants, thereby contributing to an increase in crop yield in conserved plots (Thierfelder *et al*., 2013). The addition of organic manures increases the organic matter resulting in the reduction of the soil compaction and increasing capillary and non-capillary pores as well as total pore space of the soil resulting in increased hydraulic conductivity of soil. These results are in conformity with the findings of Bhatt *et al*. (2017) and Meena *et al.* (2022b).

4.1.7. Water holding capacity

The two-year experimental data and pooled average pertaining to the impact of conservation practice and organic manures on the water holding capacity of the soil after harvest, including their interaction effect are presented in Tables 4.4(a) and 4.4(b) and graphically depicted in Figures 4.5(a) and 4.5(b).

4.1.7.1. Effect of conservation practice on water holding capacity

From the data recorded in Table 4.4(a), it was observed that in both the trial period of 2021 and 2022, C_1 *i.e*., Bench terrace, was noted as significantly highest for the water holding capacity of the soil with values logged at 68.97% and 69.54%, respectively along with the pooled average of 69.25%. The water holding capacity was observed significantly lowest in C_2 *i.e*., Non-terrace, with minimum recorded values of 65.32% and 65.62%, respectively. Similarly, a significantly lowest recorded pooled average of 65.47% was observed in C_2. As per the pooled data, an augmented increase of 5.77% over C_2 was observed with the application of C_1. This was because of the increased surface roughness and vertical surface relief as a result of terracing which thereby, increases infiltration, soil moisture, and the soil water holding capacity (Wei *et al*., 2016). Deng *et al.* (2021) also reported that terraces increase the water-holding capacity of the soil by 5.0% to 6.2% times over that of sloped land. Similar findings were reported by Tian *et al.* (2023) and Chen *et al.* (2024).

4.1.7.2. Effect of organic sources on water holding capacity

The effect of different organic sources on the water holding capacity of the soil is presented in Table 4.4(a). The data distinctly showed that during the experimental period, the organic sources significantly influenced the water-holding capacity of the soil. The water holding capacity of the soil was reported highest from O_7 (Vermicompost @ 5 t ha^{-1}) with the maximum recorded value of 70.13%, 70.64% and 70.39% in 2021, 2022 and in pooled, respectively which was observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) (70.07%, 70.56% and 70.31%). The source O_1 (Control) was deemed significantly lowest with a minimum recorded value of 59.29% and 59.31%, respectively, along with the pooled average of 59.30%. Further examination of the pooled average showed an upsurge in the application of organic sources over control by 12.11% to 18.70%.

Organic matters not only increase the water-holding capacity of the soil but also the portion of water available for plant growth and improve the soil's physical properties (Sial *et al.,* 2007). Adak *et al.* (2013) also reported that the use of such organic amendments (FYM, vermicompost) is also an effective means for enhancing soil fertility, microbial diversity and population, microbial activity, improving the soil's physical properties particularly the moisture-holding capacity of soils and increasing crop yield. Similar findings were reported by Ahlawat *et al.* (2023) suggesting that the increase in humic substances leads to a reduction in the bulk density of the soil which further results in increased porosity and water-holding capacity of soil.

4.1.7.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the water holding capacity is presented in Table 4.4(b). Here, significant variations were observed, with values ranging from 59.26% to 73.07% in 2021, 59.29% to 73.53% in 2022 and 59.27% to 73.30% in pooled, respectively. As per data, the water holding capacity of the soil was perceived to be highest in C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with a maximum value of 73.07%, 73.53% and 73.30% in 2021, 2022 and pooled, respectively. It was observed to be statistically at par with C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a recorded water holding capacity of 72.72%, 73.35% and 73.30%, respectively. Meanwhile, the least water-holding capacity of the soil during the whole experimental period and in pooled was noticed in C_2O_1 (Control), with the minimum values recorded at 59.26%, 59.29% and 59.27%, respectively. It was further observed to be statistically at par with C_1O_1 (Control), with recorded values of 59.31%, 59.33% and 59.32%. Upon further investigation of the pooled average, an augmented water holding capacity of 15.64% to 23.67% was observed in treatments with the usage of conservation practice and organic manures over the control plot. This might be due to organic matter being highly porous which thereby increases the water-holding capacity of the soil.

With the construction of terraces, the slope of the farmland's surface slowed down with an increase in the suspension time of rainfall, and as a result, an increase in the infiltration was observed (Chen *et al.,* 2020b and Xu *et al*., 2021). In addition, the presence of a good amount of soil organic matter causes the formation of granular and crumby structures leading to the soil being well aggregated (Meena *et al.,* 2022b) and as a result, the water holding capacity increased. Singh *et al.* (2021) also reported that the increase in water holding capacity could be attributed to the improvement in soil structure or aggregation through the increased formation of macro- and micro-pores and later conversion of some of the micro-pores to the macro-pores as a result of cementing action of the organic acids formed during the decomposition of organic residues.

4.1.8. Mean weight diameter

The two-year experimental data and pooled average pertaining to the impact of conservation practice and organic manures along with their interactions on the mean weight diameter of the soil after harvest are presented in Tables 4.4(a) and 4.4(b). The recorded data have been illustrated graphically in Figures 4.6(a) and 4.6(b).

4.1.8.1. Effect of conservation practice on mean weight diameter

As was apparent from the data, the mean weight diameter of the soil after harvest was recorded as significantly highest under C_1 (Bench terrace) with recorded values of 2.29 mm and 2.34 mm during the years 2021 and 2022, respectively along with the pooled average of 2.31 mm. Furthermore, during 2021 and 2022, C_2 (Non-terrace) was noted with the significantly lowest mean weight diameter with values recorded at 2.04 mm and 2.08 mm, respectively with a recorded pooled average of 2.06 mm. An upsurge of 12.14% was observed from the pooled average when conservation practice in the form of bench terrace was practised.

4.1.8.2. Effect of organic sources on mean weight diameter

The mean weight diameter of the soil on different organic sources as seen in Table 4.4(a) clearly showed significant variations which thereby influenced the treatments during the experimental period. The values were observed to vary from 1.32 mm to 2.44 mm in 2021, 1.36 mm to 2.52 mm in 2022 and 1.34 mm to 2.48 mm in pooled, respectively with an upsurged of 56.82% to 84.85% in the initial year, 47.06% to 85.29% in the succeeding year and 54.24% to 85.07% in pooled of the plots with organic sources over the control plot. The first-year data reported the highest mean weight diameter in both O_3 (FYM @ 10 t ha^{-1}) and O_7 (Vermicompost @ 5 t ha^{-1}) with a maximum value of 2.44 mm, which was observed to be statistically superior over the rest. However, in the succeeding year and in pooled, source O_7 (Vermicompost @ 5 t ha^{-1}) was deemed highest with a maximum recorded value of 2.52 mm and 2.48 mm, which was observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) with values of 2.51 mm and 2.47 mm, respectively. Again, from the table, it was apparent that during the trial period of 2021 and 2022, O_1 (Control) was deemed significantly lowest with values recorded at 1.32 mm and 1.36 mm, respectively, along with the pooled average of 1.34 mm. The increase in mean weight diameter of soil aggregates with increased addition of organic sources, especially vermicompost and FYM may be due to the positive effect of soil organic matter which affects infiltration through the development of stable soil aggregates, or crumbs. As a result highly aggregated soil has increased pore space and infiltration (Ahlawat *et al.,* 2023).

4.1.8.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the mean weight diameter is presented in Table 4.4(b). As perceived from the table, the mean weight diameter of the soil was significantly influenced by the interaction effects of the treatments during the experimental period. An upsurge of 65.91% to 98.48% in 2021, 61.76% to 97.79% in 2022 and 54.24% to 97.76% in pooled was observed in the plots where conservation practice with organic sources was carried out over the control plot. In 2021, the highest mean weight diameter was reported from C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a maximum value of 2.62 mm and was seen to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (2.60 mm), respectively. However, in 2022, C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) was observed to be highest with a maximum mean weight diameter of 2.69 mm and was perceived to be statistically at par with C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (2.67 mm), respectively. The pooled average was noted utmost in both C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) and C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a similar maximum recorded value of 2.65 mm, which was observed to be statistically superior over the rest of the treatments. The lowest mean weight diameter of the soil was detected in C_2O_1 (Control) with the minimum recorded values of 1.31 mm, 1.35 mm, and 1.33 mm, in 2021, 2022 and in pooled respectively, and was reported to be statistically at par with C_1O_1 (Control) with values of 1.32 mm, 1.36 mm and 1.34 mm.

Upon further investigation of the pooled average, an augmented mean weight diameter of 72.93% to 99.25% was observed in treatments with the usage of conservation practice and organic sources particularly vermicompost @ 5 t ha^{-1} and FYM @ 10 t ha^{-1} over the control plot. This might be due to the minimum disturbance of soil and organic sources retention which significantly enhanced organic carbon status and increased the mean weight diameter of soil aggregates. The absence of tillage excludes the possibility of physical disruption of soil aggregates (Barto *et al*., 2010), and soil organic matter remains protected within the aggregates. The enhanced soil organic carbon level favours aggregation thereby conferring stability. This improved mean weight diameter implies an improvement in soil stability, which is crucial for soil aeration, root elongation and water movement (Mondal *et al.,* 2020). Further, the addition of organic sources improves the substrate availability and water retention, which favours microbial activity. The above findings corroborate the findings of Tripathi *et al*. (2014), Mondal *et al.* (2021), Meena *et al.* (2022b), Tian *et al.* (2023) and Chen *et al.* (2024).

Table 4.4(a): Effect of conservation practice and organic manures on hydraulic conductivity, water holding capacity and mean weight diameter of soil after harvest

TREATMENT	Hydraulic conductivity (cm hr^{-1})			Water holding capacity (%)			Mean weight diameter (mm)		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	12.81	13.04	12.93	68.97	69.54	69.25	2.29	2.34	2.31
C_2 - Non-terrace	11.51	11.72	11.61	65.32	65.62	65.47	2.04	2.08	2.06
SEm±	0.07	0.04	0.04	0.13	0.12	0.09	0.01	0.01	0.01
CD (P=0.05)	0.41	0.21	0.15	0.79	0.75	0.35	0.04	0.09	0.03
CV	2.86	1.48	2.27	1.01	0.95	0.98	1.45	3.36	2.61
ORGANIC SOURCES									
O_1 - Control	9.48	9.51	9.50	59.29	59.31	59.30	1.32	1.36	1.34
O_2 - FYM @ 5 t ha^{-1}	12.81	13.14	12.98	68.02	68.63	68.32	2.31	2.36	2.33
O_3 - FYM @ 10 t ha^{-1}	13.15	13.37	13.26	70.07	70.56	70.31	2.44	2.51	2.47
O_4 - Poultry manure @ 2.5 t ha^{-1}	12.04	12.26	12.15	66.69	67.18	66.93	2.19	2.23	2.21
O_5 - Poultry manure @ 5 t ha^{-1}	12.31	12.58	12.45	67.79	68.45	68.12	2.25	2.33	2.29
O_6 - Vermicompost @ 2.5 t ha^{-1}	12.93	13.04	12.98	68.46	68.96	68.71	2.33	2.41	2.37
O_7 - Vermicompost @ 5 t ha^{-1}	13.24	13.62	13.43	70.13	70.64	70.39	2.44	2.52	2.48
O_8 - Enriched compost @ 2.5 t ha^{-1}	11.71	11.91	11.81	66.21	66.75	66.48	2.07	2.00	2.04
O_9 - Enriched compost @ 5 t ha^{-1}	11.75	12.00	11.87	67.66	67.73	67.69	2.15	2.15	2.15
SEm±	0.14	0.13	0.09	0.20	0.22	0.15	0.01	0.02	0.01
CD (P=0.05)	0.40	0.37	0.27	0.57	0.64	0.42	0.04	0.06	0.04
CV	2.79	2.51	2.65	0.72	0.81	0.77	1.69	2.38	2.07

Table 4.4(b): Interaction effect of conservation practice and organic manures on hydraulic conductivity, water holding capacity and mean weight diameter of soil after harvest

TREATMENTS	Hydraulic conductivity (cm hr^{-1})			Water holding capacity (%)			Mean weight diameter (mm)		
	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	9.50	9.52	9.51	59.31	59.33	59.32	1.32	1.36	1.34
C_1O_2	13.53	14.06	13.80	69.93	70.28	70.11	2.41	2.48	2.45
C_1O_3	14.10	14.38	14.24	73.07	73.53	73.30	2.60	2.69	2.65
C_1O_4	12.61	12.93	12.77	68.28	68.95	68.62	2.29	2.30	2.30
C_1O_5	12.95	13.28	13.11	69.63	71.03	70.33	2.37	2.44	2.41
C_1O_6	13.75	13.93	13.84	70.06	70.79	70.42	2.50	2.58	2.54
C_1O_7	14.22	14.63	14.43	72.72	73.35	73.03	2.62	2.67	2.65
C_1O_8	12.28	12.26	12.27	68.16	68.92	68.54	2.19	2.20	2.20
C_1O_9	12.35	12.40	12.38	69.56	69.66	69.61	2.28	2.32	2.30
C_2O_1	9.47	9.49	9.48	59.26	59.29	59.27	1.31	1.35	1.33
C_2O_2	12.10	12.22	12.16	66.10	66.98	66.54	2.21	2.23	2.22
C_2O_3	12.20	12.35	12.28	67.07	67.59	67.33	2.27	2.32	2.30
C_2O_4	11.48	11.59	11.53	65.10	65.40	65.25	2.08	2.16	2.12
C_2O_5	11.66	11.89	11.78	65.95	65.88	65.91	2.12	2.22	2.17
C_2O_6	12.10	12.15	12.13	66.86	67.12	66.99	2.15	2.23	2.19
C_2O_7	12.27	12.60	12.43	67.55	67.94	67.74	2.26	2.37	2.32
C_2O_8	11.13	11.56	11.35	64.26	64.58	64.42	1.96	1.80	1.88
C_2O_9	11.15	11.59	11.37	65.77	65.79	65.78	2.02	1.98	2.00
SEm±	0.20	0.18	0.13	0.28	0.32	0.21	0.02	0.03	0.02
CD (P=0.05)	0.56	0.52	0.38	0.80	0.91	0.59	0.06	0.09	0.05

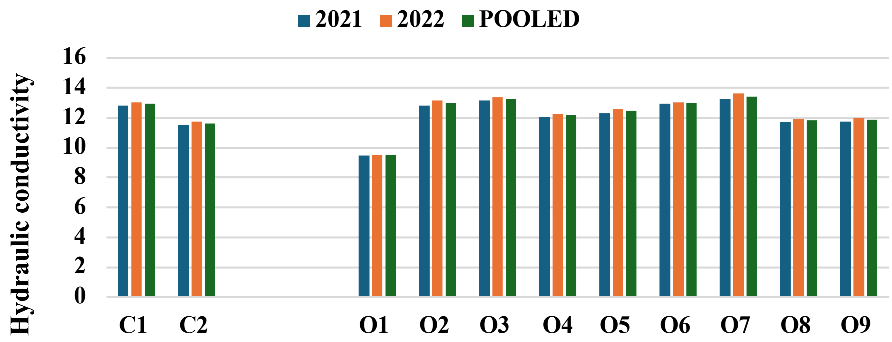

Fig. 4.4(a): Effect of conservation practice and organic manures on hydraulic conductivity of soil after harvest

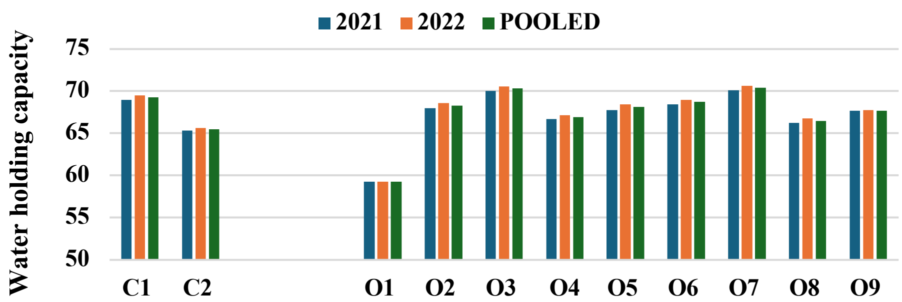

Fig. 4.5(a): Effect of conservation practice and organic manures on water holding capacity of soil after harvest

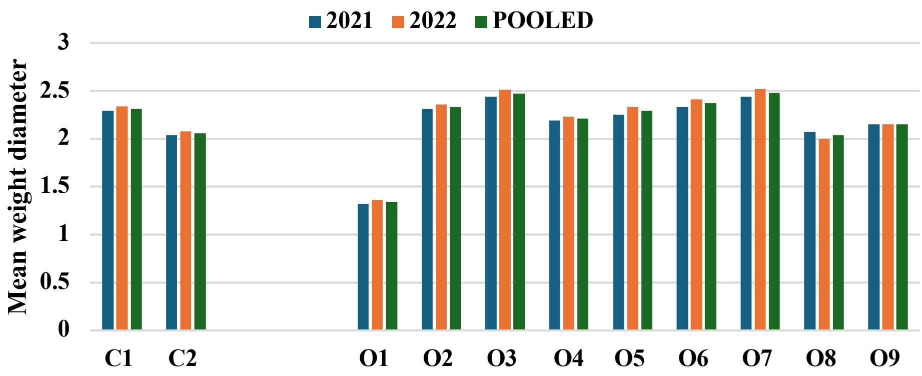

Fig. 4.6(a): Effect of conservation practice and organic manures on mean weight diameter of soil after harvest

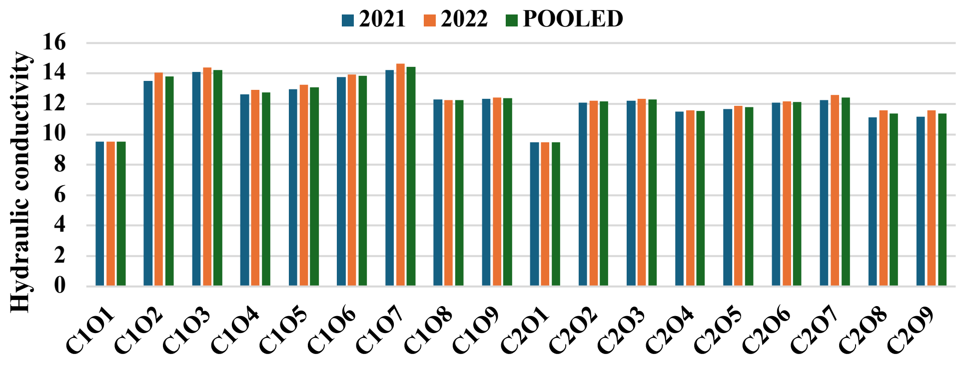

Fig. 4.4(b): Interaction effect of conservation practice and organic manures on hydraulic conductivity of soil after harvest

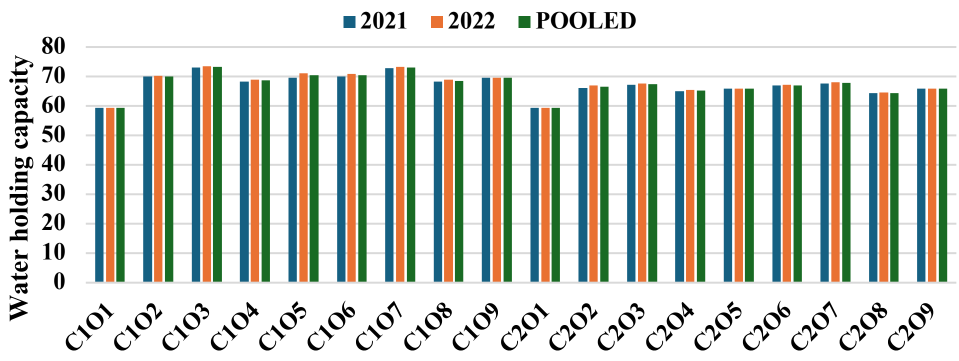

Fig. 4.5(b): Interaction effect of conservation practice and organic manures on water holding capacity of soil after harvest

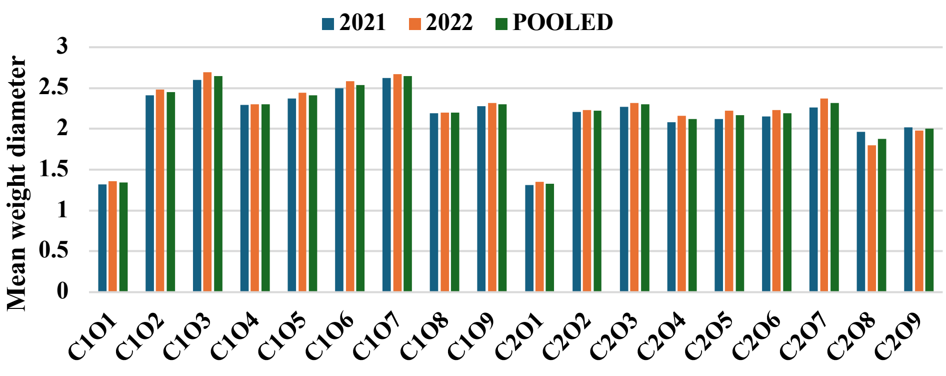

Fig. 4.6(b): Interaction effect of conservation practice and organic manures on mean weight diameter of soil after harvest

4.1.9. Available nitrogen

The two-year experimental data and pooled average on the impact of conservation practice and organic manures including their interactions on the soil available nitrogen after harvest are presented in Tables 4.5(a) and 4.5(b), and illustrated graphically in Figures 4.7(a) and 4.7(b).

4.1.9.1. Effect of conservation practice on available nitrogen

As was apparent from Table 4.5(a), the available nitrogen of the soil was recorded as significantly highest in C_1 (Bench terrace) with values recorded at 554.96 kg ha^{-1} and 559.19 kg ha^{-1} respectively, during the years 2021 and 2022. Moreover, the pooled average was also observed highest in C_1 (Bench terrace) with a recorded data of 557.08 kg ha^{-1}. Furthermore, C_2 (Non-terrace) was noted as significantly lowest with the minimum recorded values of 532.60 kg ha^{-1} and 536.62 kg ha^{-1}, respectively along with the pooled average of 534.61 kg ha^{-1}. An augmented 4.20% in the pooled available nitrogen was observed in plots with conservation practice in the form of bench terraces over non-conservation practice plots.

4.1.9.2. Effect of organic sources on available nitrogen

The effect of different organic sources on the available nitrogen of the soil is presented in Table 4.5(a). The data evidently showed significant variations with values ranging from 492.02 kg ha^{-1} to 565.85 kg ha^{-1}, 493.39 kg ha^{-1} to 570.01 kg ha^{-1} and 492.70 kg ha^{-1} to 567.93 kg ha^{-1} in 2021, 2022 and in pooled, respectively. The highest available nitrogen in both the years and in pooled was reported from O_7 (Vermicompost @ 5 t ha^{-1}) with the maximum available nitrogen of 565.85 kg ha^{-1}, 570.01 kg ha^{-1} and 567.93 kg ha^{-1} respectively, which was observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) with recorded values of 565.17 kg ha^{-1}, 569.59 kg ha^{-1} and 567.38 kg ha^{-1}. An upsurge in the pooled available nitrogen content of 15.16% and 15.27% over O_1 (Control) was observed with the application of O_7 and O_3. Again from the table, it was apparent that during 2021 and 2022, O_1 (Control) was deemed significantly lowest with values recorded at 492.02 kg ha^{-1} and 493.39 kg ha^{-1}, respectively along with the pooled average of 492.70 kg ha^{-1}.

4.1.9.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the available nitrogen is presented in Table 4.5(b). As evident from the table the available nitrogen was significantly influenced thereby resulting in varying values which ranged from 492.00 kg ha^{-1} to 582.22 kg ha^{-1} in 2021, 493.30 kg ha^{-1} to 587.24 kg ha^{-1} in 2022 and 492.65 kg ha^{-1} to 584.73 kg ha^{-1} in pooled, respectively. The highest available nitrogen was exhibited in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with maximum recorded values of 582.22 kg ha^{-1} and 587.24 kg ha^{-1} in 2021 and 2022 respectively, which was observed to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (576.33 kg ha^{-1} and 581.90 kg ha^{-1}). Meanwhile, in pooled, available nitrogen was perceived to be significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a maximum reported value of 584.73 kg ha^{-1}. The lowest soil available nitrogen as per the report was noted in C_2O_1 (Control) with the minimum recorded values of 492.00 kg ha^{-1} in 2021, 493.30 kg ha^{-1} in 2022 and 492.65 kg ha^{-1} in pooled, which was exhibited to be statistically at par with C_1O_1 (Control) (492.03 kg ha^{-1}, 493.47 kg ha^{-1} and 492.75 kg ha^{-1}).

Critical examinations of the pooled average showed an increase in the available nitrogen by 11.00% to 18.69% in plots with treatments from C_1O_2 to C_1O_9 *i.e.,* bench terrace along with organic sources as compared to the control plot. Moreover, C_1O_7 and C_1O_3 exhibited an increase in the pooled available nitrogen by 18.89% and 17.55% over C_1O_1, 18.67% and 17.53% over C_2O_1 and an increase of 10.94% and 9.87% over C_2O_8.

The leguminous nature of soybeans might have led to a higher content of total N in their litter and thus in the soils (Singh *et al.,* 2021). Nitrogen content in soil is directly related to crop growth and yield (Acharya *et al.,* 2007). Organic manures meet the nutrient requirement of crops with greater nutrient use efficiency and correct the deficiency of nutrients as and when noticed under an organic production system (Shwetha *et al.,* 2009). Vermicompost application improved the bio-available, slow-releasing nitrogen for the better growth of plants. In addition to nitrogen supply, the vermicompost supplies micronutrients like calcium, magnesium, potassium, and other important nutrients needed by the plants for their growth. Along with the application of organic manures, terracing alters the soil's physicochemical properties because of reduced soil erosion and enhanced water availability thereby increasing nitrogen availability. Manure application had a better effect on improving the soil quality of terraces as they significantly boosted soil organic carbon, total nitrogen, and microbial biomass carbon (Shi *et al*., 2022). These above results were in correlation with the findings of Yadav *et al.* (2020a), Chen *et al*. (2021) and Meena *et al*. (2024).

4.1.10. Available phosphorus

The two-year experimental data and pooled average pertaining to the impact of conservation practice and organic manures on the available phosphorus of the soil after harvest, including their interactions are presented in Tables 4.5(a) and 4.5(b), and illustrated graphically in Figures 4.8(a) and 4.8(b).

4.1.10.1. Effect of conservation practice on available phosphorus

As was discernible from Table 4.5(a), the available phosphorus of the soil was recorded as significantly highest in C_1 (Bench terrace) with recorded values of 15.08 kg ha^{-1} in 2021 and 15.15 kg ha^{-1} in 2022, respectively. Moreover, the pooled average was also observed as significantly highest in C_1 (Bench terrace) with a recorded data of 15.11 kg ha^{-1}. The significantly lowest available phosphorus was noted in C_2 (Non-terrace) with values logged at 14.40 kg ha^{-1} and 14.45 kg ha^{-1}, respectively along with pooled average of 14.42 kg ha^{-1}. An augmented 4.79% in the pooled available phosphorus was observed in plots with conservation practice in the form of bench terraces over non-conservation practice plots.

4.1.10.2. Effect of organic sources on available phosphorus

The effect of different organic sources on the available phosphorus in the soil is presented in Table 4.5(a). As was observed from the table, the available phosphorus of the soil on different organic sources evidently showed significant variations with values varying from 12.52 kg ha^{-1} to 15.71 kg ha^{-1}, 12.53 kg ha^{-1} to 15.78 kg ha^{-1} and 12.52 kg ha^{-1} to 15.74 kg ha^{-1} in 2021, 2022 and pooled, respectively. Further examinations of the pooled available phosphorus showed an upsurge of 13.74% to 25.72% over control in plots where organic sources were applied. In 2021 and 2022, the soil available phosphorus was noted highest from source O_7 (Vermicompost @ 5 t ha^{-1}) with the maximum value of 15.71 kg ha^{-1} and 15.78 kg ha^{-1} respectively, and was observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) (15.69 kg ha^{-1} and 15.77 kg ha^{-1}), O_6 (Vermicompost @ 2.5 t ha^{-1}) (15.58 kg ha^{-1} and 15.64 kg ha^{-1}) and O_2 (FYM @ 5 t ha^{-1}) (15.45 kg ha^{-1} and 15.55 kg ha^{-1}). Likewise in pooled, O_7 (Vermicompost @ 5 t ha^{-1}) with a maximum available phosphorus of 15.74 kg ha^{-1} was deemed the highest available phosphorus, which was further observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) (15.73 kg ha^{-1}) and O_6 (Vermicompost @ 2.5 t ha^{-1}) (15.61 kg ha^{-1}). In the case of the least available phosphorus, O_1 (Control) was deemed significantly lowest with a minimum value recorded at 12.52 kg ha^{-1} and 12.53 kg ha^{-1} respectively, along with the pooled average noted at 12.52 kg ha^{-1}.

4.1.10.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the available phosphorus is presented in Table 4.5(b). The available phosphorus of the soil for both the years 2021 and 2022 was observed to be significantly influenced with values ranging from 12.51 kg ha^{-1} to 16.08 kg ha^{-1} in 2021, 12.53 kg ha^{-1} to 16.16 kg ha^{-1} in 2022 and 12.52 kg ha^{-1} to 16.12 kg ha^{-1} in pooled, respectively. The highest available phosphorus was exhibited in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with maximum recorded values of 16.08 kg ha^{-1}, 16.16 kg ha^{-1} and 16.12 kg ha^{-1} in 2021, 2022 and in pooled respectively. C_1O_7 was observed to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (16.01 kg ha^{-1}) and C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (15.93 kg ha^{-1}) in the initial year, but in the succeeding year and pooled, C_1O_7 was observed to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (16.15 kg ha^{-1} and 16.08 kg ha^{-1}), C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) (15.14 kg ha^{-1} and 15.11 kg ha^{-1}) and C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}) (15.97 kg ha^{-1} and 15.90 kg ha^{-1}). The lowest soil available phosphorus was perceived in C_2O_1 (Control) with the minimum recorded values of 12.51 kg ha^{-1} in 2021 and 12.52 kg ha^{-1} in pooled, which was exhibited to be statistically at par with C_1O_1 (Control) (12.52 kg ha^{-1} and 12.53 kg ha^{-1}). Meanwhile, in 2022, the available phosphorus of the soil was deemed significantly lowest in both C_1O_1 (Control) and C_2O_1 (Control) with a similar minimum available phosphorus of 12.53 kg ha^{-1}, respectively.

Further examination of the pooled available phosphorus exhibited an upsurge in treatments with bench terrace accompanied by organic sources over control by 16.29% to 28.75%. Moreover, C_1O_7 and C_1O_3 exhibited an increase of 28.65% and 28.33% over C_1O_1, 28.75% and 28.43% over C_2O_1 and an increase of 15.89% and 15.60% over C_2O_8. The soil's available phosphorus content is the main factor responsible for the shortage of soil phosphorus and is influenced by soil quality, land use, fertilization management, *etc.* (Chen *et al*., 2018 and Zhang *et al.,* 2019). Available phosphorus for the entire soil depth in terraces was higher than that of corresponding sloping fields due to the integration of physical and biological soil management (soil bund, compost and manure application) practices which add mineral and organic fractions in soil, besides intensity of soil weathering and P fixation as a result of decreased soil erosion (Chen *et al*., 2021 and Sinore *et al*., 2022). Therefore, P activation from the leftover P reserves in the soil, rather than insufficient P reserves, plays an important role in improving the productivity of terraces. These above results were in correlation with the findings of Yadav *et al.* (2020a) and Meena *et al*. (2024).

Table 4.5(a): Effect of conservation practice and organic manures on available nitrogen and phosphorus of soil after harvest

TREATMENT	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	554.96	559.19	557.08	15.08	15.15	15.11
C_2 - Non-terrace	532.60	536.62	534.61	14.40	14.45	14.42
SEm±	1.04	1.05	0.74	0.06	0.05	0.04
CD (P=0.05)	6.31	6.38	2.90	0.34	0.30	0.15
CV	0.99	1.00	0.99	1.95	1.75	1.85
ORGANIC SOURCES						
O_1 - Control	492.02	493.39	492.70	12.52	12.53	12.52
O_2 - FYM @ 5 t ha^{-1}	556.38	561.16	558.77	15.45	15.55	15.50
O_3 - FYM @ 10 t ha^{-1}	565.17	569.59	567.38	15.69	15.77	15.73
O_4 - Poultry manure @ 2.5 t ha^{-1}	536.38	539.57	537.98	14.30	14.34	14.32
O_5 - Poultry manure @ 5 t ha^{-1}	546.65	548.88	547.76	14.79	14.84	14.82
O_6 - Vermicompost @ 2.5 t ha^{-1}	557.53	563.13	560.33	15.58	15.64	15.61
O_7 - Vermicompost @ 5 t ha^{-1}	565.85	570.01	567.93	15.71	15.78	15.74
O_8 - Enriched compost @ 2.5 t ha^{-1}	534.75	539.17	536.96	14.20	14.27	14.24
O_9 - Enriched compost @ 5 t ha^{-1}	539.29	546.28	542.78	14.39	14.46	14.42
SEm±	1.80	1.95	1.33	0.11	0.12	0.08
CD (P=0.05)	5.20	5.63	3.76	0.30	0.35	0.23
CV	0.81	0.87	0.84	1.75	2.00	1.88

Table 4.5(b): Interaction effect of conservation practice and organic manures on available nitrogen and phosphorus of soil after harvest

TREATMENTS	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})		
	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	492.03	493.47	492.75	12.52	12.53	12.53
C_1O_2	571.53	577.50	574.52	15.82	15.97	15.90
C_1O_3	576.33	581.90	579.12	16.01	16.15	16.08
C_1O_4	546.87	548.47	547.67	15.04	15.10	15.07
C_1O_5	555.90	558.60	557.25	15.08	15.14	15.11
C_1O_6	574.70	577.23	575.97	15.93	16.00	15.96
C_1O_7	582.22	587.24	584.73	16.08	16.16	16.12
C_1O_8	544.93	548.74	546.84	14.56	14.57	14.56
C_1O_9	550.10	559.59	554.85	14.64	14.69	14.67
C_2O_1	492.00	493.30	492.65	12.51	12.53	12.52
C_2O_2	541.22	544.82	543.02	15.09	15.12	15.10
C_2O_3	554.00	557.29	555.64	15.36	15.39	15.38
C_2O_4	525.90	530.67	528.28	13.56	13.59	13.58
C_2O_5	537.40	539.15	538.28	14.50	14.54	14.52
C_2O_6	540.37	549.03	544.70	15.24	15.28	15.26
C_2O_7	549.48	552.77	551.13	15.33	15.39	15.36
C_2O_8	524.57	529.61	527.09	13.85	13.98	13.91
C_2O_9	528.47	532.97	530.72	14.14	14.22	14.18
SEm±	2.55	2.76	1.88	0.15	0.17	0.11
CD (P=0.05)	7.35	7.96	5.31	0.43	0.49	0.32

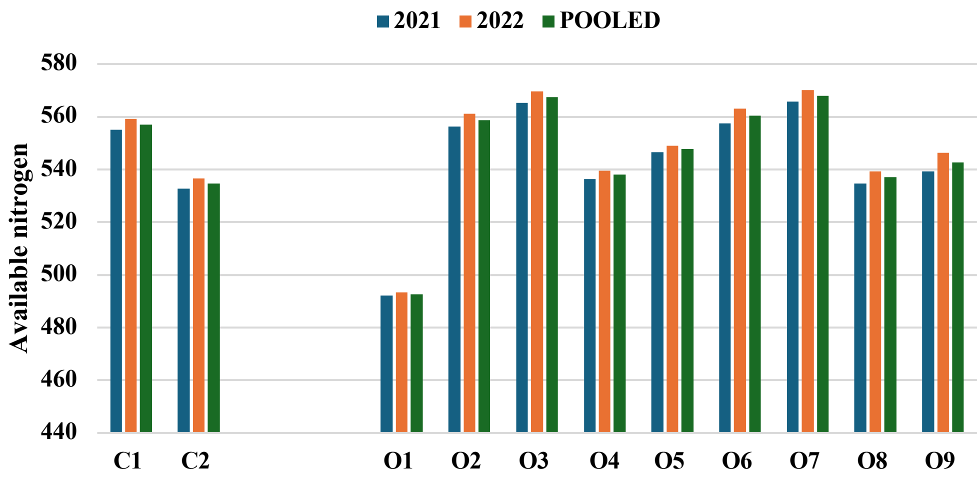

Fig. 4.7(a): Effect of conservation practice and organic manures on available nitrogen of soil after harvest

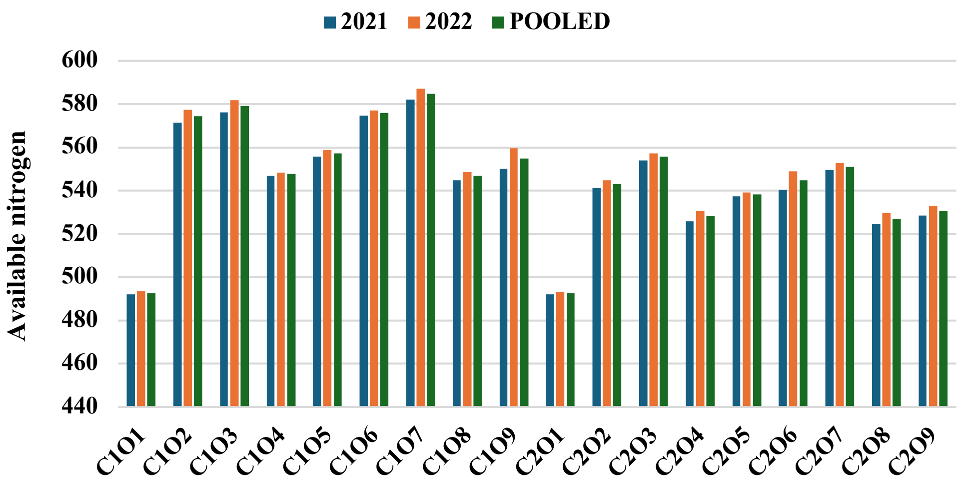

Fig. 4.7(b): Interaction effect of conservation practice and organic manures on available nitrogen of soil after harvest

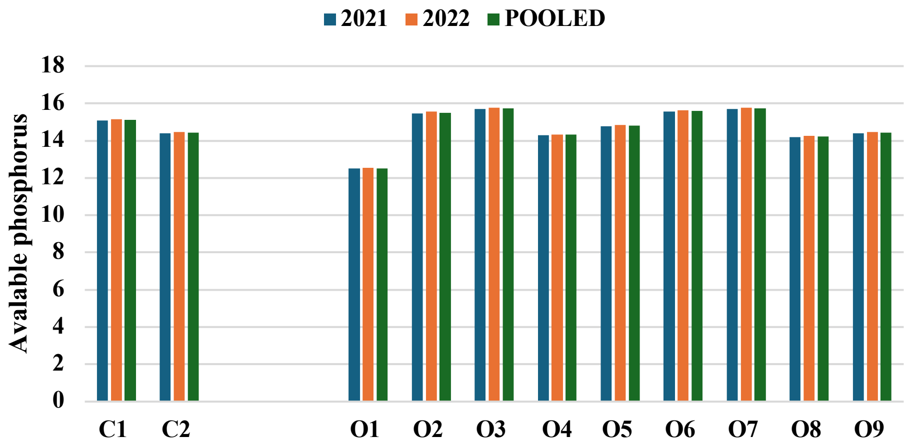

Fig. 4.8(a): Effect of conservation practice and organic manures on available phosphorus of soil after harvest

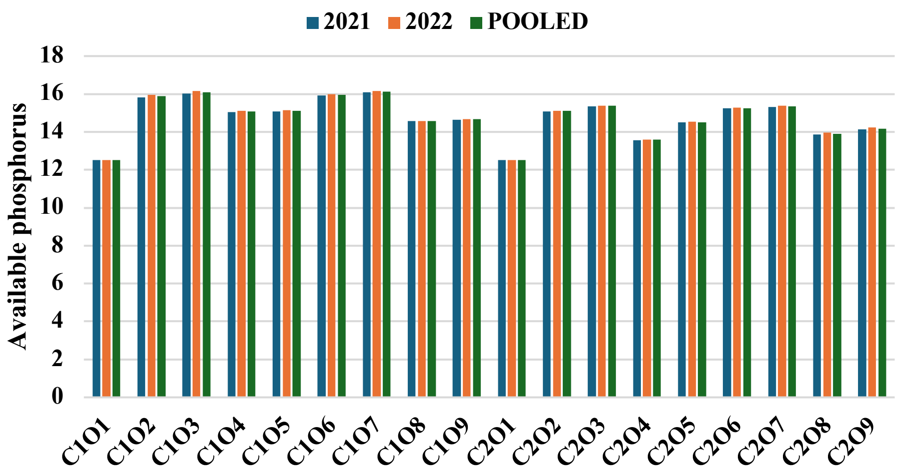

Fig. 4.8(b): Interaction effect of conservation practice and organic manures on available phosphorus of soil after harvest

4.1.11. Available potassium

The two-year experimental data and pooled average on the impact of conservation practice and organic manures on the available potassium of the soil after harvest, including their interactions are presented in Tables 4.6(a) and 4.6(b) and illustrated graphically in Figures 4.9(a) and 4.9(b), respectively.

4.1.11.1. Effect of conservation practice on available potassium

From the data recorded in Table 4.6(a) the available potassium of soil was noted significantly highest in C_1 (Bench terrace) with values logged at 163.46 kg ha^{-1} and 164.04 kg ha^{-1} in 2021 and 2022 respectively, along with the pooled average of 163.75 kg ha^{-1}. The significantly lowest soil available potassium was recorded in C_2 (Non-terrace) with the minimum recorded values of 157.85 kg ha^{-1} in 2021 and 158.22 kg ha^{-1} in 2022 respectively, along with the pooled average of 158.04 kg ha^{-1}. An augmented 3.61% in the pooled available potassium was observed in plots with bench terraces over non-terrace plots.

4.1.11.2. Effect of organic sources on available potassium

The effect of different organic sources on the available potassium in the soil is presented in Table 4.6(a). Significant variations in the available potassium were observed as a result of the application of organic sources during the period of study. The values were observed to vary from 149.49 kg ha^{-1} to 166.82 kg ha^{-1}, 150.29 kg ha^{-1} to 167.57 kg ha^{-1} and 149.89 kg ha^{-1} to 167.17 kg ha^{-1} in 2021, 2022 and in pooled, respectively. Further examination of the pooled available potassium showed an upsurge of 5.47% to 11.53% in plots where organic sources were applied over the control plot. In 2021, the available potassium of the soil was noted highest from source O_3 (FYM @ 10 t ha^{-1}) with a maximum value of 166.82 kg ha^{-1} and was observed to be statistically at par with O_7 (Vermicompost @ 5 t ha^{-1}) (166.76 kg ha^{-1}). Likewise in 2022 and in pooled, O_7

(Vermicompost @ 5 t ha^{-1}) with a maximum value of 167.57 kg ha^{-1} and 167.17 kg ha^{-1} was deemed the highest available potassium, which was further observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) (167.35 kg ha^{-1} and 167.09 kg ha^{-1}). In the case of the least available potassium, O_1 (Control) was deemed significantly lowest with a minimum value recorded at 149.49 kg ha^{-1} and 150.29 kg ha^{-1} respectively, along with the pooled average noted at 149.89 kg ha^{-1}. The results are in corroboration with those of Kiboi *et al.* (2021) *i.e.,* the addition of organic sources provided an added advantage for better microbial growth, which accelerated nutrient mineralization and led to enhanced nutrient availability, and Gadana *et al.* (2020).

4.1.11.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the available potassium is presented in Table 4.6(b). Here, the available potassium of the soil for both the years, 2021 and 2022 was perceived significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a maximum available potassium of 170.32 kg ha^{-1} and 171.21 kg ha^{-1}, respectively. It was found to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with values of 169.27 kg ha^{-1} and 170.21 kg ha^{-1}. Similarly, in the pooled average, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was noted highest with a value of 170.76 kg ha^{-1} and was observed to be significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (169.74 kg ha^{-1}). During 2021, the lowest soil available potassium was noticed in C_1O_1 (Control) with the minimum recorded value of 149.42 kg ha^{-1}, which was statistically at par with C_2O_1 (Control) (149.56 kg ha^{-1}). However, in 2022, the available potassium was deemed lowest in C_2O_1 (Control) (150.22 kg ha^{-1}), which was observed to be statistically at par with C_1O_1 (Control) with a value of 150.36 kg ha^{-1}, respectively. In pooled, both C_1O_1 (Control) and C_2O_1 (Control) were regarded as significantly lowest with similar values recorded at

149.89 kg ha^{-1}. Critical examinations of the pooled average showed an increase in the available potassium by 7.75% to 13.92% in plots with treatments from C_1O_2 to C_1O_9 *i.e.,* bench terrace along with organic manures as compared to the control plot. Moreover, C_1O_7 and C_1O_3 exhibited an increase of 13.92% and 13.24% over C_1O_1 and C_2O_1, also an increase of 10.40% and 9.74% over C_2O_8.

Available potassium is the most important indicator for detecting soil potassium deficiency. The higher availability of potassium under conservation and organic amendment practices might be attributed to reduced fixation or solubilization of fixed forms due to the higher prevalence of organic acids as well as mineralization of added organic manure (Meena *et al.,* 2019 and Meena *et al.*, 2023a). Venkatesh *et al.* (2017) also reported that the mobilization of non-exchangeable K into the soil solution increased its availability in the soil under conservation and organic management practices. These above results were in correlation with the findings of Chen *et al*. (2021), Meena *et al*. (2024) and Yadav *et al.* (2020a).

4.1.12. Available sulphur

The results on the impact of conservation practice and organic manures including their interactions on the available sulphur of the soil after harvest for the two-year documented experimental data are presented in Tables 4.6(a) and 4.6(b) and depicted graphically in Figures 4.10(a) and 4.10(b), respectively.

4.1.12.1. Effect of conservation practice on available sulphur

As was discernible from Table 4.6(a), the available sulphur of the soil was recorded as significantly highest under C_1 (Bench terrace) with recorded values of 17.75 kg ha^{-1} in 2021 and 17.89 kg ha^{-1} in 2022 respectively, along with the pooled average of 17.82 kg ha^{-1}. C_2 (Non-terrace) was noted as significantly lowest with the minimum available sulphur of 16.94 kg ha^{-1} and 17.08 kg ha^{-1}, respectively. along with a pooled value of 17.01 kg ha^{-1}. An augmented 4.76%

in the pooled available sulphur was observed in plots with bench terraces over non-terrace plots.

4.1.12.2. Effect of organic sources on available sulphur

The effect of different organic sources on the available potassium in the soil is presented in Table 4.6(a). Significant variations were observed with values ranging from 14.85 kg ha^{-1} to 18.22 kg ha^{-1}, 15.00 kg ha^{-1} to 18.43 kg ha^{-1} and 14.92 kg ha^{-1} to 18.33 kg ha^{-1} in 2021, 2022 and in pooled, respectively. The highest available sulphur in both years was reported from O_7 (Vermicompost @ 5 t ha^{-1}) with the maximum value of 18.22 kg ha^{-1} and 18.43 kg ha^{-1} respectively, which was observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) with recorded values 17.99 kg ha^{-1} and 18.17 kg ha^{-1}. Meanwhile, in pooled, the available sulphur was deemed significantly highest in O_7 (Vermicompost @ 5 t ha^{-1}) with a maximum value of 18.33 kg ha^{-1}, which was perceived as being statistically superior over the rest. Again from the table, it was apparent that during 2021 and 2022, O_1 (Control) was deemed significantly lowest with values recorded at 14.85 kg ha^{-1} and 15.00 kg ha^{-1}, respectively along with the pooled value of 14.92 kg ha^{-1}. An upsurge of 15.15% to 22.86% over the control plot was observed in plots with organic sources.

4.1.12.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the available potassium is presented in Table 4.6(b). A perusal of the data showed significant variations in the available sulphur of the soil. In 2021 and 2022, available sulphur was observed to be significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with maximum recorded values of 18.78 kg ha^{-1} and 19.10 kg ha^{-1}, respectively. Similarly, the pooled average was noted significantly higher in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a value of 18.94 kg ha^{-1}. It was observed that C_1O_7 was significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (18.50 kg ha^{-1}) only in the initial year. The lowest soil available sulphur was noticed in C_2O_1 (Control) with values recorded at 14.80 kg ha^{-1}, 14.99 kg ha^{-1} and 14.90 kg ha^{-1} in 2021, 2022 and in pooled, respectively, and it was statistically at par with C_1O_1 (Control) (14.90 kg ha^{-1}, 15.00 kg ha^{-1} and 14.95 kg ha^{-1}).

Further examination of the pooled available sulphur exhibited an upsurge in treatments with conservation practice in the form of bench terrace accompanied by organic sources over control by 16.86% to 26.69%. Moreover, C_1O_7 and C_1O_3 exhibited an increase of 16.86% and 24.21% over C_1O_1, 27.11% and 24.63% over C_2O_1 and an increase of 12.14% and 9.95% over C_2O_8. This increase could be due to the addition of an optimal dose of organic sources resulting in maximum build-up of available S because of the release of organic acids during the decomposition of organic matter ultimately causing resolution of applied as well as native S into available S compounds thereby increasing the activity and concentration of available S in soil (Tiwari *et al*., 2023). Meena *et al.* (2023a) found conservation practice coupled with organic nutrient management to be a sustainable practice to maintain the availability of micronutrients in the soils because the leaching of micronutrients into deeper soil layers was prevented by the formation of organo-mineral complexes or chelation due to organic inputs and increased soil organic matter. The above results were in correlation with the findings of Aher *et al*. (2015), Age *et al*. (2019), Chen *et al*. (2021), and Meena *et al*. (2024).

Table 4.6(a): Effect of conservation practice and organic manures on available potassium and sulphur of soil after harvest

TREATMENT	Available potassium (kg ha^{-1})			Available sulphur (kg ha^{-1})		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	163.46	164.04	163.75	17.75	17.89	17.82
C_2 - Non-terrace	157.85	158.22	158.04	16.94	17.08	17.01
SEm±	0.27	0.30	0.20	0.05	0.09	0.05
CD (P=0.05)	1.64	1.86	0.80	0.28	0.56	0.20
CV	0.87	0.98	0.93	1.40	2.75	2.19
ORGANIC SOURCES						
O_1 - Control	149.49	150.29	149.89	14.85	15.00	14.92
O_2 - FYM @ 5 t ha^{-1}	162.78	163.17	162.98	17.75	17.95	17.85
O_3 - FYM @ 10 t ha^{-1}	166.82	167.35	167.09	17.99	18.17	18.08
O_4 - Poultry manure @ 2.5 t ha^{-1}	158.64	158.88	158.76	17.22	17.28	17.25
O_5 - Poultry manure @ 5 t ha^{-1}	161.14	161.40	161.27	17.63	17.70	17.66
O_6 - Vermicompost @ 2.5 t ha^{-1}	162.60	162.92	162.76	17.67	17.89	17.78
O_7 - Vermicompost @ 5 t ha^{-1}	166.76	167.57	167.17	18.22	18.43	18.33
O_8 - Enriched compost @ 2.5 t ha^{-1}	157.71	158.46	158.09	17.15	17.20	17.18
O_9 - Enriched compost @ 5 t ha^{-1}	159.94	160.13	160.04	17.65	17.75	17.70
SEm±	0.56	0.64	0.43	0.11	0.10	0.07
CD (P=0.05)	1.60	1.86	1.20	0.31	0.30	0.21
CV	0.85	0.98	0.92	1.50	1.46	1.48

Table 4.6(b): Interaction effect of conservation practice and organic manures on available potassium and sulphur of soil after harvest

TREATMENTS	Available potassium (kg ha^{-1})			Available sulphur (kg ha^{-1})		
	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	149.42	150.36	149.89	14.90	15.00	14.95
C_1O_2	165.64	166.05	165.84	18.24	18.39	18.32
C_1O_3	169.27	170.21	169.74	18.50	18.65	18.57
C_1O_4	161.30	161.75	161.52	17.57	17.59	17.58
C_1O_5	164.53	165.00	164.77	18.03	18.07	18.05
C_1O_6	165.55	165.57	165.56	18.25	18.59	18.42
C_1O_7	170.32	171.21	170.76	18.78	19.10	18.94
C_1O_8	161.08	161.92	161.50	17.46	17.47	17.47
C_1O_9	163.99	164.31	164.15	18.01	18.11	18.06
C_2O_1	149.56	150.22	149.89	14.80	14.99	14.90
C_2O_2	159.93	160.29	160.11	17.26	17.51	17.39
C_2O_3	164.37	164.49	164.43	17.47	17.69	17.58
C_2O_4	155.98	156.01	156.00	16.86	16.97	16.92
C_2O_5	157.75	157.79	157.77	17.23	17.32	17.28
C_2O_6	159.66	160.26	159.96	17.08	17.19	17.13
C_2O_7	163.21	163.93	163.57	17.66	17.76	17.71
C_2O_8	154.34	155.01	154.67	16.84	16.93	16.89
C_2O_9	155.89	155.96	155.93	17.28	17.39	17.34
SEm±	0.79	0.91	0.60	0.15	0.15	0.11
CD (P=0.05)	2.27	2.62	1.70	0.43	0.42	0.30

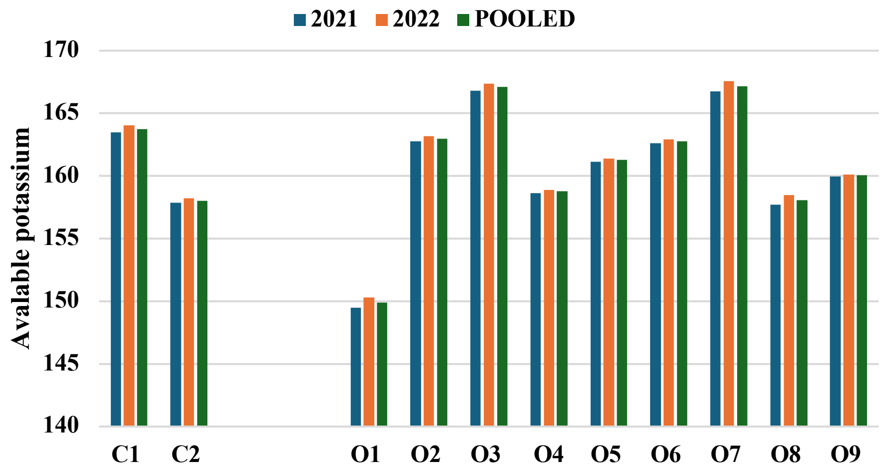

Fig. 4.9(a): Effect of conservation practice and organic manures on available potassium of soil after harvest

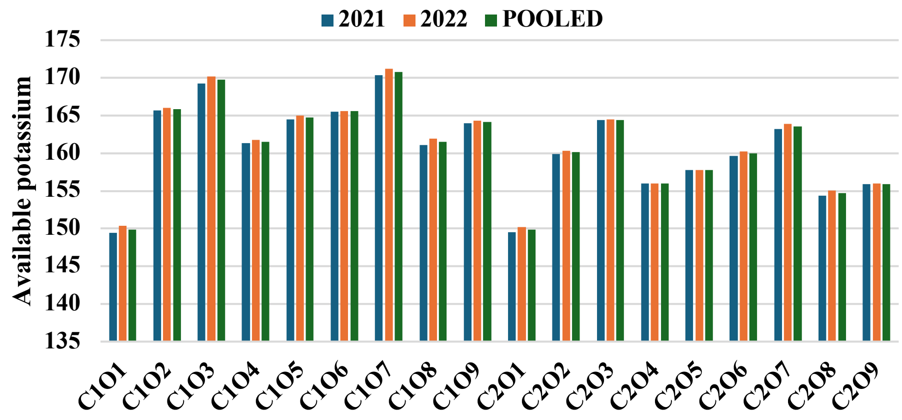

Fig. 4.9(b): Interaction effect of conservation practice and organic manures on available potassium of soil after harvest

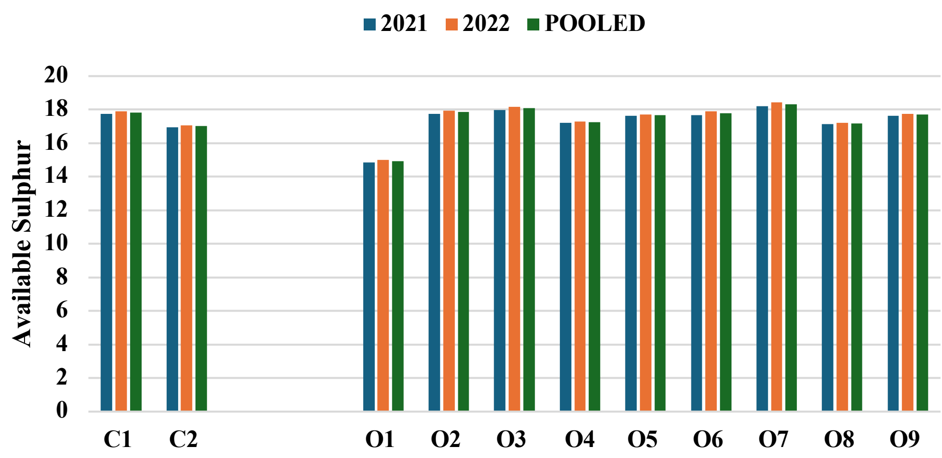

Fig. 4.10(a): Effect of conservation practice and organic manures on available sulphur of soil after harvest

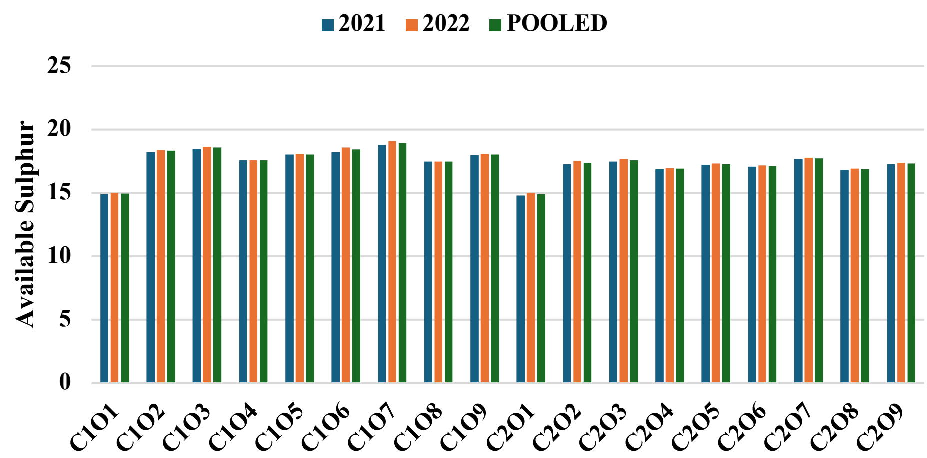

Fig. 4.10(b): Interaction effect of conservation practice and organic manures on available sulphur of soil after harvest

4.1.13. Soil microbial biomass carbon (SMBC)

The two-year experimental data along with the pooled average on the impact of conservation practices and organic manures for the soil microbial biomass carbon after harvest, including their interaction, are presented in Tables 4.7(a) and 4.7(b) and illustrated graphically in Figures 4.11(a) and 4.11(b).

4.1.13.1. Effect of conservation practice on SMBC

As was evident from table 4.7(a), the soil microbial biomass carbon was recorded as significantly highest under C_1 (Bench terrace) with maximum SMBC values of 224.55 µg g^{-1} soil and 225.13 µg g^{-1} soil during the years 2021 and 2022, respectively. Likewise, the pooled average was recorded as significantly highest under C_1 (Bench terrace) (224.84 µg g^{-1} soil). C_2 (Non-terrace) was observed significantly lowest in both years, with values recorded at 219.57 µg g^{-1} soil and 220.06 µg g^{-1} soil, respectively. Similarly, the pooled average was deemed significantly lowest under C_2 (Non-terrace) with a recorded value of 219.81 µg g^{-1} soil. An augmented 2.29% in the pooled SMBC data was observed in plots with conservation practice in the form of bench terraces over non-conservation practice plots.

4.1.13.2. Effect of organic sources on SMBC

The effect of different organic sources on the soil microbial biomass carbon in the soil is presented in Table 4.7(a), whereby significant variations were observed. The values were observed to vary from 208.04 µg g^{-1} soil to 229.52 µg g^{-1} soil, 208.20 µg g^{-1} soil to 230.58 µg g^{-1} soil and 208.12 µg g^{-1} soil to 230.05 µg g^{-1} soil in 2021, 2022 and pooled, respectively. Further examinations of the pooled SMBC showed an upsurge of 5.15% to 10.54% in plots where organic sources were applied over the control plot. During the whole experimentation, the soil microbial biomass carbon was noted highest from source O_7 (Vermicompost @ 5 t ha^{-1}) with the maximum value of 229.52 µg g^{-1} soil, 230.58 µg g^{-1} soil and 230.05 µg g^{-1} soil, respectively and was observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) with values of 228.78 µg g^{-1} soil, 229.48 µg g^{-1} soil and 229.13 µg g^{-1} soil. In the case of the least soil microbial biomass carbon, O_1 (Control) was deemed significantly lowest with a minimum value recorded at 208.04 µg g^{-1} soil and 208.20 µg g^{-1} soil respectively, along with the pooled average of 208.12 µg g^{-1} soil. This increase in soil microbial biomass carbon content with the incorporation of organic manure was also reported by Luo *et al.* (2015), Prakash (2016) and Chen *et al.* (2017).

4.1.13.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the soil microbial biomass carbon is presented in Table 4.7(b), whereby significant variations were observed. The highest soil microbial biomass carbon for the years 2021 and 2022 was perceived in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a maximum recorded values of 233.80 µg g^{-1} soil and 234.56 µg g^{-1} soil. Moreover, it was observed to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with values of 232.88 µg g^{-1} soil and 233.48 µg g^{-1} soil, respectively. The pooled average was noted significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a maximum value of 234.18. µg g^{-1} soil and was exhibited to be significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (233.18. µg g^{-1} soil). The lowest soil microbial biomass carbon for both the years 2021 and 2022 was noted in C_2O_1 (Control) with values recorded at 208.00 µg g^{-1} soil, and 208.16 µg g^{-1} soil, respectively, along with the pooled value of 208.08 µg g^{-1} soil. Moreover, it was observed that in both the years and pooled C_2O_1 was statistically at par with C_1O_1 (Control) with values logged at 208.09 µg g^{-1}soil, 208.24 µg g^{-1}soil and 208.16 µg g^{-1} soil, respectively.

Critical examinations of the pooled average showed an increase in the soil microbial biomass by 5.96% to 12.54% in plots with treatments from C_1O_2 to C_1O_9 *i.e.,* conservation practice along with organic sources as compared to the control plot. Moreover, C_1O_7 and C_1O_3 exhibited an increase of 12.54% and 12.06% over C_1O_1, 12.50% and 12.02% over C_2O_1, and 7.84% and 7.38% over C_2O_8. Therefore, a significant increase in the soil microbial biomass carbon was observed with the application of organic manures in conjunction with conservation practice as compared to control. The application of manure affects the structure and composition of the microbial community, such as bacterial and fungal abundances ascribed due to the direct addition of organic matter through FYM and an increase in root biomass which helped in the growth and development of soil microorganisms causing beneficial effects on MBC and MBN (Chen *et al.,* 2021). The supply of readily hydrolysable C and an additional supply of N due to organic manure application resulted in higher microbial activity and their biomass C and N (Tripura *et al*., 2018) which resulted in better crop yield with higher root biomass and exudates (Ge *et al*., 2017). The above findings agree with the studies of Nagwanshi *et al*. (2018), Yadav *et al*. (2020a) and Meena *et al.* (2023a).

Table 4.7(a): Effect of conservation practice and organic manures on soil microbial biomass carbon of soil after harvest

TREATMENT	Soil microbial biomass carbon ($\mu g\ g^{-1}$ soil)		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	224.55	225.13	224.84
C_2 - Non-terrace	219.57	220.06	219.81
SEm±	0.55	0.46	0.36
CD (P=0.05)	3.33	2.81	1.41
CV	1.28	1.08	1.18
ORGANIC SOURCES			
O_1 - Control	208.04	208.20	208.12
O_2 - FYM @ 5 t ha^{-1}	221.39	221.91	221.65
O_3 - FYM @ 10 t ha^{-1}	228.78	229.48	229.13
O_4 - Poultry manure @ 2.5 t ha^{-1}	219.04	219.25	219.14
O_5 - Poultry manure @ 5 t ha^{-1}	226.35	226.65	226.50
O_6 - Vermicompost @ 2.5 t ha^{-1}	221.71	222.22	221.96
O_7 - Vermicompost @ 5 t ha^{-1}	229.52	230.58	230.05
O_8 - Enriched compost @ 2.5 t ha^{-1}	218.53	219.12	218.83
O_9 - Enriched compost @ 5 t ha^{-1}	225.20	225.91	225.55
SEm±	0.49	0.83	0.48
CD (P=0.05)	1.42	2.39	1.36
CV	0.54	0.91	0.75

Table 4.7(b): Interaction effect of conservation practice and organic manures on soil microbial biomass carbon of soil after harvest

TREATMENTS	Soil microbial biomass carbon ($\mu g\ g^{-1}$ soil)		
	2021	**2022**	**POOLED**
C_1O_1	208.09	208.24	208.16
C_1O_2	223.94	224.23	224.08
C_1O_3	232.88	233.48	233.18
C_1O_4	220.82	220.94	220.88
C_1O_5	229.76	230.11	229.94
C_1O_6	223.65	224.32	223.98
C_1O_7	233.80	234.56	234.18
C_1O_8	220.01	220.98	220.49
C_1O_9	228.01	229.28	228.65
C_2O_1	208.00	208.16	208.08
C_2O_2	218.84	219.58	219.21
C_2O_3	224.68	225.49	225.08
C_2O_4	217.26	217.55	217.40
C_2O_5	222.94	223.19	223.06
C_2O_6	219.76	220.12	219.94
C_2O_7	225.23	226.60	225.92
C_2O_8	217.06	217.26	217.16
C_2O_9	222.38	222.54	222.46
SEm±	0.70	1.17	0.68
CD (P=0.05)	2.01	3.38	1.93

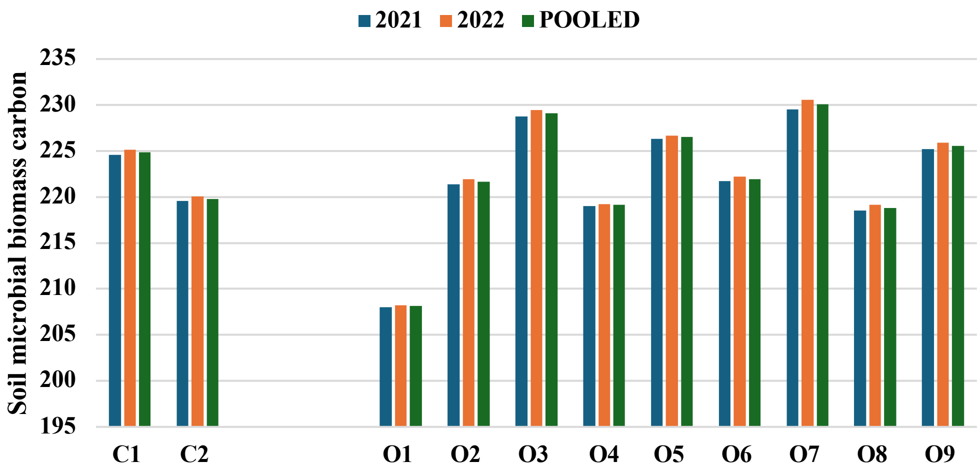

Fig. 4.11(a): Effect of conservation practice and organic manures on soil microbial biomass carbon of soil after harvest

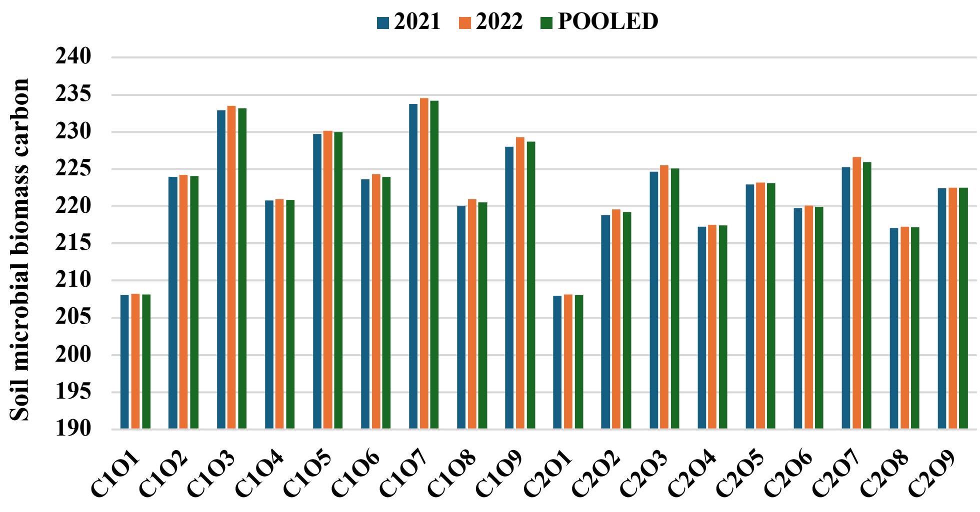

Fig. 4.11(b): Effect of conservation practice and organic manures on soil microbial biomass carbon of soil after harvest

4.2. Effect of conservation practice and organic manures on growth attributes

The biometric observations of soybean were recorded on various growth parameters, *viz*., plant height (cm), nodule weight plant^{-1} (g), number of nodules plant^{-1}, and diameter of nodules (mm) after sowing during the cropping season and harvest.

4.2.1. Plant height

A perusal of the two-year experimental data along with the pooled data pertaining to the impact of conservation practice and organic manures, including their interaction in view of the plant height are presented in Tables 4.8(a) and 4.8(b) and illustrated graphically in Figures 12(a), 12(b), 12(c) and Figure 13(a), 13(b) and 13(c), respectively. The result revealed a consistent increase in plant height from 35 DAS (days after sowing) until harvest across all treatments. The plant height increased rapidly until 70 DAS due to the active vegetative growth phase of the plant and then it started to slow down when it reached the reproductive phase. Plant height is one of the most essential growth parameters of any crop, as it determines or modifies yield-contributing characteristics and finally shapes the seed yield.

4.2.1.1. Effect of conservation practice on plant height

The data as depicted in Table 4.8(a) revealed that conservation practice significantly influenced the plant height in both seasons at all growth stages, *i.e*., 35 DAS, 70 DAS and at harvest. An appreciable increase with the advancement of days in the height of the plant and significant variations were observed within the treatments. In the case of conservation practices, the highest plant height was observed in C_1 (Bench terrace) at all growth stages. At 35 DAS, the tallest height recorded for this practice was 42.71 cm in 2021, 50.72 cm in 2022, which increased to 78.17 cm in 2021, 84.47 cm in 2022 at 70 DAS and reached its maximum height of 86.26 cm in 2021, 90.58 cm in 2022 at harvest. Additionally, the mean height was 46.71 cm at 35 DAS, which increased to 81.32 cm at 70 DAS and finally reached its peak mean height of 88.42 cm at harvest, thereby proving to be significantly highest. The lowest plant height was observed in C_2 (Non-terrace) at all the crop growth stages, with mean values recorded at 40.36 cm, 44.37 cm, and 42.36 cm at 35 DAS; 74.85 cm, 79.45 cm and 77.15 cm at 70 DAS and 82.58 cm, 83.63 cm and 83.11 cm at harvest, respectively during 2021, 2022 and in pooled.

This increase in plant height with terraces indicates their significant effects on soil erosion control, thereby improving the soil physiochemical conditions, *i.e*., it enhances soil quality and provides a stable and fertile environment which are key beneficial for the growth of soybean crop. Similar results were reported by Mesfin *et al*. (2019), Das *et al.* (2020) and Chen *et al*. (2021).

4.2.1.2. Effect of organic sources on plant height

The effect of different organic sources on the plant height is presented in Table 4.8(a). As per the examination, the plant height was observed to increase with the progression of days and with it, significant variations were observed within the sources. Among the organic sources, O_7 (Vermicompost @ 5 t ha^{-1}) was perceived as the maximum plant height in all the growth stages with the mean height recorded at 45.80 cm in 2021, 53.83 cm in 2022 and 49.82 cm in pooled for 35 DAS, which increased to 81.51 cm in 2021, 87.84 cm in 2022 and 84.67 cm in pooled at 70 DAS and thereby attaining maximum height of 89.75 cm in 2021, 92.52 cm in 2022 and 91.13 cm in pooled at harvest, which was observed to be significantly higher over the rest of the organic sources. This was followed by O_3 (FYM @ 10 t ha^{-1}), which showed a mean height of 44.91 cm, 51.20 cm and 48.05 cm (2021, 2022 and pooled) at 35 DAS, which increased to 79.78 cm, 85.87 cm and 82.83 cm (2021, 2022 and pooled) at 70 DAS and finally

88.59 cm, 90.83 cm and 89.71 cm (2021, 2022 and pooled) at harvest. Finally, the plant height was observed to be minimum in O_1 (Control) with a mean height of 35.03 cm in 2021, 38.30 cm in 2022 and 36.67 cm in pooled at 35 DAS; 68.90 cm in 2021, 69.41 cm in 2022 and 69.16 cm in pooled at 70 DAS and lastly 74.64 cm in 2021, 76.35 cm in 2022 and 75.49 cm in pooled at harvest, respectively.

Thus, from these results we can outline that amongst the organic sources, O_7 (Vermicompost @ 5 t ha^{-1}) was observed with the highest plant height at all the growth stages, which was significantly greater than the rest, indicating that with the incorporation of Vermicompost @ 5 t ha^{-1} vigorous growth were exhibited throughout the growth stages. Followed by O_3 (FYM @ 10 t ha^{-1}), though slightly lower than O_7 (Vermicompost @ 5 t ha^{-1}) it still showed substantial growth and was significantly taller than the other sources. On the other hand, O_1 (Control) exhibited the lowest plant height at all the growth stages, which indicates comparatively slower growth or a generally shorter stature compared to the other cultivars. This increase can be attributed to the increased availability of nutrients especially N and P leading to stem elongation due to cell development, rapid cell division and cell elongation in the meristematic region of plants, thereby higher plant height. Similar results were noticed by Shalu and Rattan (2023) and Sharma *et al.* (2023).

4.2.1.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the plant height is presented in Table 4.8(b). The data revealed a significant effect on plant height due to the interaction effect at all growth stages in both seasons. Through proper observation, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was perceived with the maximum plant height in all the growth stages, proving to be significantly better than the rest, followed by C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}). At 35 DAS, the height was recorded to attain its peak at 47.37 cm in 2021, 59.40 cm in 2022 and 53.38 cm in pooled, which increased to 83.18 cm in 2021, 91.10 cm in 2022 and 87.14 cm in pooled at 70 DAS and lastly 91.76 cm in 2021, 96.15 cm in 2022 and 93.96 cm in pooled at harvest. This was followed by C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}), which showed a mean height of 46.97 cm in 2021, 55.07 cm in 2022 and 51.02 cm in pooled at 35 DAS, which increased to 80.98 cm in 2021, 87.93 cm in 2022 and 84.46 cm in pooled at 70 DAS and finally 90.59 cm in 2021, 94.87 cm in 2022 and 92.73 cm in pooled at harvest, respectively. The lowest recorded plant height was observed at C_2O_1 (Control) which was also significantly at par with C_1O_1 (Control) in all growth stages during both seasons, respectively. Further evaluation of the pooled data indicates an increase in the plant height by 45.85% in 35 DAS, 26.29% at 70 DAS, 24.78% at harvest over O_1 and 28.07% in 35 DAS, 17.01% at 70 DAS and 6.60% at harvest over O_8 with the application of O_7 and 34.17% over O_1 and 9.29% over O_8 with O_3.

Incorporating organic manures into the soil brings about change in the growth attributes of plants as they increase the supply of nutrients and reduce loss of nutrients. When coupled with conservation practice, it had a positive impact on soybean plant height because of less soil disturbance, good organic matter and moisture availability. The plant height was observed to increase with higher application of vermicompost as compared to other treatments which may be due to the recovered crop nutrition through applied vermicompost, resulting in improved vegetative growth of legume crops specifically soybean. Meena *et al.* (2023b) also noticed that vermicompost enhanced the soil aeration, drainage, and biological activity, and created a favorable soil environment for deeper proliferation of roots and higher nutrient extraction which thereby contribute to vigorous plant growth. Similarly, Asefa and Wagari (2021) reported that combined treatment of vermicompost @ 2.5 t ha^{-1} with NPS fertilizers @ 75 kg ha^{-1} led to an increase in the plant height of soybean. When organic sources are coupled with conservation practices, a positive impact on soybean plant height is observed because of less soil disturbance, good organic matter, and moisture availability. Adamicˇ and Leskovšek (2021) discovered that soybean plants grown under the conservation system reached a maximum height of 117.9 cm, which was significantly taller compared to plants as the nutritional needs were provided well especially in the critical stages of growth from the slow and continuous supply of nutrients originating from the organic manures mineralization. The above results conform with the findings of Das *et al.* (2020), Meena *et al.* (2022a), Mohan *et al*. (2023) and Keerthana *et al.* (2024).

Table 4.8(a): Effect of conservation practice and organic manures on plant height of soybean

TREATMENT	Plant height (cm)								
	35 DAS			70 DAS			At harvest		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	42.71	50.72	46.71	78.17	84.47	81.32	86.26	90.58	88.42
C_2 - Non-terrace	40.36	44.37	42.36	74.85	79.45	77.15	82.58	83.63	83.11
SEm±	0.14	0.22	0.13	0.08	0.08	0.06	0.05	0.02	0.03
CD (P=0.05)	0.82	1.37	0.51	0.46	0.49	0.22	0.33	0.09	0.11
CV	1.70	2.45	2.16	0.51	0.51	0.51	0.34	0.09	0.24
ORGANIC SOURCES									
O_1 - Control	35.03	38.30	36.67	68.90	69.41	69.16	74.64	76.35	75.49
O_2 - FYM @ 5 t ha^{-1}	41.03	47.58	44.30	75.68	81.86	78.77	83.89	86.49	85.19
O_3 - FYM @ 10 t ha^{-1}	44.91	51.20	48.05	79.78	85.87	82.83	88.59	90.83	89.71
O_4 - Poultry manure @ 2.5 t ha^{-1}	40.17	46.18	43.18	74.91	81.19	78.05	82.60	85.76	84.18
O_5 - Poultry manure @ 5 t ha^{-1}	42.63	47.97	45.30	79.52	85.47	82.49	87.64	90.87	89.25
O_6 - Vermicompost @ 2.5 t ha^{-1}	40.55	47.12	43.83	75.43	81.80	78.61	84.20	86.90	85.55
O_7 - Vermicompost @ 5 t ha^{-1}	45.80	53.83	49.82	81.51	87.84	84.67	89.75	92.52	91.13
O_8 - Enriched compost @ 2.5 t ha^{-1}	40.35	46.60	43.48	74.35	79.63	76.99	82.07	85.06	83.56
O_9 - Enriched compost @ 5 t ha^{-1}	43.31	49.12	46.21	78.52	84.56	81.54	86.42	89.17	87.80
SEm±	0.38	0.25	0.23	0.25	0.18	0.15	0.11	0.08	0.07
CD (P=0.05)	1.08	0.71	0.64	0.72	0.52	0.44	0.32	0.23	0.19
CV	2.22	1.28	1.75	0.80	0.54	0.68	0.32	0.22	0.27

Table 4.8(b): Interaction effect of conservation practice and organic manures on plant height of soybean

TREATMENTS	Plant height (cm)								
	35 DAS			70 DAS			At harvest		
	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	35.07	38.40	36.73	69.15	69.48	69.32	74.69	76.68	75.69
C_1O_2	42.17	50.90	46.53	78.53	85.72	82.12	86.34	90.74	88.54
C_1O_3	46.97	55.07	51.02	80.98	87.93	84.46	90.59	94.87	92.73
C_1O_4	41.23	49.27	45.25	77.06	84.41	80.73	85.38	89.76	87.57
C_1O_5	44.03	51.13	47.58	80.67	87.68	84.18	88.71	94.86	91.79
C_1O_6	41.97	50.37	46.17	77.62	84.80	81.21	86.67	91.00	88.84
C_1O_7	47.37	59.40	53.38	83.18	91.10	87.14	91.76	96.15	93.96
C_1O_8	41.08	49.47	45.28	76.68	82.35	79.51	84.65	89.06	86.86
C_1O_9	44.48	52.47	48.48	79.66	86.73	83.19	87.53	92.08	89.81
C_2O_1	35.00	38.20	36.60	68.66	69.34	69.00	74.58	76.01	75.30
C_2O_2	39.90	44.25	42.08	72.84	78.01	75.42	81.45	82.24	81.85
C_2O_3	42.85	47.33	45.09	78.57	83.82	81.20	86.59	86.79	86.69
C_2O_4	39.11	43.10	41.11	72.77	77.96	75.36	79.81	81.77	80.79
C_2O_5	41.23	44.80	43.02	78.36	83.25	80.81	86.56	86.88	86.72
C_2O_6	39.13	43.87	41.50	73.24	78.80	76.02	81.74	82.79	82.27
C_2O_7	44.23	48.27	46.25	79.83	84.58	82.21	87.73	88.89	88.31
C_2O_8	39.62	43.73	41.68	72.02	76.92	74.47	79.48	81.07	80.27
C_2O_9	42.13	45.77	43.95	77.38	82.39	79.88	85.31	86.26	85.79
SEm±	0.53	0.35	0.32	0.35	0.26	0.22	0.15	0.11	0.10
CD (P=0.05)	1.53	1.01	0.90	1.02	0.74	0.62	0.45	0.32	0.27

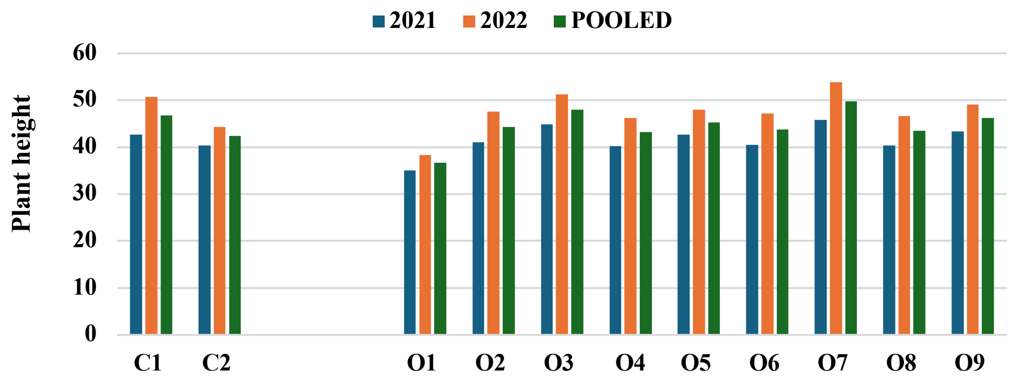

Fig. 4.12(a): Effect of conservation practice and organic manures on plant height of soybean at 35 DAS

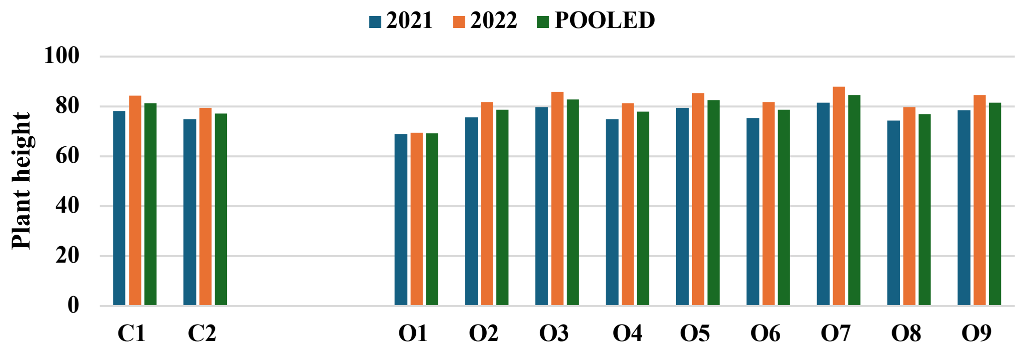

Fig. 4.12(b): Effect of conservation practice and organic manures on plant height of soybean at 70 DAS

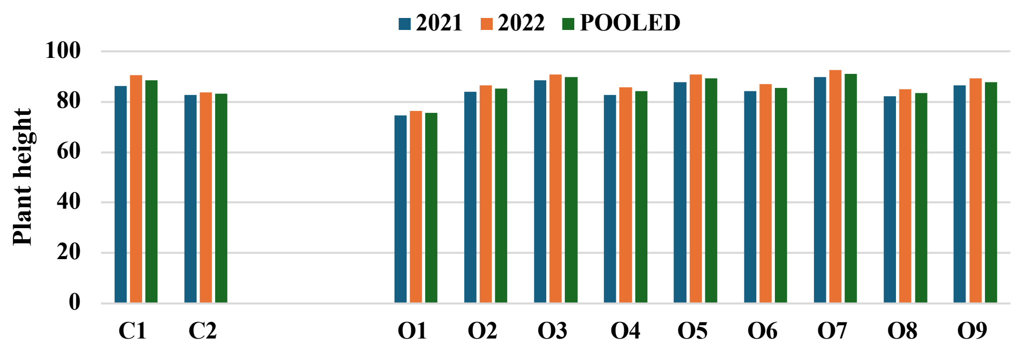

Fig. 4.12(c): Effect of conservation practice and organic manures on plant height of soybean at harvest

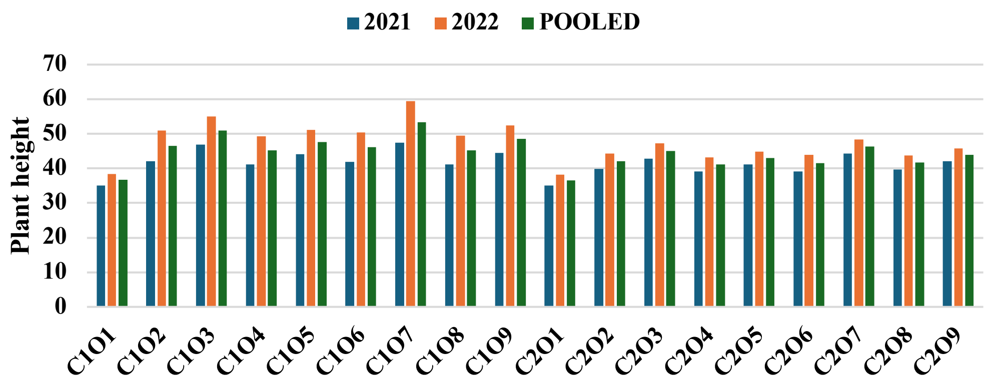

Fig. 4.13(a): Interaction effect of conservation practice and organic manures on plant height of soybean at 35 DAS

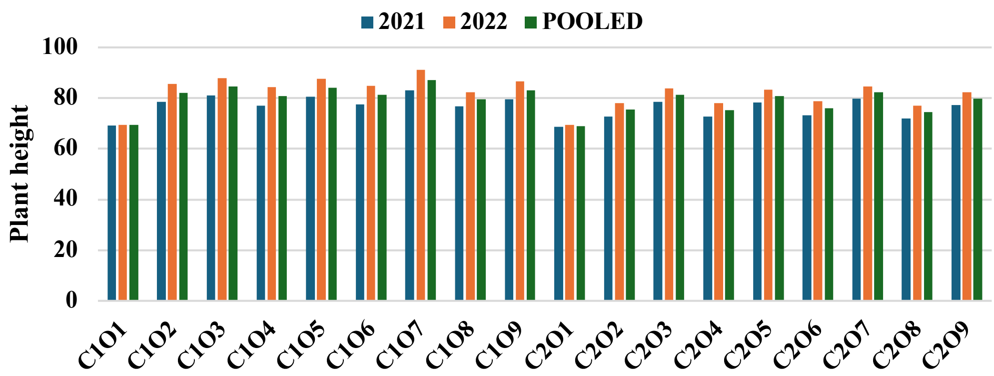

Fig. 4.13(b): Interaction effect of conservation practice and organic manures on plant height of soybean at 70 DAS

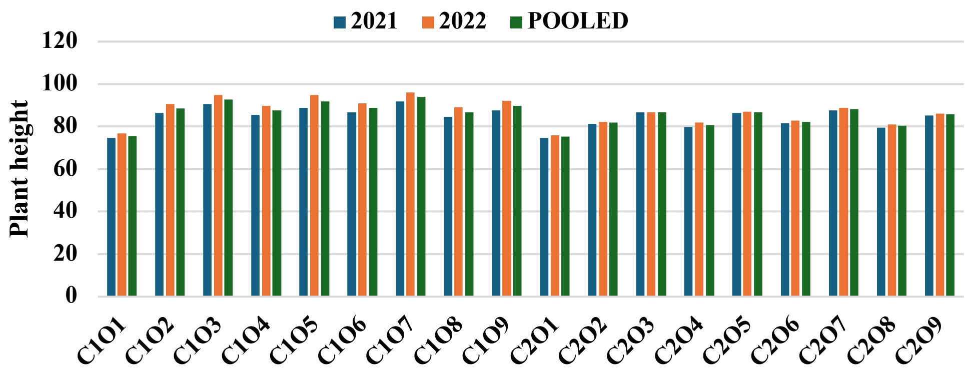

Fig. 4.13(c): Interaction effect of conservation practice and organic manures on plant height of soybean at harvest

4.2.2. Nodule weight plant^{-1}

The two-year experimental data and the pooled average, on the impact of conservation practice and organic manures and their interaction, concerning the nodule weight plant^{-1} have been presented in Tables 4.9(a) and 4.9(b), respectively.

4.2.2.1. Effect of conservation practice on nodule weight plant^{-1}

An inquisition on the two years' data and average data as per Table 4.9(a) on the nodule weight plant^{-1} recorded C_1 (Bench terrace) (0.21 g, 0.22 g and 0.22 g) to be higher over C_2 (Non-terrace) (0.19 g, 0.20 g and 0.20 g). Although higher nodule weight plant^{-1} was found in conservation practice, no significant variation was observed.

4.2.2.2. Effect of organic sources on nodule weight plant^{-1}

The effect of different organic sources on the nodule weight plant^{-1} is presented in Table 4.9(a). The highest nodule weight plant^{-1} in the initial year was observed in O_3 (FYM @ 10 t ha^{-1}) and O_7 (Vermicompost @ 5 t ha^{-1}) with the values noted at 0.23 g each, while in the final year and in pooled, it was observed in O_7 (Vermicompost @ 5 t ha^{-1}) with the values noted at 0.24 g each. The lowest nodule weight plant^{-1} was observed in O_1 (Control) with the values noted at 0.15 g in all. However no significant variation among the organic sources was seen among the treatments *i.e.*, the nodule weight plant^{-1} was not affected by the organic sources.

4.2.2.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the nodule weight plant^{-1} is presented in Table 4.9(b). In both the seasons and in pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was observed with the highest nodule weight plant^{-1}, with values noted at 0.25 g, 0.26 g and 0.25 g, respectively and the lowest was noted in both C_1O_1 (Control) and C_2O_1 (Control) with values noted at 0.15 g in all. Similarly in the interaction effect, no significant variations were observed based on the perusal data, on the number of seeds pods^{-1}.

It was observed that when conservation practices were coupled with organic sources in particular vermicompost and FYM at a higher dose, better nodulation was observed which can be attributed to the higher supply of nutrients particularly NPK and their subsequent increase in uptake (Mohan *et al*., 2023 and Verma *et al.,* 2023). This might be a result of more availability of nutrients due to combined application, which exerted beneficial effects *viz.,* better soil health and enhanced microbial activity in the soil. Although the nodule weight plant^{-1} was higher in plots with conservation practices and organic sources, no significant variations were observed among the rest of the treatments, therefore, no further comparison was done.

4.2.3. Number of nodules plant^{-1}

The two-year experimental results pertaining to the effect of conservation practice and organic manures and their interaction, along with the pooled data concerning the number of nodules plant^{-1} are presented in Table 4.9(a) and 4.9(b), respectively.

4.2.3.1. Effect of conservation practice on the number of nodules plant^{-1}

An inquisition on the two years' data and average data as per Table 4.9(a) on the number of nodules plant^{-1} recorded C_1 (Bench terrace) (46.42, 47.67 and 47.05) to be higher when compared to C_2 (Non-terrace) (42.69, 43.49 and 43.09). Although higher nodule weight plant^{-1} was found in conservation practice, no significant variation was observed.

4.2.3.2. Effect of organic sources on the number of nodules plant^{-1}

The effect of different organic sources on the number of nodules plant^{-1} is presented in Table 4.9(a). Here, the highest number of nodules plant^{-1} in both seasons and in pooled was observed in O_7 (Vermicompost @ 5 t ha^{-1}) with the values noted at 49.87, 51.09 and 50.48, respectively. It was observed that O_7 was significantly at par with O_3 (FYM @ 10 t ha^{-1}) (48.88, 49.23 and 49.06), O_9 (Enriched compost @ 5 t ha^{-1}) (46.65 and 47.38) and O_5 (Poultry manure @ 5 t ha^{-1}) (46.61 and 47.33). The lowest number of nodules plant^{-1} was observed in O_1 (Control) with the values noted at 34.33, 35.14 and 34.73.

Based on the above results, the application of organic manures was found to provide better soil and further enhanced more microbial activity in the soil (Kuotsu and Singh, 2021). According to Debela *et al.* (2021), vermicompost was found to supply necessary nutrients (N, P, S, K, Ca and Fe) that are important for nodule formation, which further enhanced root development and root nodulation. Similar findings were reported by Chatterjee *et al.* (2022) and Lestari *et al.* (2024).

4.2.3.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the number of nodules plant^{-1} is presented in Table 4.9(b). C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) exhibited the highest number of nodules plant^{-1} with the values recorded at 51.59, 52.79 and 52.19, respectively. The lowest number of nodules plant^{-1} was noted in C_2O_1 (Control) (34.22, 35.08 and 34.65) in both the seasons and in pooled. Similarly in the interaction effect, since there was no significant effect on the number of nodules plant^{-1} by the various treatments, hence no further comparison was made.

4.2.4. Diameter of nodules

The two-year experimental data and the pooled average pertaining to the impact of conservation practice and organic manures and their interaction, in relation to the diameter of nodules are presented in Tables 4.9(a) and 4.9(b), respectively.

4.2.4.1. Effect of conservation practice on the diameter of nodules

An inquisition on the two years' data and pooled as per Table 4.9(a) on the diameter of nodules revealed C_1 (Bench terrace) (5.31 mm, 5.34 mm and 5.33 mm) with a higher diameter of nodules over C_2 (Non-terrace) (5.26 mm, 5.28 mm and 5.27 mm). However, no significant variation was observed.

4.2.4.2. Effect of organic sources on the diameter of nodules

The effect of different organic sources on the diameter of nodules is presented in Table 4.9(a). The highest diameter of nodules in the initial year was observed in both O_3 (FYM @ 10 t ha^{-1}) and O_7 (Vermicompost @ 5 t ha^{-1}) with similar values of 5.41 mm, while in the final and pooled the organic source O_7 (Vermicompost @ 5 t ha^{-1}) with recorded values of 5.46 mm and 5.43 mm was noted highest. The lowest was observed in O_1 (Control) with the values noted at 4.69 mm, 4.70 and 4.69 mm, in 2021, 2022 and in pooled respectively. However, no significant variation among the organic sources was seen among the treatments *i.e.*, the diameter of the nodules was not affected by the organic sources.

4.2.4.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the diameter of nodules is presented in Table 4.9(b). As per data, the diameter of nodules in 2021 was observed the highest in both C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (5.44 mm) and C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (5.44 mm), while in 2022 and in pooled the highest diameter of nodules was noted in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (5.54 mm and 5.49 mm), respectively. C_2O_1 (Control) was noted with the lowest diameter of nodules in both seasons and in pooled with values noted at 4.64 mm, 4.65 mm, and 4.65 mm. The interaction effect among the treatments showed no significant variations, which was similar to the effect of conservation practice and the effect of organic sources, therefore no further comparison was carried out.

Table 4.9(a): Effect of conservation practice and organic manures on nodule weight plant^{-1}, no. of nodules plant^{-1} and diameter of nodules of soybean

TREATMENTS	Nodule weight plant^{-1} (g)			No of nodules plant^{-1}			Diameter of nodules (mm)		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	0.21	0.22	0.22	46.38	47.60	46.99	5.31	5.34	5.33
C_2 - Non-terrace	0.19	0.20	0.20	42.35	43.08	42.72	5.26	5.28	5.27
SEm±	0.01	0.01	0.01	0.79	0.86	0.58	0.18	0.14	0.11
CD (P=0.05)	NS	NS	NS	NS	NS	2.29	NS	NS	NS
CV	37.25	25.56	31.80	9.21	9.85	9.54	17.34	13.78	15.65
ORGANIC SOURCES									
O_1 - Control	0.15	0.15	0.15	34.33	35.14	34.73	4.69	4.70	4.69
O_2 - FYM @ 5 t ha^{-1}	0.21	0.21	0.21	43.98	45.45	44.71	5.36	5.37	5.36
O_3 - FYM @ 10 t ha^{-1}	0.23	0.23	0.23	48.88	49.23	49.06	5.41	5.44	5.42
O_4 - Poultry manure @ 2.5 t ha^{-1}	0.19	0.20	0.19	42.42	43.99	43.20	5.32	5.33	5.33
O_5 - Poultry manure @ 5 t ha^{-1}	0.21	0.22	0.21	46.61	47.33	46.97	5.38	5.38	5.38
O_6 - Vermicompost @ 2.5 t ha^{-1}	0.21	0.21	0.21	44.45	45.47	44.96	5.38	5.41	5.39
O_7 - Vermicompost @ 5 t ha^{-1}	0.23	0.24	0.24	49.87	51.09	50.48	5.41	5.46	5.43
O_8 - Enriched compost @ 2.5 t ha^{-1}	0.20	0.20	0.20	42.13	42.98	42.56	5.30	5.32	5.31
O_9 - Enriched compost @ 5 t ha^{-1}	0.21	0.22	0.22	46.65	47.38	47.01	5.36	5.39	5.37
SEm±	0.02	0.02	0.01	1.30	1.38	0.95	0.25	0.22	0.17
CD (P=0.05)	NS	NS	NS	3.76	3.98	2.68	NS	NS	NS
CV	19.29	24.96	22.38	7.20	7.46	7.53	11.59	10.19	10.91

Table 4.9(b): Interaction effect of conservation practice and organic manures on nodule weight plant^{-1}, no. of nodules plant^{-1} and diameter of nodules of soybean

TREATMENTS	Nodule weight plant^{-1} (g)			No of nodules plant^{-1}			Diameter of nodules (mm)		
	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	0.15	0.15	0.15	34.44	35.20	34.82	4.73	4.75	4.74
C_1O_2	0.22	0.22	0.22	45.65	47.57	46.61	5.38	5.39	5.39
C_1O_3	0.24	0.24	0.24	51.51	52.16	51.84	5.44	5.49	5.47
C_1O_4	0.20	0.21	0.20	44.14	46.52	45.33	5.33	5.35	5.34
C_1O_5	0.22	0.23	0.22	50.91	51.88	51.40	5.39	5.40	5.39
C_1O_6	0.23	0.23	0.23	46.63	47.50	47.06	5.43	5.45	5.44
C_1O_7	0.25	0.26	0.25	51.59	52.79	52.19	5.44	5.54	5.49
C_1O_8	0.21	0.21	0.21	44.31	45.69	45.00	5.31	5.34	5.33
C_1O_9	0.22	0.23	0.23	48.58	49.74	49.16	5.38	5.40	5.39
C_2O_1	0.15	0.15	0.15	34.22	35.08	34.65	4.64	4.65	4.65
C_2O_2	0.19	0.20	0.20	42.30	43.34	42.82	5.34	5.34	5.34
C_2O_3	0.21	0.22	0.22	46.58	46.31	46.44	5.37	5.39	5.38
C_2O_4	0.18	0.19	0.19	40.69	41.46	41.08	5.31	5.32	5.31
C_2O_5	0.20	0.21	0.21	45.63	46.43	46.03	5.36	5.37	5.37
C_2O_6	0.20	0.20	0.20	42.27	43.43	42.85	5.33	5.36	5.34
C_2O_7	0.22	0.22	0.22	47.81	49.38	48.60	5.37	5.39	5.38
C_2O_8	0.19	0.19	0.19	39.95	40.94	40.45	5.29	5.31	5.30
C_2O_9	0.20	0.21	0.21	44.72	45.01	44.87	5.34	5.37	5.35
SEm±	0.02	0.03	0.02	4.60	4.87	3.35	0.35	0.31	0.24
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.3. Yield attributes and yield

The study on the effect of conservation and organic sources showed significant yield-contributing characters, *viz*., number of seeds pods^{-1}, number of pods plant^{-1}, test weight (g), seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%).

4.3.1. Number of seeds pods^{-1}

The two-year experimental results and the pooled average on the impact of conservation practice and organic manures, in relation to the number of seeds pods^{-1}, including their interaction are presented in Tables 4.10(a) and 4.10(b), respectively.

4.3.1.1. Effect of conservation practice on the number of seeds pods^{-1}

An inquisition on the two-year and pooled data as per Table 4.10(a) revealed that although no significant variation was observed in the number of seeds pods^{-1}, C_1 (Bench terrace) (4.46, 4.58 and 4.52) was seen with a higher number of seeds pods^{-1} than C_2 (Non-terrace) (4.23, 4.34 and 4.29).

4.3.1.2. Effect of organic sources on the number of seeds pods^{-1}

The effect of different organic sources on the number of seeds pods^{-1} is presented in Table 4.10(a). The highest number of seeds pods^{-1} in both seasons and pooled was observed in O_7 (Vermicompost @ 5 t ha^{-1}) with the values noted at 4.63, 4.79 and 4.71 while the lowest number of seeds pods^{-1} was observed in O_1 (Control) with the values noted at 3.75, 3.89 and 3.82, in 2021, 2022 and in pooled respectively. Asefa and Wagari (2021) noticed that applying 75 kg NPS ha^{-1} + 2.5 t VC ha^{-1} increased the minimum number of seeds pod^{-1} by 0.01% as compared to treatments. No significant variation among the organic sources was seen among the treatments *i.e*., the number of seeds pods^{-1} was not affected by the organic sources, hence no further comparison.

4.3.1.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the number of seeds pods^{-1} is presented in Table 4.10(b). In 2021, C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (4.77) was observed with the highest number of seeds pods^{-1} while in 2022 and pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (4.89 and 4.82) was observed the highest. The lowest number of seeds pods^{-1} was noted in C_2O_1 (Control) (3.71, 3.81 and 3.76) in both the seasons and in pooled. The above results corroborate the findings of Kuotsu and Singh (2021). No further comparison was carried out since no significant variations were observed in the interaction effect of conservation practice and organic manures on the number of seeds pods^{-1}.

4.3.2. Number of pods plant^{-1}

The two-year experimental results and the pooled average pertaining to the effect of conservation practice and organic manures and their interaction, in relation to the number of pods plant^{-1} are presented in Tables 4.10(a) and 4.10(b), respectively.

4.3.2.1. Effect of conservation practice on the number of pods plant^{-1}

A perusal of the two-year data as per Table 4.10(a) revealed C_1 (Bench terrace) with the maximum number of pods plant^{-1} with values noted at 66.00 and 68.34, along with the pooled data recorded at 67.17. The lowest was recorded from C_2 (Non-terrace) with values noted at 62.01 and 63.76, along with the pooled data of 62.89, respectively. A critical examination of the data showed an augmented pooled pods plant^{-1} of 6.81% over C_2. This increase might be due to a better soil environment for root growth and development under conservation organic due to less disturbance of soil, good organic matter and moisture availability (Meena *et al*., 2022a).

4.3.2.2. Effect of organic sources on the number of pods plant^{-1}

The effect of different organic sources on the number of pods plant^{-1} is presented in Table 4.10(a). Significant variations were observed as per records with the values ranging from 50.86 to 68.66 in 2021; 51.38 to 70.99 in 2022 and 51.12 to 69.82 in pooled, respectively. In 2021, the number of pods plant^{-1} was noted highest (68.66) in O_7 (Vermicompost @ 5 t ha^{-1}), which was observed to be statistically superior to all the other organic sources. Similarly, in 2022 and in pooled, O_7 (Vermicompost @ 5 t ha^{-1}) was observed to be significantly highest with recorded values of 70.99 and 69.82 and was further observed to be statistically superior over the rest. The number of pods plant^{-1} was perceived to be lowest in O_1 (Control) in both the experimental years as well as pooled with values of 50.86, 51.38 and 51.12, respectively.

Further evaluation of the pooled data indicates an increased number of pods plant^{-1} by 36.58% over O_1 and 11.25% over O_8 with the application of O_7 and an increase of 34.17% over O_1 and 9.29% over O_8 with O_3. The number of pods per plant was observed to increase with higher application of vermicompost, possibly due to the availability of more nutrients than the other treatments. Similar results were observed by Rana *et al*. (2020) whereby the application of vermicompost @ 5 t ha^{-1} recorded a significantly higher number of pods per plant over the rest of the treatments.

4.3.2.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the number of pods plant^{-1} is presented in Table 4.10(b). Significant variations between the treatments were observed, with values ranging from 50.09 to 70.68 in 2021; 50.78 to 73.87 in 2022 and 50.44 to 72.28 in pooled. In the initial experimental trial, the highest number of pods plant^{-1} (70.68) was recorded in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-}

^{1}), which was observed to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (69.84). Meanwhile, in the succeeding year and in pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (73.87 and 72.28) was perceived with the maximum number of pods plant^{-1} and was observed to be statistically superior over the rest.

In both the experimental years, the number of pods plant^{-1} was observed to be significantly lowest in C_2O_1 (Control) with recorded values of 50.09 and 50.78. Likewise, the pooled data was also reported significantly lowest in C_2O_1 (Control) with a value of 50.44. A deeper analysis of the data further conveyed that application of C_1O_7 and C_1O_3 augmented the pooled number of pods plant^{-1} in seed by 43.30% and 40.80% over C_2O_1 and 19.21% and 17.14% over C_2O_8.

The above results are in parallel to those of Alam *et al.* (2024) and Verma *et al.* (2023), whereby they pointed out that conservation agriculture provides favourable physical conditions for proper plant establishment at early growth stages and the addition of organic amendments further enhances the growth by improving the soil quality and increases the yield. Meena *et al.* (2022a) also reported a higher number of pods plant^{-1} (58.13), in plots with conservation chemicals due to less disturbance of soil by conservation practice, application of crop residue and FYM at the initial crop growth period and direct influence on dry matter production at successive stages by increased photosynthetic efficiency. The above findings are in corroboration with Awasthi *et al.* (2020), Heidari *et al*. (2020) and Yadav *et al.* (2024).

Table 4.10(a): Effect of conservation practice and organic manures on no. of seeds pods^{-1} and no. of pods plant^{-1} of soybean

TREATMENTS	No. of seeds pods^{-1}			No. of pods plant^{-1}		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	4.46	4.58	4.52	66.00	68.34	67.17
C_2 - Non-terrace	4.23	4.34	4.29	62.01	63.76	62.89
SEm±	0.11	0.08	0.07	0.08	0.04	0.05
CD (P=0.05)	NS	NS	NS	0.51	0.27	0.19
CV	12.94	9.07	11.13	0.68	0.35	0.54
ORGANIC SOURCES						
O_1 - Control	3.75	3.89	3.82	50.86	51.38	51.12
O_2 - FYM @ 5 t ha^{-1}	4.29	4.40	4.34	65.85	67.78	66.81
O_3 - FYM @ 10 t ha^{-1}	4.63	4.72	4.67	67.55	69.64	68.59
O_4 - Poultry manure @ 2.5 t ha^{-1}	4.25	4.32	4.29	64.02	66.05	65.04
O_5 - Poultry manure @ 5 t ha^{-1}	4.47	4.59	4.53	66.67	68.99	67.83
O_6 - Vermicompost @ 2.5 t ha^{-1}	4.45	4.51	4.48	65.98	68.48	67.23
O_7 - Vermicompost @ 5 t ha^{-1}	4.63	4.79	4.71	68.66	70.99	69.82
O_8 - Enriched compost @ 2.5 t ha^{-1}	4.22	4.31	4.26	61.64	63.88	62.76
O_9 - Enriched compost @ 5 t ha^{-1}	4.45	4.59	4.52	64.86	67.30	66.08
SEm±	0.20	0.20	0.14	0.24	0.20	0.16
CD (P=0.05)	NS	NS	NS	0.68	0.59	0.44
CV	11.10	11.24	11.18	0.90	0.75	0.83

Table 4.10(b): Interaction effect of conservation practice and organic manures on no. of seeds $pods^{-1}$ and no. of pods $plant^{-1}$ of soybean

TREATMENTS	No. of seeds $pods^{-1}$			No. of pods $plant^{-1}$		
	2021	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1O_1	3.79	3.97	3.88	51.62	51.97	51.80
C_1O_2	4.39	4.53	4.46	68.25	70.12	69.19
C_1O_3	4.77	4.80	4.78	69.84	72.20	71.02
C_1O_4	4.29	4.45	4.37	66.53	68.75	67.64
C_1O_5	4.62	4.72	4.67	68.94	71.23	70.08
C_1O_6	4.62	4.69	4.66	67.40	70.90	69.15
C_1O_7	4.74	4.89	4.82	70.68	73.87	72.28
C_1O_8	4.40	4.42	4.41	63.67	66.08	64.88
C_1O_9	4.51	4.72	4.62	67.06	69.95	68.50
C_2O_1	3.71	3.81	3.76	50.09	50.78	50.44
C_2O_2	4.19	4.28	4.23	63.44	65.44	64.44
C_2O_3	4.48	4.63	4.56	65.26	67.07	66.17
C_2O_4	4.21	4.20	4.21	61.51	63.35	62.43
C_2O_5	4.31	4.46	4.39	64.40	66.76	65.58
C_2O_6	4.27	4.34	4.30	64.55	66.05	65.30
C_2O_7	4.51	4.68	4.60	66.63	68.11	67.37
C_2O_8	4.04	4.19	4.11	59.60	61.67	60.63
C_2O_9	4.38	4.45	4.42	62.65	64.65	63.65
SEm±	0.28	0.29	0.20	0.33	0.29	0.22
CD (P=0.05)	NS	NS	NS	0.96	0.83	0.62

4.3.3. Test weight

The two-year experimental results and the pooled average on the impact of conservation practice and organic manures and their interaction, concerning the test weight, are presented in Tables 4.11(a) and 4.11(b), respectively.

4.3.3.1. Effect of conservation practice on test weight

An inquisition on the two years' data and pooled as per Table 4.11(a) revealed C_1 (Bench terrace) (80.32 g, 82.51 g and 81.41 g) with a higher test weight than C_2 (Non-terrace) (79.41 g, 80.41 g and 79.91 g). However, no significant variation was observed in test weight (g) among the forms of conservation practice.

4.3.3.2. Effect of organic sources on test weight

The effect of different organic sources on the test weight is presented in Table 4.11(a). The highest test weight in both seasons and pooled was observed in O_7 (Vermicompost @ 5 t ha^{-1}) with the values noted at 82.55 g, 83.57 g and 83.06 g, which might be due to the positive effects of vermicompost on assimilates translocation, activation of photosynthetic enzymes, chlorophyll formation and improvement of plant growth (Kohnaward *et al.,* 2012). The lowest test weight was observed in O_1 (Control) with values noted at 75.51 g, 77.52 g and 76.51 g, in 2021, 2022 and in pooled respectively. However, organic amendments did not significantly influence the test weight, as being a vertical character, it is less sensitive to management levels (Singh, 2018).

4.3.3.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the test weight is presented in Table 4.11(b). As per data, it was observed that in 2021, 2022 and in pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was observed with the highest test weight with values noted at 83.96 g, 85.42 g and 84.69 g while the lowest in 2021 and in pooled was noted C_2O_1 (75.27 g and 76.57 g) with 2022 at C_2O_1 (Control) (77.17 g). Similar to the effect of conservation practice and the effect of organic sources, no significant variations were observed in the interaction effect among the treatments on the test weight, therefore no further comparison was made.

Table 4.11(a): Effect of conservation practice and organic manures on test weight of soybean

TREATMENTS	Test weight (g)		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	80.32	82.51	81.41
C_2 - Non-terrace	79.41	80.41	79.91
SEm±	1.24	0.60	0.69
CD (P=0.05)	NS	NS	NS
CV	8.08	3.80	6.28
ORGANIC SOURCES			
O_1 - Control	75.51	77.52	76.51
O_2 - FYM @ 5 t ha^{-1}	79.91	81.57	80.74
O_3 - FYM @ 10 t ha^{-1}	80.83	82.43	81.63
O_4 - Poultry manure @ 2.5 t ha^{-1}	79.65	81.03	80.34
O_5 - Poultry manure @ 5 t ha^{-1}	80.23	82.14	81.19
O_6 - Vermicompost @ 2.5 t ha^{-1}	80.58	82.16	81.37
O_7 - Vermicompost @ 5 t ha^{-1}	82.55	83.57	83.06
O_8 - Enriched compost @ 2.5 t ha^{-1}	79.48	80.85	80.17
O_9 - Enriched compost @ 5 t ha^{-1}	80.06	81.83	80.95
SEm±	1.32	1.77	1.11
CD (P=0.05)	NS	NS	NS
CV	4.06	5.34	4.75

Table 4.11(b): Interaction effect of conservation practice and organic manures on test weight of soybean

TREATMENTS	Test weight (g)		
	2021	2022	POOLED
C_1O_1	75.27	77.86	76.57
C_1O_2	80.34	82.56	81.45
C_1O_3	81.00	83.66	82.33
C_1O_4	80.23	81.77	81.00
C_1O_5	80.73	83.27	82.00
C_1O_6	80.46	83.40	81.93
C_1O_7	83.96	85.42	84.69
C_1O_8	80.27	81.83	81.05
C_1O_9	80.60	82.79	81.70
C_2O_1	75.74	77.17	76.46
C_2O_2	79.48	80.59	80.04
C_2O_3	80.66	81.20	80.93
C_2O_4	79.07	80.29	79.68
C_2O_5	79.73	81.02	80.38
C_2O_6	80.70	80.93	80.81
C_2O_7	81.13	81.72	81.43
C_2O_8	78.68	79.87	79.28
C_2O_9	79.52	80.86	80.19
SEm±	1.87	2.51	1.57
CD (P=0.05)	NS	NS	NS

4.3.4. Seed yield

A perusal of the two-year experimental results and the pooled average pertaining to the impact of conservation practice and organic manures in view of the seed yield, including their interaction are presented in Tables 4.12(a) and 4.12(b) and illustrated graphically in Figures 4.14(a) and 14(b).

4.3.4.1. Effect of conservation practice on seed yield

Critical analysis of the data from Table 4.12(a) revealed that conservation practices significantly influenced the seed yield in both seasons. The highest seed yield (1875.73 kg ha^{-1} in 2021, 2048.19 kg ha^{-1} in 2022 and 1961.96 kg ha^{-1} in pooled) was recorded in C_1 (Bench terrace), which was observed to be significantly superior while the lowest seed yield was recorded in C_2 (Non-terrace) with values noted at 1655.11 kg ha^{-1} in 2021, 1729.10 kg ha^{-1} in 2022 and 1692.11 kg ha^{-1} in pooled. Keeping this data in mind further analysis was carried out, whereby an upsurge in the pooled seed yield of 15.95% with the use of conservation practice over non-conservation practice was observed.

This increase was due to the cumulative effect of soil moisture which ultimately helps improve the nutrient-supplying capacity of soil and use efficiency, thus directly influencing on uptake of higher nutrients in conservation practices over non-conservation practices. Hörbe *et al*. (2021) also suggested that these higher crop yields demonstrate the efficiency of terraces as a method of reducing water deficits and enhancing their productivity since their presence was associated with higher water availability and soybean and corn terraces controlled runoff. Similar results were reported by Age *et al.* (2019), Age *et al*. (2020), Deng *et al*. (2021) and Alam *et al.* (2024) whereby the soybean seed yield increased due to conservation practices.

4.3.4.2. Effect of organic sources on seed yield

The effect of different organic sources on the seed yield is presented in Table 4.12(a). A perusal of the data from the table showed that seed yield differed significantly in both seasons among the different organic sources under study, with values ranging from 937.46 kg ha^{-1} to 2086.68 kg ha^{-1} in 2021, 964.60 kg ha^{-1} to 2278.24 kg ha^{-1} in 2022 and 951.03 kg ha^{-1} to 2182.46 kg ha^{-1} in pooled, respectively. O_7 (Vermicompost @ 5 t ha^{-1}) exhibited the highest seed yield among the sources, with a maximum seed yield of 2086.68 kg ha^{-1} in 2021, 2278.24 kg ha^{-1} in 2022 along with the pooled average of 2182.46 kg ha^{-1}, which was statistically superior over the rest of the sources. This was followed by O_3 (FYM @ 10 t ha^{-1}) which was significantly higher over the rest in both seasons, with values noted at 1989.81 kg ha^{-1} in 2021, 2181.80 kg ha^{-1} in 2022 as well as 2085.81 kg ha^{-1} in pooled. Meanwhile, O_1 (Control) was reported with a significant minimum seed yield in both years, with values recorded at 937.46 kg ha^{-1} in 2021, 964.60 kg ha^{-1} in 2022 as well as 951.03 kg ha^{-1} in pooled.

Further inspection of the pooled data showed an increased seed yield of 129.48% over control and 24.76% over enriched compost @ 2.5 t ha^{-1} when vermicompost @ 5 t ha^{-1} was applied. Likewise, an upsurge of 119.32% over control and 19.23% over enriched compost @ 2.5 t ha^{-1} was observed in plots where FYM @ 10 t ha^{-1} was applied. Vermicompost shows an enhancement over FYM based on circumstantial evidence because vermicompost contains the optimum nutrient C: N ratio and high-status-available nutrients, having hormones that increase the level of enzymes (Panuccio *et al.,* 2021).

The improved crop performance under the application of organic manures might be due to the cumulative effects on soil available nutrients, enhanced organic carbon, higher microbial population, increased enzyme activities and due to the residual effect (Aher *et al.,* 2018). The increase in seed yield of soybean with 100 % N through phoshpocompost + remaining P through chemical fertilizer could be attributed to the cumulative effect of better growth that produced a higher number of pods which ultimately increased the seed yield (Age *et al*., 2019 and Age *et al*., 2020). Asefa and Wagari (2021) also reported that the high availability of phosphorus and sulphur in vermicompost increases the seed yield of soybeans. Similarly, the findings of Morya *et al*. (2018), Keerthana *et al.* (2024) and Lestari *et al*. (2024), reported that the application of vermicompost because of supplying optimum nourishment conditions improves the growth and thereby seed yield in soybean crops.

4.3.4.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the seed yield is presented in Table 4.12(b). Significant variations were observed as per data during both the experimental years which also showed a great surge in the seed yield between the seasons. The values were observed to range from 923.63 kg ha^{-1} to 2284.50 kg ha^{-1} in 2021, 952.60 kg ha^{-1} to 2535.69 kg ha^{-1} in 2022 as well as 938.11 kg ha^{-1} to 2410.09 kg ha^{-1} in pooled, respectively.

In both the initial and final experimental trials, the seed yield was recorded as significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a maximum seed yield of 2284.50 kg ha^{-1} and 2535.69 kg ha^{-1} and was observed to be significantly higher over the rest of the treatments. C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) was reported second highest and was observed to be statistically superior over the remaining treatments. Similarly in the pooled data, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was observed to be significantly higher than all the other treatments with a maximum pooled seed yield of 2410.09 kg ha^{-1}. The seed yield was observed significantly lowest in C_2O_1 (Control) in both the experimental years with a minimum seed yield of 923.63 kg ha^{-1} and 952.60 kg ha^{-1}, which was statistically at par with C_2O_1 (Control) with values of 951.29 kg ha^{-1} and 976.61 kg ha^{-1}, respectively.

Likewise, the pooled data was also reported significantly lowest in C_2O_1 (Control) (938.11 kg ha^{-1}) and was significantly at par with C_2O_1 (Control) (963.95 kg ha^{-1}).

With treatment, C_1O_7 and C_1O_3 an augmented pooled seed yield of 147.34% and 140.16% over C_2O_1 and 47.75% and 38.12% over C_2O_8 was observed upon further examination. This increment might be due to the positive effects of vermicompost on assimilates translocation, activation of photosynthetic enzymes, chlorophyll formation and improvement of plant growth (Kohnaward *et al.,* 2012). In general, the application of organics improved the agronomic performance of soybeans and increased crop yield. Vermicompost increased the soil organic carbon, phosphates, nitrates, exchangeable calcium, and some other nutrients in the soil for plant growth (Jindo *et al*., 2016 and Wang *et al*., 2017) which led to a higher yield of soybean. The increase in yield with treatments of conservation practice and organic manure may be due to the addition of organics and conservation of soil and water which enhances soil fertility and results in higher yield. These results are in close conformity with the findings of Age *et al*. (2019). The solubilization of native as well as applied nutrient fertilizers at higher levels with crop residues produces complexing agents and nutrients are released after microbial decay of crop residue ultimately increasing the grain yield. In addition to that when soybean was cultivated in terraces, plant growth was seen to greatly improve and increase crop yields because of various mechanisms *viz.,* reducing soil erosion, improving soil moisture levels, increasing nutrient availability, expanding arable land, and creating controlled farming conditions (Chen *et al*., 2024). Jadhao *et al.* (2018) also noticed that the residual effect of balanced fertilization with secondary nutrients and micronutrients in conjunction with to use of conservation practice results in an increase in soybean seed yield. Similar findings were reported by Deng *et al*. (2021), Verma *et al.* (2023) and Yadav *et al.* (2024).

4.3.5. Stover yield

A perusal of the two-year experimental results and pooled average on the impact of conservation practice and organic manures including their interaction, on the stover yield are presented in Tables 4.12(a) and 4.12(b) and illustrated graphically in Figures 4.15(a) and 15(b).

4.3.5.1. Effect of conservation practice on stover yield

From the data recorded in Table 4.12(a), it was revealed that conservation practices significantly influenced the stover yield in both seasons, whereby the highest stover yield was recorded in C_1 (Bench terrace) with values noted at 2828.83 kg ha^{-1} in 2021, 2966.88 kg ha^{-1} in 2022 and 2897.85 kg ha^{-1} in pooled, which was observed to be significantly superior. The lowest stover yield was documented in C_2 (Non-terrace) with recorded values of 2673.12 kg ha^{-1} in 2021, 2763.07 kg ha^{-1} in 2022 and 2718.10 kg ha^{-1} in pooled, respectively. Upon further analysis, an upsurge in the pooled stover yield of 6.61% was reported with the use of conservation practice over non-conservation practice.

4.3.5.2. Effect of organic sources on stover yield

The effect of different organic sources on the stover yield is presented in Table 4.12(a). A perusal of the data from the table showed significant variations of the stover yield among the different organic sources during both the seasons of study, with values ranging from 1464.23 kg ha^{-1} to 3086.47 kg ha^{-1} in 2021, 1472.43 kg ha^{-1} to 3255.55 kg ha^{-1} in 2022 and 1468.33 kg ha^{-1} to 3171.01 kg ha^{-1} in pooled, respectively. Organic source O_7 (Vermicompost @ 5 t ha^{-1}) exhibited the highest stover yield among the sources in the initial year as well as in pooled, with a maximum stover yield of 3086.47 kg ha^{-1} and 3171.01 kg ha^{-1}, which was further observed to be statistically superior over the rest of the sources. This was followed by O_3 (FYM @ 10 t ha^{-1}) which was also significantly higher over the rest but not statistically at par with O_7 (Vermicompost @ 5 t ha^{-1}). In the final year of the study, the maximum stover yield (3255.55 kg ha^{-1}) was perceived in O_7 (Vermicompost @ 5 t ha^{-1}) and was statistically at par with O_3 (FYM @ 10 t ha^{-1}) (3218.47 kg ha^{-1}).

O_1 (Control) was reported with a significant minimum stover yield in both years, with values recorded at 1464.23 kg ha^{-1} in 2021, 1472.43 kg ha^{-1} in 2022 and 1468.33 kg ha^{-1} in pooled. Further analysis of the study reported the pooled data with an augmented stover yield of 115.96% and 111.99% over control and 12.71% and 10.64% over enriched compost @ 2.5 t ha^{-1} in plots were vermicompost @ 5 t ha^{-1} and FYM @ 10 t ha^{-1} was applied.

4.3.5.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the stover yield is presented in Table 4.12(b). Here, significant variations in the stover yield among the treatments were observed in both seasons. Irrespective of the treatments the stover yield of soybean varied from 1414.80 kg ha^{-1} to 3200.38 kg ha^{-1} in 2021, 1429.03 kg ha^{-1} to 3405.49 kg ha^{-1} in 2022 as well as 1421.91 kg ha^{-1} to 3302.94 kg ha^{-1} in pooled, respectively. In the initial experimental trial, the stover yield was reported significantly highest (3200.38 kg ha^{-1}) in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}), which was statistically superior over the rest of the available treatments. Similarly, in pooled the maximum stover yield of 3302.94 kg ha^{-1} was reported in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}). The second-best treatment was perceived in C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with a stover yield of 3118.73 kg ha^{-1} in 2021 and 3222.78 kg ha^{-1} in pooled. While, in the succeeding year, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (3405.49 kg ha^{-1}) was also deemed with the maximum stover yield and was significantly at par only with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with a stover yield of 3326.82 kg ha^{-1}.

The stover yield was observed lowest in C_2O_1 (Control) with a minimum recorded straw yield of 1414.80 kg ha^{-1}, 1429.03 kg ha^{-1} in 2021 and 2022 which was also reported to be significantly at par with treatment C_1O_1 (Control) (1513.65 kg ha^{-1} and 1515.83 kg ha^{-1}). Likewise, the pooled data was also reported as significantly lowest in C_2O_1 (Control) with a stover yield of 1421.91 kg ha^{-1} and was also significantly at par with C_1O_1 (Control) (1514.74 kg ha^{-1}), respectively. Treatments C_1O_7 and C_1O_3 increased the pooled stover yield to the extent of 115.77% and 126.65% over C_2O_1 and 20.77% and 17.84% over C_2O_8.

The increase in the higher application of organic sources of nutrients was due to higher uptake and metabolism leading to an additional and easy availability of nutrients. The improvement in soil fertility status facilitated quick and greater availability of plant nutrients, which enhanced the growth and development of the crop, significantly increasing the seed and stover yields of soybeans (Tomar and Khajanji, 2009). Age *et al.* (2019) and Age *et al.* (2020) further noticed that the seed and straw yields were significantly influenced by the various integrated plant nutrient supply treatments with the application of phosphor-compost in conjunction with chemical fertilizers and organic manures, resulting in a significantly higher uptake of nutrients under conservation practices. Kuotsu and Singh (2021) also observed that the vegetative growth of soybean was enhanced when nutrients were applied in higher amounts. The application of conservation practices with crop residue and FYM as per a report by Meena *et al.* (2022a) brings about lesser soil disturbance and directly influences dry matter production at successive stages by increased photosynthetic efficiency. Similar findings were put up by Heidari *et al.* (2020), Mohan *et al.* (2023), Verma *et al.* (2023) and Chen *et al.* (2024), whereby they highlighted the effectiveness of terracing in conjunction with the application of organic manures in enhancing agricultural productivity and sustainability as terracing provide favourable physical conditions for proper plant establishment at early growth stages to soybean crops thereby contributing to higher seed yield and consequently stover yield.

Table 4.12(a): Effect of conservation practice and organic manures on seed yield and stover yield of soybean

TREATMENTS	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	1875.73	2048.19	1961.96	2828.83	2966.88	2897.85
C_2 - Non-terrace	1655.11	1729.10	1692.11	2673.12	2763.07	2718.10
SEm±	1.89	5.25	2.79	2.92	7.95	4.24
CD (P=0.05)	11.50	31.95	10.96	17.76	48.39	16.63
CV	0.56	1.44	1.12	0.55	1.44	1.11
ORGANIC SOURCES						
O_1 - Control	937.46	964.60	951.03	1464.23	1472.43	1468.33
O_2 - FYM @ 5 t ha^{-1}	1809.19	1922.14	1865.66	2851.90	2956.95	2904.42
O_3 - FYM @ 10 t ha^{-1}	1989.81	2181.80	2085.81	3006.86	3218.47	3112.67
O_4 - Poultry manure @ 2.5 t ha^{-1}	1737.78	1888.40	1813.09	2804.43	2964.17	2884.30
O_5 - Poultry manure @ 5 t ha^{-1}	1912.20	2015.02	1963.61	2991.47	3085.04	3038.26
O_6 - Vermicompost @ 2.5 t ha^{-1}	1854.76	2003.76	1929.26	2844.54	2978.10	2911.32
O_7 - Vermicompost @ 5 t ha^{-1}	2086.68	2278.24	2182.46	3086.47	3255.55	3171.01
O_8 - Enriched compost @ 2.5 t ha^{-1}	1705.50	1793.15	1749.33	2769.00	2857.66	2813.33
O_9 - Enriched compost @ 5 t ha^{-1}	1855.39	1950.71	1903.05	2939.85	2996.41	2968.13
SEm±	3.08	11.95	6.17	13.25	19.33	11.72
CD (P=0.05)	8.86	34.42	17.43	38.16	55.70	33.11
CV	0.43	1.55	1.17	1.18	1.65	1.45

Table 4.12(b): Interaction effect of conservation practice and organic manures on seed yield and stover yield of soybean

TREATMENTS	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	951.29	976.61	963.95	1513.65	1515.83	1514.74
C_1O_2	1898.48	2113.13	2005.80	2876.15	3076.25	2976.20
C_1O_3	2145.65	2360.32	2252.99	3118.73	3326.82	3222.78
C_1O_4	1820.28	2058.11	1939.19	2866.35	3103.49	2984.92
C_1O_5	2029.68	2185.40	2107.54	3101.26	3208.95	3155.11
C_1O_6	1965.88	2194.14	2080.01	2870.90	3057.31	2964.10
C_1O_7	2284.50	2535.69	2410.09	3200.38	3405.49	3302.94
C_1O_8	1813.97	1920.98	1867.48	2853.51	2930.20	2891.85
C_1O_9	1971.80	2089.33	2030.57	3058.49	3077.54	3068.02
C_2O_1	923.63	952.60	938.11	1414.80	1429.03	1421.91
C_2O_2	1719.89	1731.15	1725.52	2827.64	2837.65	2832.64
C_2O_3	1833.98	2003.27	1918.63	2894.99	3110.12	3002.55
C_2O_4	1655.27	1718.68	1686.98	2742.51	2824.85	2783.68
C_2O_5	1794.71	1844.64	1819.68	2881.68	2961.14	2921.41
C_2O_6	1743.63	1813.38	1778.50	2818.18	2898.88	2858.53
C_2O_7	1888.86	2020.79	1954.83	2972.56	3105.62	3039.09
C_2O_8	1597.03	1665.31	1631.17	2684.49	2785.11	2734.80
C_2O_9	1738.97	1812.10	1775.54	2821.20	2915.27	2868.24
SEm±	4.35	16.90	8.72	18.74	27.34	16.57
CD (P=0.05)	12.53	48.67	24.65	53.97	78.77	46.82

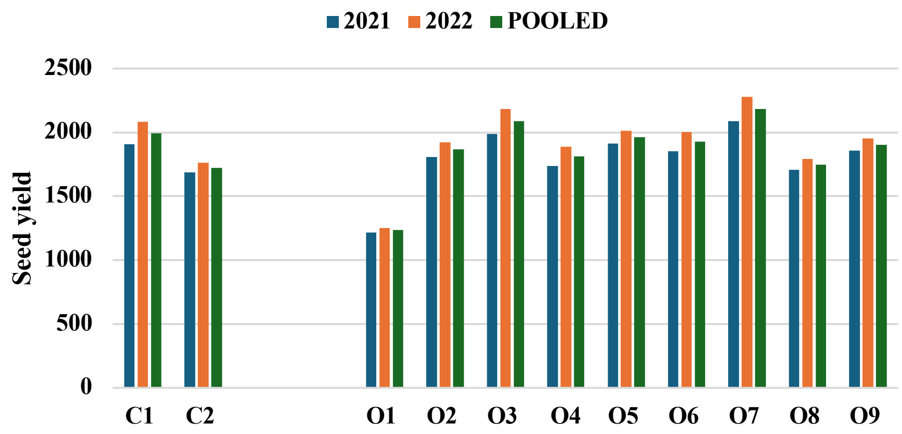

Fig. 4.14(a): Effect of conservation practice and organic manures on seed yield of soybean

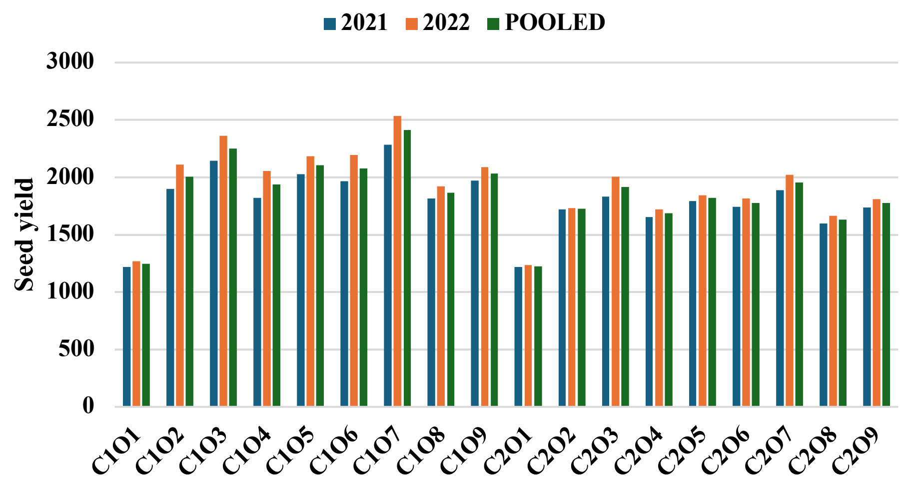

Fig. 4.14(b): Interaction effect of conservation practice and organic manures on seed yield of soybean

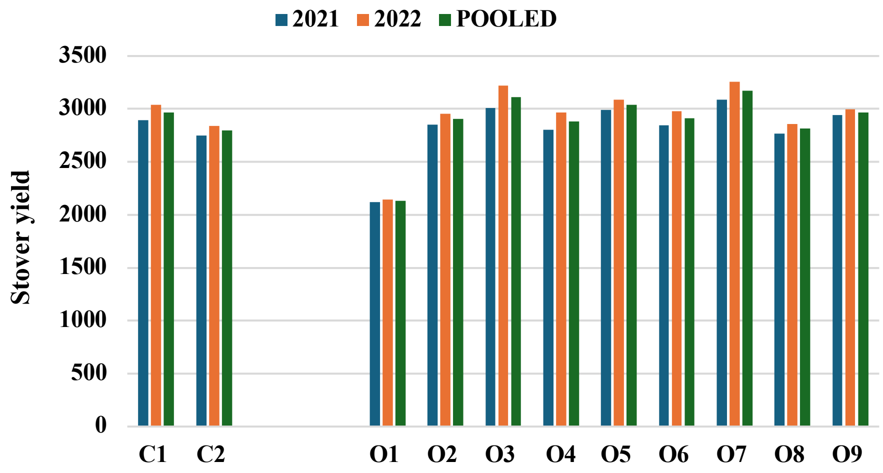

Fig. 4.15(a): Effect of conservation practice and organic manures on stover yield of soybean

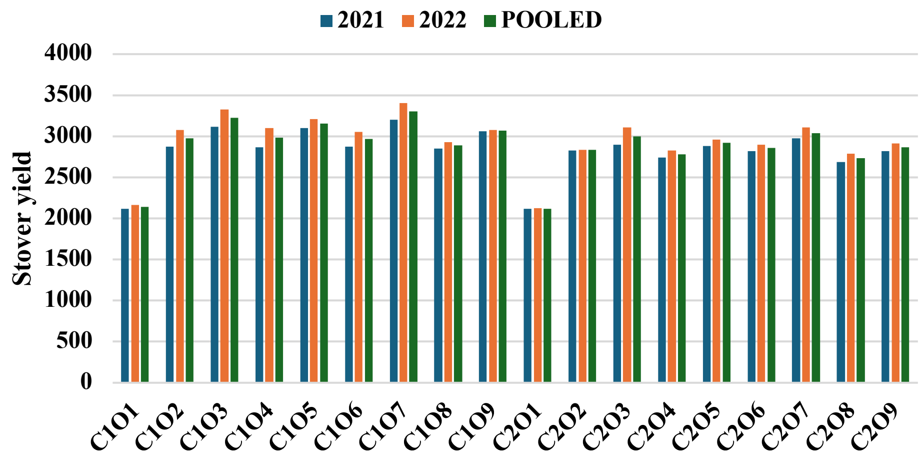

Fig. 4.15(b): Interaction effect of conservation practice and organic manures on stover yield of soybean

4.3.6. Biological yield

A perusal of the two-year experimental results and pooled average on the impact of conservation practice and organic manures including their interaction on the biological yield are presented in Tables 4.13(a) and 4.13(b), respectively.

4.3.6.1. Effect of conservation practice on biological yield

As per Table 4.13(a), the biological yield was significantly influenced during the whole experimental period with the use of conservation practice over non-conservation practice. C_1 (Bench terrace) was recorded as significantly highest in both years with values of 4704.55 kg ha^{-1} in 2021 and 5015.06 kg ha^{-1} in 2022, along with the pooled average of 4859.81 kg ha^{-1}. The lowest biological yield was observed in C_2 (Non-terrace) with values of 4328.22 kg ha^{-1}, 4492.18 kg ha^{-1} and 4410.20 kg ha^{-1} in 2021, 2022 and pooled, respectively. Upon further analysis, an upsurge in the pooled stover yield of 10.19% was reported with the use of bench terrace over non-terrace.

4.3.6.2. Effect of organic sources on biological yield

The effect of different organic sources on the biological yield is presented in Table 4.13(a). A review of the data indicated that the use of organic sources *viz*., vermicompost and FYM at higher recommended doses had a significant effect on the biological yield during the two years of experimentation. The biological yield was reported maximum in source O_7 (Vermicompost @ 5 t ha^{-1}) with 5173.15 kg ha^{-1} and 5533.80 kg ha^{-1} in 2021 and 2022 respectively, along with a pooled average of 5353.47 kg ha^{-1}, which was observed to be statistically superior over the rest of the sources. This was followed by O_3 (FYM @ 10 t ha^{-1}) which was also significantly higher over the rest in both seasons but statistically not at par with O_7 (Vermicompost @ 5 t ha^{-1}), with values noted at 4996.67 kg ha^{-1} in 2021, 5400.27 kg ha^{-1} in 2022 as well as 5198.47 kg ha^{-1} in pooled. The minimum biological yield was reported in O_1 (Control), with values recorded at 2401.69 kg ha^{-1}, 2437.03 kg ha^{-1} and 2419.36 kg ha^{-1} in 2021, 2022 and pooled, respectively. Further inspection of the pooled data reported an increase in the biological yield of 121.28% over control and 17.33% over enriched compost @ 2.5 t ha^{-1} when vermicompost @ 5 t ha^{-1} was applied. Likewise, an upsurge of 114.87% over control and 13.94% over enriched compost @ 2.5 t ha^{-1} was observed in plots where FYM @ 10 t ha^{-1} was applied.

4.3.6.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the biological yield is presented in Table 4.13(b). Significant variations were observed in the biological yield in both seasons. Irrespective of the treatments the biological yield of soybean was observed to vary from 2338.43 kg ha^{-1} to 5484.88 kg ha^{-1} in 2021, 2381.63 kg ha^{-1} to 5941.18 kg ha^{-1} in 2022 as well as 2360.03 kg ha^{-1} to 5713.03 kg ha^{-1} in pooled, respectively. The biological yield was reported significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a maximum biological yield of 5484.88 kg ha^{-1} and 5941.18 kg ha^{-1} in 2021 and 2022, respectively, which was statistically superior over the rest of the available treatments. Similarly, in pooled the maximum biological yield of 5713.03 kg ha^{-1} was reported in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}). The second-best treatment was perceived in C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with a biological yield of 5264.38 kg ha^{-1} in 2021, 5687.70 kg ha^{-1} in 2022, along with the pooled value of 5475.76 kg ha^{-1}.

The biological yield was observed lowest in C_2O_1 (Control) with a minimum recorded yield of 2338.43 kg ha^{-1}, 2381.63 kg ha^{-1} in 2021 and 2022 which was also reported to be significantly at par with treatment C_1O_1 (Control) (2464.95 kg ha^{-1} and 2492.44 kg ha^{-1}). Likewise, the pooled data was also reported as significantly lowest in C_2O_1 (Control) with a biological yield of 2360.03 kg ha^{-1} and was also significantly at par with C_1O_1 (Control) (2478.69

kg ha^{-1}), respectively. Treatments C_1O_7 and C_1O_3 reported an increase in the pooled biological yield to the extent of 142.07% and 132.02% over C_2O_1 and 30.85% and 25.42% over C_2O_8. The increment in the biological yield might be due to favourable vegetative (haulm) and reproductive growth (Meena *et al*., 2024). The above findings conform with those of Heidari *et al*. (2020), Asefa and Wagari (2021), Meena *et al.* (2022a), Mohan *et al.* (2023), Verma *et al.* (2023) and Chen *et al.* (2024).

4.3.7. Harvest index

A perusal of the two-year experimental results along with the pooled data on the impact of conservation practice and organic manures including their interaction, on the harvest index, are presented in Table 4.13(a) and 4.13(b), respectively.

4.3.7.1. Effect of conservation practice on harvest index

As per the data from Table 4.13(a), the use of conservation practice over non-conservation practice had a significant influence on the harvest index during the whole experimental period. The maximum harvest index was observed in C_1 (Bench terrace) with values of 39.76% in 2021 and 40.70% in 2022, as well as a pooled value of 40.23% and the minimum harvest index, was recorded in C_2 (Non-terrace) with values of 38.29%, 38.55% and 38.42% in 2021, 2022 and pooled, respectively.

4.3.7.2. Effect of organic sources on harvest index

The effect of different organic sources on the harvest index is presented in Table 4.13(a). The use of organic sources *viz.,* vermicompost and FYM at higher recommended doses showed significant variations among the treatments during the two years of experimentation. The harvest index was reported maximum in source O_7 (Vermicompost @ 5 t ha^{-1}) with recorded values of

40.26% and 41.05% in 2021 and 2022 respectively, along with a pooled value of 40.65%, which was observed to be statistically superior over the rest of the sources. The second-best harvest index though not statistically at par with O_7 was detected in O_3 (FYM @ 10 t ha^{-1}) and was further observed to be significantly higher over the rest in both seasons, with values noted at 39.77%, 40.35% and 40.06% in 2021, 2022 and in pooled, respectively. The minimum harvest index was reported in O_8 (Enriched compost @ 2.5 t ha^{-1}), with values of 38.08%, 38.51% and 38.30% in 2021, 2022 and pooled, respectively. Further inspection of the pooled data reported an increase of 3.38% in the harvest index over control and 6.14% over enriched compost @ 2.5 t ha^{-1} when vermicompost @ 5 t ha^{-1} was applied. Likewise, an upsurge of 1.88% over control and 4.60% over enriched compost @ 2.5 t ha^{-1} was observed in plots where FYM @ 10 t ha^{-1} was applied, implying greater accumulation of dry matter in seeds (Tomar and Khajanji, 2009). Similar results were observed by Meena *et al.* (2022b).

4.3.7.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the harvest index is presented in Table 4.13(b). Significant variations were observed in the harvest index in both seasons. Irrespective of the treatments the harvest index was observed to vary from 37.30% to 41.66% in 2021, 37.42% to 42.68% in 2022 as well as 37.36% to 42.17% in pooled, respectively. In both the experimentation period, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was reported significantly highest with a maximum harvest index of 41.66% and 42.68% in 2021 and 2022, respectively, which was statistically superior over the rest. Similarly, in pooled, the maximum harvest index of 42.17% was reported in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}).

Meanwhile, the harvest index in the initial year and in pooled was reported lowest in C_2O_8 (Non-terrace + Enriched compost @ 2.5 t ha^{-1}) with a minimum recorded value of 37.30% and 37.42%, respectively, which was also reported to be significantly at par with treatment C_2O_4 (Non-terrace + Poultry manure @ 2.5 t ha^{-1}) (37.64% and 37.73%). Though C_2O_8 (Non-terrace + Enriched compost @ 2.5 t ha^{-1}) was also reported as significantly lowest in the final year with a harvest index of 36.80%, however, it was significantly at par with both C_2O_4 (Non-terrace + Poultry manure @ 2.5 t ha^{-1}) (37.83%) and C_2O_2 (Non-terrace + FYM @ 5 t ha^{-1}) (37.89%), respectively. The harvest index was reported with augmented pooled data of 12.87% and 10.12% over C_2O_8 and 11.47% and 8.75% over C_2O_8 when treatments C_1O_7 and C_1O_3 were used.

The harvest index is the relationship of the economic yield (biomass and grain) to the total or biological yield expressed as the coefficient of effectiveness. Thus, the harvest index (HI) is the balance between the productive parts of the plant and the reserves, which form the economic yield. This indicates that treatments that produce more yield would also produce a higher harvest index. The findings conform with the findings of Heidari *et al*. (2020), Asefa and Wagari (2021), Meena *et al.* (2022a), Mohan *et al.* (2023), Verma *et al.* (2023) and Chen *et al.* (2024).

Table 4.13(a): Effect of conservation practice and organic manures on biological yield and harvest index of soybean

TREATMENTS	Biological yield (kg ha^{-1})			Harvest index (%)		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	4704.55	5015.06	4859.81	39.76	40.70	40.23
C_2 - Non-terrace	4328.22	4492.18	4410.20	38.29	38.55	38.42
SEmy	3.48	11.69	6.10	0.04	0.05	0.03
CD (P=0.05)	21.19	71.12	23.94	0.21	0.33	0.13
CV	0.40	1.28	0.97	0.47	0.71	0.60
ORGANIC SOURCES						
O_1 - Control	2401.69	2437.03	2419.36	39.05	39.59	39.32
O_2 - FYM @ 5 t ha^{-1}	4661.08	4879.09	4770.08	38.79	39.31	39.05
O_3 - FYM @ 10 t ha^{-1}	4996.67	5400.27	5198.47	39.77	40.35	40.06
O_4 - Poultry manure @ 2.5 t ha^{-1}	4542.20	4852.57	4697.39	38.24	38.85	38.54
O_5 - Poultry manure @ 5 t ha^{-1}	4903.67	5100.06	5001.87	38.97	39.45	39.21
O_6 - Vermicompost @ 2.5 t ha^{-1}	4699.29	4981.86	4840.57	39.43	40.13	39.78
O_7 - Vermicompost @ 5 t ha^{-1}	5173.15	5533.80	5353.47	40.26	41.05	40.65
O_8 - Enriched compost @ 2.5 t ha^{-1}	4474.50	4650.80	4562.65	38.08	38.51	38.30
O_9 - Enriched compost @ 5 t ha^{-1}	4795.23	4947.12	4871.18	38.67	39.39	39.03
SEm±	15.17	25.16	14.69	0.09	0.18	0.10
CD (P=0.05)	43.71	72.48	41.51	0.26	0.52	0.29
CV	0.82	1.30	1.10	0.57	1.13	0.90

Table 4.13(b): Interaction effect of conservation practice and organic manures on biological yield and harvest index of soybean

TREATMENTS	Biological yield (kg ha^{-1})			Harvest index (%)		
	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	2464.95	2492.44	2478.69	38.59	39.18	38.89
C_1O_2	4774.63	5189.37	4982.00	39.76	40.72	40.24
C_1O_3	5264.38	5687.15	5475.76	40.76	41.51	41.14
C_1O_4	4686.63	5161.60	4924.12	38.84	39.87	39.36
C_1O_5	5130.94	5394.34	5262.64	39.56	40.51	40.04
C_1O_6	4836.78	5251.45	5044.12	40.64	41.78	41.21
C_1O_7	5484.88	5941.18	5713.03	41.66	42.68	42.17
C_1O_8	4667.48	4851.18	4759.33	38.87	39.60	39.23
C_1O_9	5030.30	5166.87	5098.58	39.20	40.44	39.82
C_2O_1	2338.43	2381.63	2360.03	39.50	40.00	39.75
C_2O_2	4547.53	4568.80	4558.17	37.82	37.89	37.86
C_2O_3	4728.97	5113.39	4921.18	38.78	39.18	38.98
C_2O_4	4397.78	4543.53	4470.66	37.64	37.83	37.73
C_2O_5	4676.40	4805.78	4741.09	38.38	38.38	38.38
C_2O_6	4561.80	4712.26	4637.03	38.22	38.48	38.35
C_2O_7	4861.42	5126.41	4993.92	38.85	39.42	39.13
C_2O_8	4281.52	4450.43	4365.98	37.30	37.42	37.36
C_2O_9	4560.17	4727.37	4643.77	38.14	38.34	38.24
SEm±	21.46	35.58	20.78	0.13	0.26	0.14
CD (P=0.05)	61.82	102.50	58.70	0.37	0.74	0.41

4.4. Quality attributes

4.4.1. Protein content

The two-year recorded experimental data and pooled average on the impact of conservation practices and organic manures on protein content after harvest along with their interactions are presented in Tables 4.14(a) and 4.14(b), respectively.

4.4.1.1. Effect of conservation practice on protein content

A perusal of the data from the Table 4.14(a) revealed that in both the years of the experiment, C_1 (Bench terrace) was found significantly highest with a protein content of 38.38% and 38.59%, along with the pooled data recorded at 38.49%. The lowest protein content was recorded from C_2 (Non-terrace) with a value of 37.67% and 37.98%, with the pooled data of 37.83%, respectively. An upsurge of 1.74% was observed in the pooled protein content when C_1 was being practised over C_2, due to the improvement of soil aeration conditions and sequential aeration with terracing thereby increasing the values of growth parameters and chemical constitutes as well as yield, and quality of soybean. Similar results were noted by Helmy and El-Sherpiny (2022).

4.4.1.2. Effect of organic sources on protein content

The effect of different organic sources on the protein content is presented in Table 4.14(a). It was apparent that there were significant variations in the protein content of the seed with respect to different organic sources in both the years of the experiment, ranging from 31.53% to 39.49% in 2021; 31.67% to 39.89% in 2022 and 31.60% to 39.69% in pooled, respectively. For 2021, the maximum protein content was recorded in O_7 (Vermicompost @ 5 t ha^{-1}) with a value of 39.49%, which was significantly at par with O_3 (FYM @ 10 t ha^{-1}) and O_5 (Poultry manure @ 5 t ha^{-1}) with a protein content of 39.40% and 39.22%;

while the minimum protein content (31.53%) was observed in O_1 (Control). For the succeeding year, O_7 (Vermicompost @ 5 t ha^{-1}) was recorded with the highest protein content of 39.89% and observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) (39.77%). The least was observed in O_1 (Control) with a protein content of 31.67%. Similarly in pooled, O_7 (Vermicompost @ 5 t ha^{-1}) was observed to be significantly highest with a recorded protein content of 39.67%, which was statistically at par with O_3 (FYM @ 10 t ha^{-1}) (39.58%) and O_5 (Poultry manure @ 5 t ha^{-1}) (39.36%); while O_1 (Control) was recorded with the least protein content of 31.60%, respectively.

Further evaluation of the pooled data indicated that the protein content in the seed reported a rise of 25.60% over O_1 with the application of O_7 and 25.25% over O_1 with the application of O_3. This could be due to better availability of desired and required nutrients in the crop root zone resulting from its solubilisation caused by the organic acids produced from the decaying organic matter and also the increased uptake by soybean root due to their association with mycorrhizal filaments increasing the ascribing area of roots. The presence of sulphur in SSP was also involved in the synthesis of fatty acids which increases the protein quality through the synthesis of certain amino acids such as cysteine, cystine and methionine (Devi *et al.,* 2013). Gao *et al.* (2020) also reported that the quality of the grain was enhanced because of better uptake of vital nutrients, resulting in healthier and better-developed seeds with increased levels of amino acids, starch, carbohydrates, and proteins. The results are in conformity with the findings of Meena *et al.* (2023b).

Thus, the application of organic manures enhanced the nutrient content in the seed which thereby increased the protein content as compared to control.

4.4.1.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the protein content is presented in Table 4.14(b). A critical study of the data revealed significant variations because of the treatments, ranging from 31.50% to 39.97% in 2021; 31.61% to 40.32% in 2022 and 31.56% to 40.14% in pooled, respectively.

In the 1st experimental trial, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was observed with the maximum protein content of 39.97% and was statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}), C_1O_5 (Bench terrace + Poultry manure @ 5 t ha^{-1}) and C_1O_9 (Bench terrace + Enriched compost @ 5 t ha^{-1}) with recorded protein content of 39.93%, 39.68% and 39.58%, respectively. For 2022 and in pooled, the maximum protein content was also perceived in treatment C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a value of 40.32% and 40.14%, respectively and was further observed to be statistically at par with C_1O_3 (Bench terrace+ FYM @ 10 t ha^{-1}) (40.24% and 40.08%). In both the experimental years, the lowest protein content (31.50% and 31.61%) was recorded in C_2O_1 (Control), which was significantly at par with C_1O_1 (Control) with a protein content of 31.55% and 31.73%, respectively. Likewise, the pooled data was also reported lowest in C_2O_1 (Control) with a protein content of 31.56% and was significantly at par with C_1O_1 (Control) with a protein content of 31.64%, respectively.

Further observation reported that the addition of organic manures within conservation practice (C_1O_2 to C_1O_9) at a higher recommended dose significantly enhanced the nitrogen and sulphur content which thereby increased the overall protein content in seed in comparison to treatments carried out in non-conservation practice (C_2O_2 to C_2O_9) and control (C_1O_1 and C_2O_1) during both the years of experimentation. Additionally, the pooled data showed that protein content in seed had an upsurge of 27.19% and 27.00% over C_2O_1 and

5.49% and 5.34% over C_2O_9 with the application of C_1O_7 and C_1O_3. This may be due to the combined effect of terracing and organic manure, as terrace changed the slope of farmland thereby reducing soil erosion, and increasing rainfall infiltration which significantly improves surface soil moisture and thereby growth, yield of soybean seed and application of organic manures improved nodulation which increases the nutrient uptake, improved aeration, and microclimate of rhizosphere (Ali *et al*., 2019) thereby increasing the protein content of seed. Similar findings were reported by Kuotsu and Singh (2021) and Bhutto *et al.* (2023).

4.4.2. Oil content

The two-year experimental data and average pooled on the impact of conservation practices and organic manures on the oil content of the seed after harvest, including their interaction, are presented in Table 4.14(a) and 4.14(b), respectively.

4.4.2.1. Effect of conservation practice on oil content

As was apparent from Table 14(a), it was observed that in both the years of the experiment, the oil content was recorded significantly maximum under C_1 (Bench terrace) with values logged at 18.77% and 18.95%, respectively along with the pooled average recorded at 18.86%. Meanwhile, the lowest oil content was recorded in C_2 (Non-terrace) with an oil content of 18.35% and 18.42%, along with a recorded pooled data of 18.38%, respectively. From this observation, an augmented pooled oil content of 2.61% could be deduced over C_2. Our findings corroborate with that of Moushani *et al.* (2021) whereby oil content in soybean fields under a conservation cropping system (20.0 ± 10.26%) was higher over the soybean fields under a conventional cropping system (19.0 ± 22.15%).

4.4.2.2. Effect of organic sources on oil content

The effect of different organic sources on oil content is presented in Table 4.14(a). Significant variations were apparent as per data in view of the oil content of seed in both years, with values ranging from 17.32% to 19.16% in 2021; 17.37% to 19.47% in 2022 and 17.35% to 19.31% in pooled, respectively.

The oil content in both years was noted significantly highest over the rest of the organic sources in O_7 (Vermicompost @ 5 t ha^{-1}) with values recorded at 19.16% and 19.47%, which was followed by source O_3 (FYM @ 10 t ha^{-1}) with an oil content of 19.03% and 19.25%, respectively. The least oil content in both the experimental years was observed in O_1 (Control) with an oil content of 17.32% and 17.37%, respectively. Likewise, for the pooled data, O_7 (Vermicompost @ 5 t ha^{-1}) was also recorded with a significantly highest oil content of 19.13%, followed by O_3 (FYM @ 10 t ha^{-1}) (19.14%) and the least was observed in O_1 (Control) with an oil content of 17.35%, respectively.

A critical investigation of the data further conveyed that application of O_7 (Vermicompost @ 5 t ha^{-1}) and O_3 (FYM @ 10 t ha^{-1}) augmented the pooled oil content by 11.30% and 10.32% over O_1 (Control) and 4.83% and 3.91% over O_8 (Enriched compost @ 2.5 t ha^{-1}). The increase in oil content might be because of the application of organic sources that contained comparatively high levels of macro and micronutrients which improved the quality production of the soybean seed over that of control, thus, proving that organic fertilisers have a significant effect on the oil content and fatty acid composition of oil crops. Our result corroborates with that of Mohammadi (2015) whereby the application of organic manure alone increased the oil yield of soybean due to increased oleic acid. Another study showed that vermicompost regulates the ratio of omega-3 and omega-6 essential fatty acids, provides a lower LA/ALA (linoleic acid/linolenic acid) ratio, and increases the P/S ratio (polyunsaturated fatty acids/saturated fatty acids), thus increasing the oil yield and oil content 34.85% and 33.67%

over control (Makkar *et al*., 2019). Similar results were put up by Ma *et al.* (2024).

4.4.2.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on oil content is presented in Table 4.14(b). Significant variations between the treatments were observed, with values ranging from 17.22% to 19.51% in the year 2021; 17.26% to 19.97% in 2022 and 17.24% to 19.74% in the pooled, respectively.

In both the initial and final experimental year, the highest oil content was recorded in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with an oil content of 19.51% and 19.97% and was observed to be significantly higher over the rest of the treatments. Followed by C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (19.27%) which was statistically at par with C_1O_5 (Bench terrace + Poultry manure @ 5 t ha^{-1}) with an oil content of 19.12% as per initial year data while in the final year C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (19.67%) was observed to be second highest and superior over the rest. Similarly in the pooled data, C_1O_7 (Bench terrace+ Vermicompost @ 5 t ha^{-1}) was observed to be significantly higher than all the other treatments with an oil content of 19.74%, which was followed by C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (19.47%), respectively. In both experimental years, the oil content was observed to be significantly lowest in C_2O_1 (Control) with an oil content of 17.22% and 17.26%. Likewise, the pooled data was also reported significantly lowest in C_2O_1 (Control) with an oil content of 17.24%, respectively.

Practising conservation for cultivation in the form of bench terrace and with-it organic manure incorporation greatly influenced the overall results, increasing the oil content over the practice of non-terrace. Further investigation of the pooled data reported an increase in the oil content of seed by 14.50% over

C_2O_1, 13.12% over C_2O_1, 8.34% over C_2O_8 and 8.05% over C_2O_4 with the application of C_1O_7, also an upsurge of 12.94% over C_2O_1, 11.58% over C_2O_1, 6.86% over C_2O_8 and 6.57% over C_2O_4 with the application of C_1O_3. Kuotsu and Singh (2021) reported that the increase in oil content might be attributed to balanced nutrition and supply of organic nutrients which increased the conversion of primary fatty acids metabolites to end products of fatty acid and the conservation practice further allowed the soil to be conserved leading to a proper and balanced absorption of the organic nutrients. A similar report was reported by Alzamel *et al.* (2022) stating that when organic fertilizer was used as a nitrogen source, the oil content of sunflower (*Helianthus annuus* L.) seeds was significantly increased.

Table 4.14(a): Effect of conservation practice and organic manures on protein content and oil content of soybean

TREATMENT	Protein content (%)			Oil content (%)		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	38.38	38.59	38.49	18.77	18.95	18.86
C_2 - Non-terrace	37.67	37.98	37.83	18.35	18.42	18.38
SEm±	0.03	0.04	0.02	0.02	0.02	0.02
CD (P=0.05)	0.21	0.21	0.10	0.15	0.15	0.07
CV	0.46	0.48	0.47	0.68	0.67	0.68
ORGANIC SOURCES						
O_1 - Control	31.53	31.67	31.60	17.32	17.37	17.35
O_2 - FYM @ 5 t ha^{-1}	38.44	38.66	38.55	18.49	18.57	18.53
O_3 - FYM @ 10 t ha^{-1}	39.40	39.77	39.58	19.03	19.25	19.14
O_4 - Poultry manure @ 2.5 t ha^{-1}	38.28	38.45	38.37	18.38	18.49	18.43
O_5 - Poultry manure @ 5 t ha^{-1}	39.22	39.50	39.36	18.86	18.95	18.91
O_6 - Vermicompost @ 2.5 t ha^{-1}	38.51	38.77	38.64	18.57	18.64	18.61
O_7 - Vermicompost @ 5 t ha^{-1}	39.49	39.89	39.69	19.16	19.47	19.31
O_8 - Enriched compost @ 2.5 t ha^{-1}	38.21	38.41	38.31	18.38	18.46	18.42
O_9 - Enriched compost @ 5 t ha^{-1}	39.15	39.47	39.31	18.85	18.94	18.90
SEm±	0.10	0.08	0.06	0.04	0.04	0.03
CD (P=0.05)	0.29	0.22	0.18	0.11	0.13	0.08
CV	0.65	0.48	0.57	0.51	0.58	0.55

Table 4.14(b): Interaction effect of conservation practice and organic manures on protein content and oil content of soybean

TREATMENTS	Protein content (%)			Oil content (%)		
	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	31.55	31.73	31.64	17.42	17.48	17.45
C_1O_2	38.83	38.96	38.90	18.69	18.80	18.75
C_1O_3	39.93	40.24	40.08	19.27	19.67	19.47
C_1O_4	38.52	38.67	38.59	18.50	18.69	18.60
C_1O_5	39.68	39.94	39.81	19.12	19.21	19.17
C_1O_6	38.84	38.97	38.91	18.80	18.85	18.82
C_1O_7	39.97	40.32	40.14	19.51	19.97	19.74
C_1O_8	38.51	38.63	38.57	18.57	18.68	18.63
C_1O_9	39.58	39.88	39.73	19.07	19.18	19.13
C_2O_1	31.50	31.61	31.56	17.22	17.26	17.24
C_2O_2	38.05	38.35	38.20	18.28	18.35	18.32
C_2O_3	38.86	39.30	39.08	18.78	18.83	18.81
C_2O_4	38.05	38.23	38.14	18.25	18.28	18.27
C_2O_5	38.77	39.07	38.92	18.61	18.69	18.65
C_2O_6	38.19	38.57	38.38	18.34	18.43	18.39
C_2O_7	39.01	39.46	39.24	18.81	18.96	18.88
C_2O_8	37.90	38.20	38.05	18.19	18.24	18.22
C_2O_9	38.72	39.07	38.89	18.63	18.70	18.67
SEm±	0.14	0.11	0.09	0.05	0.06	0.04
CD (P=0.05)	0.41	0.31	0.25	0.16	0.18	0.12

4.5. Plant analysis

4.5.1. Nutrient content in seed and stover

The two-year experimental data and the pooled average pertaining to the effect of conservation practices and organic manures including their interaction, in relation to the nitrogen, phosphorus, potassium and sulphur content in seed and stover after harvest are presented in Tables 4.15(a) and 4.15(b), Tables 4.16(a) and 4.16(b), respectively.

4.5.1.1. Nitrogen content in seed and stover

The data on the nitrogen content in seed and stover are presented in Tables 4.15(a) and 4.15(b). As per the report, the incorporation of organic sources particularly vermicompost and FYM at a dose of 5 t ha^{-1} and 10 t ha^{-1} in addition to the use of conservation practice in the form of bench terrace significantly influenced the treatments overall thereby increasing the content of nitrogen in both seed and stover over the use of the non-conservation practice.

4.5.1.1.1. Effect of conservation practice on nitrogen content in seed and stover

A perusal of the data from Table 4.15(a) revealed C_1 (Bench terrace) to be significantly highest with a nitrogen content of 6.14% and 6.17%, along with the pooled average of 6.16%. The lowest was recorded from C_2 (Non-terrace) with values noted at 6.03% and 6.08%, along with the pooled average of 6.05%, respectively. A critical examination of the data showed an augmented pooled nitrogen content of 1.82% over C_2 (Non-terrace).

Similarly, in the case of nitrogen content in stover, C_1 (Bench terrace) was observed to be significantly highest in both the years of the experiment, with nitrogen content of 1.37% in 2021, 1.39% in 2022, along with the pooled average of 1.38%. The lowest in both the experimentation was also recorded in C_2 (Non-terrace) with values recorded at 1.31% and 1.34% along with the pooled average of 1.33%, respectively. A critical examination of the data revealed that conservation practice augmented pooled nitrogen content in stover by 3.76% over C_2 (Non-terrace) as terracing increases the moisture by avoiding water loss and effectively enhancing the crop's endurance to droughts and consequently increases crop yield and higher nutrient content (Deng *et al.,* 2021).

Further, as per the report, practising conservation measures in the form of bench terraces for cultivation significantly influenced the treatments overall thereby increasing the content of nitrogen in seed and stover over the use of non-conservation practice.

4.5.1.1.2. Effect of organic sources on nitrogen content in seed and stover

The effect of different organic sources on nitrogen content in seed and stover is presented in Table 4.15(a). It was apparent from the data that there were significant variations in the content of nitrogen in both seed and stover during the years 2021 and 2022 with respect to different organic sources, ranging from (5.04% to 6.32%) and (1.11% to 1.42%) in 2021; (5.07% to 6.38%) and (1.12% to 1.45%) in 2022 and (5.06% to 6.35%) and (1.12% to 1.43%) in pooled, respectively. In 2021, the nitrogen content in seed was noted highest (6.32%) in O_7 (Vermicompost @ 5 t ha^{-1}), which was significantly at par with O_3 (FYM @ 10 t ha^{-1}) and O_5 (Poultry manure @ 5 t ha^{-1}) with a nitrogen content of 6.30% and 6.28%. While in the succeeding year and pooled, O_7 (Vermicompost @ 5 t ha^{-1}) was observed to be significantly highest with a nitrogen content of 6.38% and 6.35% and was further observed to be statistically at par with O_3 (FYM @ 10 t ha^{-1}) (6.36% and 6.33%). The least nitrogen content in both the experimental years as well as pooled were observed in O_1 (Control) with content of 5.04%, 5.07% and 5.06%, respectively. Further evaluation of the pooled data indicates an increased content of nitrogen in seed by 25.49% over O_1 and 3.59% over O_8

with the application of O_7, 25.10% over O_1 and 3.26% over O_8 with the application of O_3.

In the case of stover, the recorded data of the experimentation showed that amongst the organic sources, the nitrogen content was noted significantly highest in O_7 (Vermicompost @ 5 t ha^{-1}) with a nitrogen content of 1.42% in 2021, 1.45% in 2022 and 1.43% in pooled whereas, the least nitrogen content in both the experimental years as well as pooled were observed in O_1 (Control) with content of 1.11%, 1.12% and 1.12%, respectively. The application of poultry manure and enriched compost enhanced the nitrogen content in stover as compared to control. It was further observed that application of vermicompost and FYM especially at a higher dose enhances the nitrogen content in stover significantly over poultry manure and enriched compost. Further evaluation of the pooled data indicated that nitrogen content in stover increased to 27.68% over O_1 and 5.93% over O_4 and O_8 with O_7 and 25.89% over O_1 and 4.44% over O_4 and O_8 with O_3.

Though the application of poultry manure and enriched compost enhanced the nitrogen content in seed as compared to the control, it was observed that vermicompost as well as FYM application especially at a higher dose best enhances the nitrogen content in seed and does significantly better over poultry manure and enriched compost. Gangwar *et al*. (2023) reported a significantly highest concentration of N, P and K by seed and stover with the use of vermicompost as compared to control due to the ability of the vermicompost to accelerate the availability of nutrients in the soil, through a faster overhaul of organic matter and the availability of growth hormones that accelerate plant growth besides fulvic acid and humic acid contained in organics which bind toxic substances in the soil. The above findings corroborate those of Meena *et al*. (2022b) and Meena *et al.* (2023b).

4.5.1.1.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on nitrogen content in seed and stover is presented in Table 4.15(b). Here, significant variations between the treatments were observed, ranging from (5.04% to 6.40%) and (1.10% to 1.45%) in the year 2021; (5.06% to 6.45%) and (1.12% to 1.50%) in 2022 and (5.05% to 6.42%) and (1.11% to 1.48%) in pooled. During 2021, the maximum nitrogen content in seed (6.40%) was recorded in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}), which was observed to be statistically at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (6.39%) and C_1O_5 (Bench terrace + Poultry manure @ 5 t ha^{-1}) (6.35%). While in 2022 and in pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (6.45% and 6.42%) was also deemed maximum and was significantly at par only with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (6.44% and 6.41%). In both the experimental years, the nitrogen content was observed lowest in C_2O_1 (Control) with a nitrogen content of 5.04% and 5.06%, which was also reported to be significantly at par with treatment C_1O_1 (Control) (5.05% and 5.08%). Likewise, the pooled data was also reported as significantly lowest in C_2O_1 (Control) with a nitrogen content of 5.05% and was also significantly at par with C_1O_1 (Control) (5.06%), respectively. A deeper analysis of the data further conveyed that the application of C_1O_7 and C_1O_3 augmented pooled nitrogen content in seed by 27.13% and 26.93% over C_2O_1 and 5.42% and 5.25% over C_2O_8.

For stover, in the initial experimental trial, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (1.45%) was observed with the highest nitrogen content and was significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (1.43%). However, in the succeeding year, the highest nitrogen content was reported in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (1.50%), which was also statistically higher than the rest of the treatments. This was also the same for the pooled data where the highest significant nitrogen content was recorded in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a content of 1.48%. In both the experimental years, the nitrogen content was observed to be considerably lowest in C_2O_1 (Control) with a nitrogen content of 1.10% in 2021, 1.12% in 2022 and 1.11% in pooled. From the pooled data it was observed that N content in stover increased by 33.33% and 30.97% over C_2O_1 and C_1O_1 with the application of C_1O_7 and an increase of 29.73% and 27.43% over C_2O_1 and $C_1O_1$with application of C_1O_3.

Soybean being a legume crop may have aided in the abundant availability of N thus leading to more uptake. Also, minimal stress due to conserved practice directly influences root growth plus the addition of organic manures improves the soil quality and root conditions and subsequently increases the nutrient content and uptake. The above findings corroborate those of Heidari *et al.* (2020), Feilinezhad *et al.* (2022), Meena *et al.* (2022a), Lv *et al.* (2023), Meena *et al.* (2023a), Verma *et al.* (2023) and Chen *et al.* (2024).

4.5.1.2. Phosphorus content in seed and stover

The data regarding the phosphorus content in seed and stover is presented in Tables 4.15(a) and 4.15(b). The results showed that with application of organic manures particularly vermicompost and FYM in addition to the use of conservation practice in the form of bench terrace significantly increased the phosphorus content in seed and stover over the use of non-conservation practice.

4.5.1.2.1. Effect of conservation practice on phosphorus content in seed and stover

As per examination of the data from Table 4.15(a), C_1 (Bench terrace) was found significantly highest in both the experiment trials with a phosphorus content of 0.45% and 0.47%, respectively along with the pooled data recorded at 0.46%. The lowest was statistically recorded from C_2 (Non-terrace) with values of 0.44% and 0.45%, and pooled data of 0.44%, respectively. A critical analysis of the data reported an increase with the use of conservation practice in the phosphorus content by 4.55% over C_2 (Non-terrace).

Similar results were observed in the case of phosphorus content in stover with respect to the conservation practices. C_1 (Bench terrace) was depicted as significantly highest in both the experimentation period with the phosphorus content of 0.22% and 0.23%, respectively along with the pooled data recorded at 0.22%. Meanwhile, the lowest phosphorus content was observed in C_2 (Non-terrace) with recorded values of 0.19% in 2021, 0.21% in 2022 and 0.20% in pooled, respectively.

Conservation practice enhanced the supply of nutrients and increased the P content in both seed and stover for their effective uptake. The higher content of phosphorus may be attributed to the higher yield obtained under these plots as nutrient uptake is a function of yield and nutrient content. The above results corroborate the findings of Deng *et al.* (2021).

4.5.1.2.2. Effect of organic sources on phosphorus content in seed and stover

The effect of different organic sources on phosphorus content in seed and stover is presented in Table 4.15(a). Here, significant variations were observed in both the experimental trials with respect to different organic sources, with values ranging from (0.35% to 0.49%) and (0.15% to 0.23%) in 2021; (0.36% to 0.51%) and (0.16% to 0.26%) in 2022 and (0.35% to 0.50%) and (0.15% to 0.24%) in pooled, respectively.

The highest phosphorus content in seed in the initial year was perceived in O_7 (Vermicompost @ 5 t ha^{-1}) with a value of 0.49% and was observed to be significantly at par with O_3 (FYM @ 10 t ha^{-1}) (0.48%). However, in the final year and in pooled, O_7 (Vermicompost @ 5 t ha^{-1}) was observed to be significantly higher over the rest with values noted as 0.51% in 2022 and 0.50%

in pooled. On the other hand, phosphorus content was deemed significantly lowest O_1 (Control) (0.35% and 0.36%) in both the experimental years as well as in the pooled (0.35%), respectively thereby showing that it was statistically the lowest amongst all the other sources. An augmented pooled data of phosphorus content in seed after the thorough examination was observed to be 42.86% and 37.14% over O_1 and 16.28% and 11.62% over O_8 with the application of O_7 and O_3, respectively.

Likewise, for stover, O_7 (Vermicompost @ 5 t ha^{-1}) was deemed significantly highest during the whole experimental trial as well as in pooled with recorded maximum phosphorus content of 0.23%, 0.26% and 0.24%, respectively and were observed to be considerably higher than the rest of the organic sources. Nonetheless, phosphorus content in stover was perceived to be significantly lowest in O_1 (Control) (0.15% and 0.16%) in the whole experimental years as well as in pooled (0.15%), respectively. A deeper investigation of the pooled data reported an increase in the phosphorus content in stover by 60.00% and 53.33% over control with the application of O_7 and O_3. The concentration of phosphorus in soil increased because of increased microbial content in soil due to organic formulation by lowering soil pH and thereby more uptake by plants.

Meena *et al.* (2023b) explained that with the application of vermicompost, there was an expected increase in the availability of phosphorus to the plant as a result the content of phosphorus in the plant also increased, which was due to the better buffering capacity of vermicompost for incipient moisture stress and improving phosphorus availability to the plant. Similar results on the phosphorus content in seed and stover were reported by Age *et al.* (2019), Azad *et al.* (2022) and Gangwar *et al*. (2023).

4.5.1.2.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on phosphorus content in seed and stover is presented in Table 4.15(b). Significant variations were observed among the treatments with values ranging from (0.35% to 0.51%) and (0.15% to 0.25%) in the initial year; (0.35% to 0.53%) and (0.16% to 0.28%) in the final year and (0.35% to 0.52%) and (0.16% to 0.26%) in pooled, respectively. As per results obtained from both the experimental trials, the phosphorus content in seed was recorded statistically highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (0.51% and 0.53%), with the pooled value of 0.52%. Again in the initial year, the phosphorus content was observed significantly lower in both C_2O_1 (Control) and C_1O_1 (Control) with a similar value of 0.35%. However from the final recorded data and pooled, C_1O_1 (Control) (0.35%) was reported least and was also significantly at par with C_2O_1 (Control) (0.36%), respectively. Further evaluation indicated an increase in pooled content of phosphorus by 48.57% and 40.00% over C_2O_1 (Control) and 23.81% and 16.67% over C_2O_4 (Non-terrace + Poultry manure @ 2.5 t ha^{-1}) and C_2O_8 (Non-terrace + Enriched compost @ 2.5 t ha^{-1}) with application of vermicompost @ 5 t ha^{-1} and FYM @ 10 t ha^{-1} in conjunction with bench terrace.

As per the recorded data for stover, the highest phosphorus content in both the experimental trials was recorded in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (0.25% and 0.28%); which was also observed to be significantly higher than all the other organic sources. Similarly, in the pooled data C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with a phosphorus content of 0.26% was also observed to be significantly higher over the rest of the treatments. C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) was reported second highest with a pooled value of 0.25%. On the other hand, the phosphorus content in stover was observed to be significantly lowest in C_1O_1 (Control) and C_2O_1

(Control) during both the experimental years, with recorded data of 0.15% each in the initial year and 0.16% in the final year respectively, while in pooled the phosphorus content was observed to be significantly lowest in C_2O_1 (Control) with a value of 0.15%. Further evaluation indicated an increase in phosphorus content in stover by 73.33% and 66.67% over control on application of vermicompost @ 5 t ha^{-1} and FYM @ 10 t ha^{-1} in conjunction with bench terrace over control.

This increasing content of phosphorus might be due to the improved nutritional environment in the rhizosphere by the combined use of conservation practice and incorporation of organic manures in the soil as well as its utilization in the plant system leading to enhanced translocation to reproductive structures and plant parts. Higher nutrient uptake with organic manure application is attributed to the solubilization of native nutrients, chelation of complex intermediate organic manure molecules produced during the decomposition of added organic manures, their mobilization, and accumulation of different nutrients in different plant parts, thereby higher content (Yadav *et al*., 2013). Our findings agree with those of Kumbhar *et al.* (2021), Feilinezhad *et al.* (2022), Meena *et al.* (2022a), Lv *et al.* (2023), Verma *et al.* (2023) and Chen *et al.* (2024).

Table 4.15(a): Effect of conservation practice and organic manures on nitrogen and phosphorus content in seed and stover

TREATMENTS	Nitrogen content (%)						Phosphorus content (%)					
	Seed			Stover			Seed			Stover		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	6.14	6.17	6.16	1.37	1.39	1.20	0.45	0.47	0.46	0.22	0.23	0.22
C_2 - Non-terrace	6.03	6.08	6.05	1.31	1.34	1.16	0.44	0.45	0.44	0.19	0.21	0.20
SEm±	0.005	0.006	0.004	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	0.033	0.034	0.015	0.009	0.014	0.007	0.009	0.004	0.003	0.005	0.007	0.003
CV	0.463	0.478	0.471	0.596	0.856	0.740	1.716	0.706	1.297	1.988	2.591	2.333
ORGANIC SOURCES												
O_1 - Control	5.04	5.07	5.06	1.11	1.12	0.92	0.35	0.36	0.35	0.15	0.16	0.15
O_2 - FYM @ 5 t ha^{-1}	6.15	6.19	6.17	1.36	1.39	1.19	0.46	0.48	0.47	0.20	0.22	0.21
O_3 - FYM @ 10 t ha^{-1}	6.30	6.36	6.33	1.39	1.43	1.24	0.48	0.49	0.48	0.22	0.25	0.23
O_4 - Poultry manure @ 2.5 t ha^{-1}	6.13	6.15	6.14	1.33	1.36	1.18	0.43	0.44	0.44	0.19	0.21	0.20
O_5 - Poultry manure @ 5 t ha^{-1}	6.28	6.32	6.30	1.38	1.41	1.22	0.46	0.48	0.47	0.21	0.22	0.22
O_6 - Vermicompost @ 2.5 t ha^{-1}	6.16	6.20	6.18	1.37	1.39	1.20	0.47	0.48	0.47	0.21	0.23	0.22
O_7 - Vermicompost @ 5 t ha^{-1}	6.32	6.38	6.35	1.42	1.45	1.26	0.49	0.51	0.50	0.23	0.26	0.24
O_8 - Enriched compost @ 2.5 t ha^{-1}	6.11	6.15	6.13	1.33	1.36	1.18	0.42	0.44	0.43	0.19	0.20	0.20
O_9 - Enriched compost @ 5 t ha^{-1}	6.26	6.32	6.29	1.37	1.39	1.22	0.44	0.46	0.45	0.21	0.23	0.22
SEm±	0.016	0.012	0.010	0.005	0.003	0.004	0.002	0.004	0.002	0.001	0.002	0.001
CD (P=0.05)	0.046	0.035	0.028	0.015	0.008	0.010	0.006	0.012	0.007	0.003	0.004	0.003
CV	0.647	0.482	0.570	0.980	0.473	0.765	1.198	2.266	1.830	1.229	1.683	1.492

Table 4.15(b): Interaction effect of conservation practice and organic manures on nitrogen and phosphorus content in seed and stover

TREATMENTS	Nitrogen content (%)						Phosphorus content (%)					
	Seed			Stover			Seed			Stover		
	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	5.05	5.08	5.06	1.13	1.13	1.13	0.35	0.36	0.36	0.15	0.16	0.16
C_1O_2	6.21	6.23	6.22	1.38	1.42	1.40	0.47	0.49	0.48	0.22	0.23	0.22
C_1O_3	6.39	6.44	6.41	1.43	1.46	1.44	0.49	0.50	0.49	0.24	0.27	0.25
C_1O_4	6.16	6.19	6.17	1.36	1.39	1.37	0.44	0.46	0.45	0.21	0.22	0.22
C_1O_5	6.35	6.39	6.37	1.41	1.43	1.42	0.46	0.49	0.47	0.23	0.24	0.23
C_1O_6	6.21	6.24	6.23	1.39	1.42	1.41	0.47	0.49	0.48	0.23	0.24	0.23
C_1O_7	6.40	6.45	6.42	1.45	1.50	1.48	0.51	0.53	0.52	0.25	0.28	0.26
C_1O_8	6.16	6.18	6.17	1.35	1.39	1.37	0.43	0.45	0.44	0.21	0.22	0.22
C_1O_9	6.33	6.38	6.36	1.40	1.42	1.41	0.45	0.47	0.46	0.22	0.24	0.23
C_2O_1	5.04	5.06	5.05	1.10	1.12	1.11	0.35	0.35	0.35	0.15	0.16	0.15
C_2O_2	6.09	6.14	6.11	1.33	1.37	1.35	0.45	0.46	0.46	0.19	0.21	0.20
C_2O_3	6.22	6.29	6.25	1.36	1.40	1.38	0.47	0.47	0.47	0.21	0.23	0.22
C_2O_4	6.09	6.12	6.10	1.31	1.34	1.32	0.42	0.43	0.42	0.17	0.20	0.19
C_2O_5	6.20	6.25	6.23	1.34	1.38	1.36	0.45	0.46	0.46	0.19	0.21	0.20
C_2O_6	6.11	6.17	6.14	1.34	1.37	1.35	0.46	0.47	0.47	0.20	0.22	0.21
C_2O_7	6.24	6.31	6.28	1.38	1.40	1.39	0.48	0.49	0.49	0.21	0.24	0.22
C_2O_8	6.06	6.11	6.09	1.31	1.33	1.32	0.41	0.43	0.42	0.17	0.18	0.18
C_2O_9	6.19	6.25	6.22	1.33	1.36	1.34	0.43	0.45	0.44	0.19	0.21	0.20
SEm±	0.023	0.017	0.014	0.008	0.004	0.004	0.003	0.006	0.003	0.001	0.002	0.001
CD (P=0.05)	0.066	0.049	0.040	0.022	0.011	0.012	0.009	0.017	0.010	0.004	0.006	0.004

4.5.1.3. Potassium content in seed and stover

The data regarding the potassium content in seed and stover of soybean are presented in Tables 4.16(a) and 4.16(b). A critical examination of the data shows that potassium content in seed and stover increased significantly with the application of vermicompost and FYM in addition to the use of conservation practice in the form of a bench terrace.

4.5.1.3.1. Effect of conservation practice on potassium content in seed and stover

Regarding the potassium content in seed, a perusal data from Table 4.16(a) revealed C_1 (Bench terrace) to be significantly superior during both seasons with a noted maximum potassium content of 1.47% and 1.48%, along with the pooled data recorded at 1.47%, while the lowest was recorded from C_2 (Non-terrace) with noted statistics of 1.44% and 1.45%, along with the pooled data of 1.45%, respectively. Similarly, for the potassium content in stover, C_1 (Bench terrace) was also found significantly highest with a noted maximum potassium content of 1.19% in 2021 and 1.21% in 2022, along with the pooled data recorded at 1.20%, and C_2 (Non-terrace) was recorded with the lowest potassium content with noted data of 1.15%, 1.16% and 1.16% in 2021, 2022 and pooled, respectively. Thus showing an increase in the pooled potassium content in seed of 1.36% over C_2 and stover of 3.45% over C_2.

Under conservation practices, soil organic matter increased, which contributes significantly to plant needs, especially during the early growth stages hence nutrient concentration in the surface soil layers was likely higher under conservation practices than under non-conservation practices. Also, the higher content of potassium in both seed and stover may be attributed to the higher yield obtained under these plots as nutrient uptake is a function of yield and nutrient content, hence conservation practice further enhanced the supply of nutrients and increased the N, P and K content in both seed and stover for their effective uptake. The above results corroborate the findings of Guzzetti *et al.* (2020) and Deng *et al.* (2021).

4.5.1.3.2. Effect of organic sources on potassium content in seed and stover

The effect of different organic sources on potassium content in seed and stover is presented in Table 4.16(a). Slight variations within the organic sources were evident in regards to the potassium content in seed and stover from the two-year experimental trials, with values ranging from (1.27% to 1.52%) and (0.91% to 1.25%) in 2021; (1.27% to 1.54%) and (0.92% to 1.27%) in 2022 and (1.27% to 1.53%) and (0.92% to 1.26%) in pooled, respectively.

The maximum potassium content in seed for both the years and in pooled was noted in O_7 (Vermicompost @ 5 t ha^{-1}), with recorded maximum potassium content of 1.52%,1.54% and 1.53%, respectively. It was followed by O_3 (FYM @ 5 t ha^{-1}). However, the lowest significant potassium content in both the experimental period and pooled was observed solely in O_1 (Control) with a similar recorded value of 1.27%, respectively. It was also observed that the incorporation of organic manures (O_2 to O_9) significantly enhanced the potassium content in the seed in comparison to Control (O_1). Further, from the pooled data it was observed that potassium content in seed increased by 20.47% and 18.11% over control with application of O_7 and O_3.

From the initial and final recorded data, the potassium content in stover was noted significantly highest in O_7 (Vermicompost @ 5 t ha^{-1}) (1.25% and 1.27%) followed by O_3 (FYM @ 5 t ha^{-1}) (1.23% and 1.25%). Similarly, the pooled data was recorded statistically highest in O_7 (Vermicompost @ 5 t ha^{-1}) (1.26%). In view of the significantly lowest potassium content in stover, O_1 (Control) was solely recorded in both the experimental period and pooled with a noted value of 0.91% in 2021 and 0.92% in both 2022 and pooled, respectively.

It was also observed that the application of organic manures (O_2 to O_9) significantly enhanced potassium content in stover in comparison to Control (O_1) during both years of experimentation. Further, from the pooled data it was observed that potassium content in stover increased by 36.96% and 34.78% over control with application of O_7 and O_3.

The higher availability of K may be due to the beneficial effect of organic manures on the reduction of potassium fixation thereby enhancing the content of K in grain and stover (Devi *et al.,* 2013). Gangwar *et al*. (2023) also reported a significantly higher concentration of N, P and K by seed and stover with the use of vermicompost as compared to control due to the ability of the vermicompost to accelerate the availability of nutrients in the soil. Similar results were reported by Lohar and Hase (2022).

4.5.1.3.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on potassium content in seed and stover is presented in Table 4.16(b). Significant variations in the potassium content in both seed and stover were observed within the treatments during the experimental period, with values ranging from (1.27% to 1.54%) and (0.91% to 1.27%) in 2021; (1.27% to 1.56%) and (0.92% to 1.30%) in 2022 and (1.27% to 1.55%) and (0.91% to 1.29%) in pooled, respectively.

Treatment C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was observed with the significantly highest potassium content in seed over the rest in both the experimental trials and also pooled with a potassium content of 1.54% in the initial and 1.56% in the final year and 1.55% in pooled, respectively, which was followed by C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (1.52%). On the other hand, the potassium content was deemed significantly lowest in both the experimental years as well as in pooled treatments C_1O_1 (Control) and C_2O_1

(Control) with similar potassium content values of 1.27%, respectively. It was also observed that the application of organic manures within conservation practice (C_1O_2 to C_1O_9) significantly enhanced potassium content in seed in comparison to treatments carried out in non-conservation practice (C_2O_2 to C_2O_9) and control (C_1O_1 and C_2O_1) during both the years of experimentation. Further, from the pooled data it was observed that potassium content in seed increased by 22.05% and 19.69% over C_1O_1 and C_2O_1 with the application of C_1O_7 and C_1O_3.

Similarly, the potassium content in stover was observed highest in treatment C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) during the whole experimentation with the maximum potassium content of 1.27% and 1.30%, which were perceived to be significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (1.25% and 1.28%), respectively. Similarly in the pooled, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) (1.29%) was also deemed highest and was observed to be significantly at par with C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) (1.27%), respectively. On the other hand, the potassium content was deemed significantly lowest in treatments C_1O_1 (Control) and C_2O_1 (Control) with similar potassium content value of 0.91% in the initial period, whereas for both the succeeding period and pooled, the lowest was observed in C_2O_1 (Control) with values recorded at 0.92% and 0.91% and were significantly at par with C_1O_1 (Control) (0.93% and 0.92%), respectively. It was also observed that the application of organic manures within conservation practice (C_1O_2 to C_1O_9) significantly enhanced potassium content in seed in comparison to treatments carried out in non-conservation practice (C_2O_2 to C_2O_9) and control (C_1O_1 and C_2O_1) during both the years of experimentation. Further, from the pooled data it was observed that potassium content in stover increased by 41.76% and 39.56% over C_2O_1 and by 11.21% and 9.48% over C_2O_4 and C_2O_8 with the application of C_1O_7 and C_1O_3.

The increased potassium content in seed and stover may be due to the ample availability of nutrients in the soil and the positive interaction between the conservation practice and organic fertilizers. Similar results were reported by Heidari *et al*. (2020), Meena *et al.* (2022a), Verma *et al.* (2023) and Chen *et al.* (2024).

4.5.1.4. Sulphur content in seed and stover

The data regarding the sulphur content in seed and stover of soybean are presented in Tables 4.16(a) and 4.16(b). The results of the data reported that with application of organic manures particularly vermicompost and FYM in addition to the use of conservation practice in the form of bench terraces significantly increased the sulphur content in seed and stover.

4.5.1.4.1. Effect of conservation practice on sulphur content in seed and stover

Evaluated data on sulphur content in seed from Table 4.16(a) revealed C_1 (Bench terrace) to be significantly highest in both the years of experimentation and pooled, with recorded sulphur content of 0.25%, 0.27% and 0.26%, respectively and C_2 (Non-terrace) with the lowest sulphur content with recorded values of 0.24% in 2021 and 0.25% in 2022, along with the pooled at 0.24%, respectively. A critical examination of the data revealed that with conservation practice an augmented pooled sulphur content in seeds of 8.33% over C_2 (Non-terrace).

Similarly in the sulphur content in stover, C_1 (Bench terrace) was also observed to be significantly highest in both the years and pooled, with recorded sulphur content of 0.30%, 0.31% and 0.30%, respectively, while the sulphur content was recorded significantly lowest from C_2 (Non-terrace) with values noted at 0.28% and 0.29%, along with the pooled at 0.28%, respectively. A critical examination of the data revealed an augmented pooled sulphur content of 7.14% over C_2 when conservation practice is in use.

Conservation practices bring about a greater amount of water-stable aggregates and organic matter in the surface soil layers, consequently boosting soil water-holding capacity and infiltration rate. The increase in organic matter in the soil contributes significantly to plant growth, thus higher nutrient concentration in the surface soil layers. Also, the higher content of sulphur in both seed and stover was attributed to the higher yield obtained under these plots as nutrient uptake is a function of yield and nutrient content. Thus, conservation practice further enhanced the supply of nutrients and increased the sulphur content in both seed and stover. The above results corroborate the findings of Guzzetti *et al.* (2020), Chen *et al*. (2021) and Deng *et al.* (2021).

4.5.1.4.2. Effect of organic sources on sulphur content in seed and stover

The effect of different organic sources on sulphur content in seed and stover is presented in Table 4.16(a). Irrespective of the years the sulphur content in seed as per the table revealed significant variations because of applications of organic sources with values ranging from (0.19% to 0.28%) and (0.25% to 0.32%) in the initial year, (0.19% to 0.31%) and (0.25% to 0.34%) in the succeeding year and (0.19% to 0.30%) and (0.25% to 0.33%) in pooled, respectively.

For the initial year, the maximum sulphur content was perceived in sources O_7 (Vermicompost @ 5 t ha^{-1}) (0.28%), which was significantly at par with O_3 (FYM @ 10 t ha^{-1}) with a sulphur content of 0.27%. However, in the succeeding year and pooled, O_7 (Vermicompost @ 5 t ha^{-1}) with a value of 0.31% and 0.30% was reported to be significantly highest, thus statistically superior over the remainders. Moreover, sulphur content was observed significantly lowest in O_1 (Control) for both the trials and pooled with similar logged data of

0.19%, respectively. Thus, O_7 (Vermicompost @ 5 t ha^{-1}) was perceived to be statistically superior over the rest of the organic sources. A deeper analysis of the data further conveyed that application of O_7 and O_3 augmented pooled sulphur content in seed by 57.89% and 47.37% over O_1 (Control) and 25.00% and 16.67% over O_8 (Enriched compost @ 2.5 t ha^{-1}) and O_4 (Poultry manure @ 2.5 t ha^{-1}).

Sources O_7 (Vermicompost @ 5 t ha^{-1}) (0.32% and 0.34%) as per the initial and final year recorded data, was perceived with the maximum sulphur content in stover. Similarly, the pooled data reported a higher sulphur content of 0.33% in O_7 (Vermicompost @ 5 t ha^{-1}). Moreover, O_1 (Control) was reported with a significantly lowest sulphur content in both the trials as well as in pooled with similar logged data of 0.25%, respectively. Thus, O_7 was perceived to be statistically higher over the rest of the organic sources which was followed by O_3 (FYM @ 10 t ha^{-1}) and O_5 (Poultry manure @ 5 t ha^{-1}). A deeper analysis of the data further conveyed that the application of O_7 augmented pooled sulphur content in stover by 32.00% over O_1 (Control). Likewise with the application of O_3 and O_5 an augmented pooled sulphur content of 24.00% was observed over O_1.

The increase in sulphur content in seed and stover was due to the native dissolution of sulphur, solubilized by the production of organic acids from the root region of the crop. Also, proper establishment of roots, higher absorption of mineral nutrients from the soil, transport of more nutrients to seeds, vigorous plant growth and higher seed and stover yields under proper availability of nutrients results in higher content of sulphur in seed and stover (Narendra *et al.,* 2023). Similar results were observed by Bezabeh *et al.* (2021).

4.5.1.4.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on sulphur content in seed and stover is presented in Table 4.16(b). Significant variations in the sulphur content in seed and stover during the experimental trials were observed, with values ranging from (0.18% to 0.30%) and (0.25% to 0.34%) in 2021; (0.19% to 0.33%) and (0.25% to 0.36%) in 2022 and (0.19% to 0.31%) and (0.25% to 0.35%) in pooled, respectively.

In both the experimental trials, the highest sulphur content in seed was recorded in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with values logged at 0.30% and 0.33%, respectively along with the pooled at 0.31%, which was also observed to be significantly superior over the rest of the treatments. C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) was reported second highest with a pooled value of 0.29%. The lowest sulphur content for both years was observed in C_2O_1 (Control) with values noted at 0.18% and 0.19% respectively, which was observed to be significantly at par with C_1O_1 (Control) (0.19% and 0.20%). The pooled data was however reported significantly lowest in both C_1O_1 (Control) and C_2O_1 (Control) with a similar sulphur content of 0.19%, respectively. Critical examinations of the pooled data further revealed that sulphur content in seed was enhanced by 63.16% and 52.63% with the application of C_1O_7 and C_1O_3 over C_2O_1 and 34.78% and 26.09% over C_2O_8.

The sulphur content in stover was observed to be highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) during both seasons with values recorded at 0.34% and 0.36%, respectively along with the pooled at 0.35%, thereby revealing to be statistically superior over the rest of the treatments. C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) was seen to be the second highest with a pooled value of 0.33%. In 2021, the sulphur content of stover was deemed significantly lowest in both C_1O_1 (Control) and C_2O_1 (Control) with a similar sulphur content value of 0.25%. However, in 2022 and in pooled, C_2O_1 (Control) with values noted at 0.25% each was reported lowest. Further observation in 2022 showed C_2O_1 (Control) to be significantly at par with C_1O_1 (Control) (0.26%), respectively. Critical examinations of the pooled data further revealed that sulphur content in stover was enhanced by 40.00% and 32.00% with the application of C_1O_7 and C_1O_3 over C_2O_1 and 25.00% and 17.86% over C_2O_8.

The improved plant growth and yield through enhanced plant nutrient availability facilitates higher uptake of nutrients from the soil and later its accumulation in the seeds (Chaithra and Hebsur, 2018) leading to an increased content of sulphur in seed and stover. Similar results were reported by Heidari *et al*. (2020), Meena *et al.* (2022a), Meena *et al.* (2022b), Verma *et al.* (2023) and Chen *et al.* (2024).

Table 4.16(a): Effect of conservation practice and organic manures on potassium and sulphur content in seed and stover

TREATMENT	Potassium content (%)						Sulphur content (%)					
	Seed			Stover			Seed			Stover		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	1.47	1.48	1.47	1.19	1.21	1.20	0.25	0.27	0.26	0.30	0.31	0.31
C_2 - Non-terrace	1.44	1.45	1.45	1.15	1.16	1.16	0.24	0.25	0.24	0.28	0.29	0.28
SEm±	0.001	0.001	0.001	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	0.006	0.005	0.003	0.016	0.015	0.007	0.005	0.006	0.002	0.005	0.003	0.002
CV	0.377	0.309	0.345	1.180	1.107	1.144	1.739	1.944	1.851	1.383	0.891	1.156
ORGANIC SOURCES												
O_1 - Control	1.27	1.27	1.27	0.91	0.92	0.92	0.19	0.19	0.19	0.25	0.25	0.25
O_2 - FYM @ 5 t ha^{-1}	1.47	1.48	1.47	1.19	1.20	1.19	0.24	0.26	0.25	0.29	0.29	0.29
O_3 - FYM @ 10 t ha^{-1}	1.50	1.51	1.50	1.23	1.25	1.24	0.27	0.29	0.28	0.31	0.31	0.31
O_4 - Poultry manure @ 2.5 t ha^{-1}	1.46	1.46	1.46	1.18	1.19	1.18	0.23	0.24	0.24	0.28	0.29	0.29
O_5 - Poultry manure @ 5 t ha^{-1}	1.48	1.49	1.49	1.21	1.23	1.22	0.26	0.26	0.26	0.30	0.32	0.31
O_6 - Vermicompost @ 2.5 t ha^{-1}	1.47	1.49	1.48	1.20	1.21	1.20	0.26	0.27	0.26	0.29	0.30	0.30
O_7 - Vermicompost @ 5 t ha^{-1}	1.52	1.54	1.53	1.25	1.27	1.26	0.28	0.31	0.30	0.32	0.34	0.33
O_8 - Enriched compost @ 2.5 t ha^{-1}	1.45	1.46	1.45	1.17	1.19	1.18	0.24	0.25	0.24	0.28	0.29	0.29
O_9 - Enriched compost @ 5 t ha^{-1}	1.48	1.48	1.48	1.21	1.22	1.22	0.24	0.26	0.25	0.30	0.31	0.30
SEm±	0.002	0.001	0.001	0.005	0.005	0.004	0.002	0.003	0.002	0.001	0.002	0.001
CD (P=0.05)	0.005	0.004	0.003	0.014	0.015	0.010	0.006	0.008	0.005	0.003	0.004	0.003
CV	0.296	0.236	0.267	1.041	1.107	1.075	2.230	2.520	2.389	0.910	1.247	1.097

Table 4.16(b): Interaction effect of conservation practice and organic manures on potassium and sulphur content in seed and stover

TREATMENTS	Potassium content (%)						Sulphur content (%)					
	Seed			Stover			Seed			Stover		
	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	1.27	1.27	1.27	0.91	0.93	0.92	0.19	0.20	0.19	0.25	0.26	0.26
C_1O_2	1.48	1.49	1.48	1.21	1.22	1.22	0.24	0.26	0.25	0.30	0.31	0.30
C_1O_3	1.51	1.53	1.52	1.25	1.28	1.27	0.28	0.31	0.29	0.32	0.33	0.33
C_1O_4	1.46	1.47	1.47	1.20	1.21	1.21	0.23	0.24	0.24	0.30	0.31	0.30
C_1O_5	1.49	1.50	1.50	1.23	1.25	1.24	0.26	0.28	0.27	0.31	0.32	0.32
C_1O_6	1.48	1.49	1.49	1.22	1.23	1.22	0.26	0.27	0.27	0.31	0.32	0.31
C_1O_7	1.54	1.56	1.55	1.27	1.30	1.29	0.30	0.33	0.31	0.34	0.36	0.35
C_1O_8	1.46	1.47	1.47	1.20	1.20	1.20	0.24	0.26	0.25	0.29	0.30	0.29
C_1O_9	1.49	1.50	1.50	1.23	1.24	1.23	0.25	0.27	0.26	0.31	0.32	0.31
C_2O_1	1.27	1.27	1.27	0.91	0.92	0.91	0.18	0.19	0.19	0.25	0.25	0.25
C_2O_2	1.46	1.47	1.46	1.16	1.18	1.17	0.24	0.25	0.24	0.28	0.28	0.28
C_2O_3	1.49	1.50	1.49	1.21	1.23	1.22	0.26	0.28	0.27	0.30	0.29	0.30
C_2O_4	1.45	1.46	1.45	1.15	1.16	1.16	0.23	0.24	0.24	0.27	0.28	0.27
C_2O_5	1.47	1.48	1.48	1.19	1.20	1.20	0.25	0.25	0.25	0.29	0.31	0.30
C_2O_6	1.46	1.48	1.47	1.17	1.18	1.18	0.25	0.26	0.25	0.28	0.29	0.28
C_2O_7	1.50	1.52	1.51	1.22	1.24	1.23	0.27	0.30	0.28	0.31	0.31	0.31
C_2O_8	1.44	1.45	1.44	1.15	1.17	1.16	0.23	0.23	0.23	0.27	0.28	0.28
C_2O_9	1.46	1.47	1.46	1.19	1.20	1.20	0.24	0.25	0.25	0.29	0.30	0.29
SEm±	0.002	0.002	0.002	0.007	0.008	0.005	0.003	0.004	0.002	0.002	0.002	0.001
CD (P=0.05)	0.007	0.006	0.004	0.020	0.022	0.015	0.009	0.011	0.007	0.004	0.006	0.004

4.5.2. Nutrient uptake in seed and stover

A perusal of the two-year experimental data and pooled average on the impact of conservation practices and organic manures and their interaction on the nitrogen, phosphorus, potassium and sulphur uptake in seed and stover after harvest are presented in Tables 4.17(a) and 4.17(b) and Tables 4.18(a) and 4.18(b), respectively.

4.5.2.1. Nitrogen uptake in seed and stover

As observed from Table 4.17(a) and 4.17(b), nitrogen uptake in both seed and stover showed significant influence among the treatments. It was further observed that the use of conservation practice (bench terrace) along with the application of vermicompost and FYM significantly enhanced the nitrogen uptake in both seed and stover of soybean during the years of experimentation.

4.5.2.1.1. Effect of conservation practice on nitrogen uptake in seed and stover

As apparent from the data presented in Table 4.17(a) on the nitrogen uptake in seed and stover under different conservation practices, C_1 (Bench terrace) was observed to be significantly highest in both the years with recorded values of 116.56 kg ha^{-1} and 39.10 kg ha^{-1} in 2021 and 128.07 kg ha^{-1} and 41.90 kg ha^{-1} in 2022, with pooled value of 122.31 kg ha^{-1} and 40.50 kg ha^{-1}, respectively. Meanwhile, the lowest nitrogen uptake for both seed and stover was recorded in C_2 (Non-terrace) with values logged at 100.71 kg ha^{-1} and 35.42 in kg ha^{-1} in 2021; 106.15 kg ha^{-1}and 37.41 kg ha^{-1} in 2022 as well as 103.43 kg ha^{-1} and 36.41 kg ha^{-1} in pooled, respectively.

A critical examination of the pooled data revealed that conservation practice augmented nitrogen uptake in seeds and stover by 18.25% and 11.23% over C_2 (Non-terrace). The highest uptake of nitrogen might be attributed to better availability and distribution of plant nutrients which was required for proper growth of soybean because of relatively better soil moisture regimes and slower organic matter decomposition under conservation practices, thus directly influencing the uptake of higher nutrients in conservation practices over non-conservation practices. The results conform with those of Aher *et al.* (2019), Age *et al.* (2020), Feilinezhad *et al.* (2022) and Lv *et al.* (2023).

4.5.2.1.2. Effect of organic sources on nitrogen uptake in seed and stover

The effect of different organic sources on nitrogen uptake in seed and stover is presented in Table 4.17(a). Irrespective of the years, nitrogen uptake in seed and stover revealed significant variations with applications of organic sources ranging from (47.29 kg ha^{-1} to 131.99 kg ha^{-1}) and (16.31 kg ha^{-1} to 43.74 kg ha^{-1}) in the initial year, (48.88 kg ha^{-1} to 145.58 kg ha^{-1}) and (16.54 kg ha^{-1} to 47.21 kg ha^{-1}) in the succeeding year as well as (48.08 kg ha^{-1} to 138.79 kg ha^{-1}) and (16.42 kg ha^{-1} to 45.47 kg ha^{-1}) in pooled, respectively. As apparent from the table, the maximum nitrogen uptake in seed (131.99 kg ha^{-1} and 145.58 kg ha^{-1}) was reported in O_7 (Vermicompost @ 5 t ha^{-1}) during both the experimentation, with the pooled average of 138.79 kg ha^{-1} respectively, thus proving to be statistically superior to all the other organic sources. It was followed by O_3 (FYM @ 10 t ha^{-1}) with the pooled nitrogen uptake value noted at 132.26 kg ha^{-1}. The least nitrogen uptake was recorded in O_1 (Control) with values logged at 47.29 kg ha^{-1}, 48.88 kg ha^{-1} and 48.08 kg ha^{-1} during 2021, 2022 and in pooled. A deeper analysis of the data further conveyed that application of O_7 (Vermicompost @ 5 t ha^{-1}) and O_3 (FYM @ 10 t ha^{-1}) augmented pooled nitrogen uptake in seed by 188.66% and 175.08% over O_1 (Control) and 29.37% and 23.28% over O_8 (Enriched compost @ 2.5 t ha^{-1}).

Similar results were observed regarding the nitrogen uptake in stover, where the maximum nitrogen uptake (43.74 kg ha^{-1} 47.21 kg ha^{-1}) was perceived in O_7 (Vermicompost @ 5 t ha^{-1}) during 2021 and 2022 respectively, with pooled value of 45.47 kg ha^{-1} while the minimum nitrogen uptake (16.31 kg ha^{-1}, 16.54 kg ha^{-1} and 16.42 kg ha^{-1}) was recorded in O_1 (Control). It was further observed that O_7 was statistically superior over the rest of the organic sources which was followed by O_3 (FYM @ 10 t ha^{-1}). A critical investigation of the data further conveyed that application of O_7 (Vermicompost @ 5 t ha^{-1}) augmented pooled nitrogen uptake in stover by 176.92% over O_1 (Control) and 19.94% over O_8 (Enriched compost @ 2.5 t ha^{-1}).

The effect of different organic manures on the uptake of nitrogen by seed and straw of soybean proved most effective and significantly increased total uptake. Aher *et al.* (2021) reported that the soybean-wheat sequence registered an increment of 2-11% in total N uptake over RDF. The increased nitrogen content and uptake might be due to an increase and adequate supply of all essential nutrients directly through organic sources to the crop or indirectly through checking the losses of nutrients from soil solution thereby increasing the nutrient use efficiency (Tyagi *et al.,* 2014, Tyagi and Singh, 2019 and Karhale *et al.,* 2021). Similar results were reported by Mandale *et al.* (2018), Morya *et al*. (2018), Age *et al.* (2019) and Nissa *et al.* (2023).

4.5.2.1.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the nitrogen uptake in seed and stover is presented in Table 4.17(b). The data revealed significant variations in the nitrogen uptake in both the seed and stover throughout the experimentation period and in pooled with values ranging from (46.56 kg ha^{-1} to 146.10 kg ha^{-1}) and (15.59 kg ha^{-1} to 46.49 kg ha^{-1}) in 2021, (48.18 kg ha^{-1} to 163.57 kg ha^{-1}) and (15.98 kg ha^{-1} to 51.03 kg ha^{-1}) in 2022 and (47.37 kg ha^{-1} to 154.83 kg ha^{-1}) and (15.78 kg ha^{-1} to 48.76 kg ha^{-1}) in pooled, respectively. Application of organic manures in conjunction with the use of conservation practice in the form of bench terrace (C_1O_2 to C_1O_9) showed a significant effect on nitrogen uptake of seed and stover over those in control and non-conservation practice.

In the whole experimental period, the nitrogen uptake in seed was reported to be significantly higher in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with values recorded at 146.10 kg ha^{-1} and 163.57 kg ha^{-1}, respectively with the pooled at 154.83 kg ha^{-1}, thereby revealing to be statistically superior to the rest of the treatments. The lowest nitrogen uptake for both the years and pooled was observed in C_2O_1 (Control) with values logged at 46.56 kg ha^{-1}, 48.18 kg ha^{-1} and 47.37 kg ha^{-1}, respectively, which was observed to be significantly at par with C_1O_1 (Control) (48.02 kg ha^{-1}, 49.58 kg ha^{-1} and 48.80 kg ha^{-1}). Critical examination of the pooled data further revealed that nitrogen uptake was enhanced by 226.85% and 205.09% in seed with the application of C_1O_7 and C_1O_3 over C_2O_1 and 55.91% and 45.52% over C_2O_8.

Similarly, the nitrogen uptake in stover was observed maximum in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with values of 46.49 kg ha^{-1}, 51.03 kg ha^{-1} and 48.76 kg ha^{-1} during 2021, 2022 and in pooled respectively, which was deemed significantly highest than the rest. The lowest nitrogen uptake for both the years and pooled was observed in C_2O_1 (Control) with values noted at 15.59 kg ha^{-1}, 15.98 kg ha^{-1} and 15.78 kg ha^{-1}, respectively, and was observed to be significantly at par with C_1O_1 (Control) (17.03 kg ha^{-1}, 17.10 kg ha^{-1} and 17.06 kg ha^{-1}). Further examination of the pooled data indicated an enhanced nitrogen uptake of 209.00% over C_2O_1 and 34.77% over C_2O_8 with the application of C_1O_7, while with the application of C_1O_3, an augmented nitrogen uptake of 194.93% over C_2O_1 and 28.63.% over C_2O_8 were observed.

The higher uptake of nitrogen under conservation practices and combined application of organic sources in seed and straw might be due to the optimum availability and better utilization of nutrients by the soybean crop because of more root biomass and proliferation and complementary interaction among the organic sources which resulted in a greater uptake of nitrogen, and higher dry matter production. The minimum soil disturbance allows conservation practices to retain the crop residues on the soil surface and preserve the soil organic matter, which serves as a reservoir of nitrogen, leading to gradual decomposition and release of nitrogen into the soil. This leads to increased availability of nitrogen for plant uptake. The findings conform with those of Age *et al*. (2019), Singh *et al.* (2020), Shilpa *et al*. (2023) and Chen *et al.* (2024).

4.5.2.2. Phosphorus uptake in seed and stover

The uptake of phosphorus in seed and stover of soybean on the effect of conservation practices and organic sources is shown in Table 4.17(a) and 4.17(b). Here, it was observed that in addition to conservation practice incorporation of organic sources particularly vermicompost and FYM significantly influenced the treatments and further enhanced the phosphorus uptake.

4.5.2.2.1. Effect of conservation practice on phosphorus uptake in seed and stover

The data on phosphorus uptake in seed and stover under different conservation practices as presented in Table 4.17(a) depicted C_1 (Bench terrace) to be significantly highest in both the years with recorded values of 8.63 kg ha^{-1} and 6.28 kg ha^{-1} in 2021 and 9.83 kg ha^{-1} and 7.04 kg ha^{-1} in 2022, with the pooled value of 9.23 kg ha^{-1} and 6.66 kg ha^{-1}, respectively while the lowest phosphorus uptake in both seed and stover were recorded in C_2 (Non-terrace) with values logged at 7.32 kg ha^{-1} and 5.10 kg ha^{-1} in 2021; 7.85 kg ha^{-1} and 5.78 kg ha^{-1} in 2022 as well as 7.59 kg ha^{-1} and 5.44 kg ha^{-1} in pooled, respectively. An analytical examination of the pooled data revealed that conservation practice augmented nitrogen uptake in seeds and stover by 21.61% and 22.43% over C_2 (Non-terrace).

The available P under conservation practice helped to restore high P in soil which led to improved uptake by soybean seed and halum, which can be ascribed to the immediate availability of readily assimilable form of phosphorus in fertilizer treatment by plants, while in organic treatments P availability is initially less due to immobilization which is released subsequently, thereby, ensuring availability of P throughout the growing period (Age *et al.*, 2019). Conservation practices improve the breakdown of incorporated organic manure and mineralization by enhancing soil aeration and soil microbial activity, thereby leading to an increase in the P uptake of seed and stover.

4.5.2.2.2. Effect of organic sources on phosphorus uptake in seed and stover

The effect of different organic sources on phosphorus uptake in seed and stover is presented in Table 4.17(a). Significant variations were observed in the phosphorus uptake in seed and stover, with values ranging from (3.27 kg ha^{-1} to 10.31 kg ha^{-1}) and (2.21 kg ha^{-1} to 7.07 kg ha^{-1}) in the initial year, (3.46 kg ha^{-1} to 11.76 kg ha^{-1}) and (2.34 kg ha^{-1} to 8.36 kg ha^{-1}) in the succeeding year as well as (3.36 kg ha^{-1} to 11.04 kg ha^{-1}) and (2.27 kg ha^{-1} to 7.71 kg ha^{-1}) in pooled, respectively.

Regarding the phosphorus uptake in seed, organic sources O_7 (Vermicompost @ 5 t ha^{-1}) was observed to be significantly highest with a recorded value of 10.31 kg ha^{-1} in the initial year, 11.76 kg ha^{-1} in the final year and 11.04 kg ha^{-1} in the pooled respectively, thus proving to be statistically superior to all the other organic sources. The second highest was observed in O_3 (FYM @ 10 t ha^{-1}) with a pooled value of 10.11 kg ha^{-1}. Again, in both years the least phosphorus uptake was reported in O_1 (Control) with a value of 3.27 kg ha^{-1} and 3.46 kg ha^{-1} along with pooled at 3.36 kg ha^{-1}, respectively thereby showing that it was statistically the lowest amongst all the other sources. An augmented pooled data of phosphorus uptake in seed after thorough examination was observed to be 228.57% and 200.89% over O_1 (Control) and 46.42% and 34.08%

over O_8 (Enriched compost @ 2.5 t ha^{-1}) with the application of O_7 (Vermicompost @ 5 t ha^{-1}) and O_3 (FYM @ 10 t ha^{-1}), respectively.

Similarly, the phosphorus uptake in stover was observed to be significantly highest in organic sources O_7 (Vermicompost @ 5 t ha^{-1}) with recorded values of 7.07 kg ha^{-1} in the initial year, 8.36 kg ha^{-1} in the final year and 7.71 kg ha^{-1} in the pooled respectively, which was reported to be statistically superior over the rest. Moreover, O_1 (Control) was reported with the least phosphorus uptake with the values logged at 2.21 kg ha^{-1} in 2021 and 2.34 kg ha^{-1} in 2022, along with pooled at 2.27 kg ha^{-1}, respectively thereby showing that it was statistically the lowest. After a thorough examination, it was observed that phosphorus uptake in stover had an augmented pooled data of 239.67% over O_1 (Control) and 38.17% over O_8 (Enriched compost @ 2.5 t ha^{-1}) with the application of O_7 (Vermicompost @ 5 t ha^{-1}), respectively.

The increased phosphorus uptake of seed and stover in organic plots was due to the enhanced nutrients available in the soil thereby reducing the fixation of phosphorus and ultimately improving the efficient use of added phosphorus. Slow and timely release of phosphorus into the rhizosphere providing the appropriate conditions for plant uptake of exchangeable P in readily available forms is also another reason. Similar findings were reported by Morya *et al*. (2018), Aher *et al*. (2019), Age *et al.* (2019), Tyagi and Singh (2019) and Nissa *et al.* (2023).

4.5.2.2.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on phosphorus uptake in seed and stover is presented in Table 4.17(b). Significant variations were observed, regarding the interaction effect on the phosphorus uptake in seed and stover within the treatments during the experimentation period and pooled, with values ranging from (3.19 kg ha^{-1} to 11.58 kg ha^{-1}) and (2.13 kg ha^{-1} to 7.91 kg ha^{-1}) in 2021, (3.36 kg ha^{-1} to 13.55 kg ha^{-1}) and (2.24 kg ha^{-1} to 9.42 kg ha^{-1}) in 2022 and (3.27 kg ha^{-1} to 12.57 kg ha^{-1}) and (2.19 kg ha^{-1} to 8.67 kg ha^{-1}) in pooled, respectively.

The phosphorus uptake in seed was observed to be comparatively higher in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) during the whole experimental period with values recorded at 11.58 kg ha^{-1} in the first year, 13.55 kg ha^{-1} in the second year and 12.57 kg ha^{-1} in pooled, thereby revealing to be statistically superior to the rest of the treatments. Meanwhile, the phosphorus uptake was reported to be lowest in C_2O_1 (Control) with recorded values of 3.19 kg ha^{-1} and 3.36 kg ha^{-1} in 2021 and 2022, along with the pooled average of 3.27 kg ha^{-1}, which was observed to be significantly at par with C_1O_1 (Control) with values logged at 3.36 kg ha^{-1}, 3.55 kg ha^{-1} and 3.45 kg ha^{-1}, respectively. Critical examination of the pooled data further revealed augmented phosphorus uptake of 284.40% and 240.67% in seed with the application of C_1O_7 and C_1O_3 over C_2O_1 and 81.91% and 61.22% over C_2O_8.

Irrespective of years, phosphorus uptake in stover was observed maximum in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with values of 7.91 kg ha^{-1}, 9.42 kg ha^{-1} and 8.67 kg ha^{-1} during 2021, 2022 and in pooled respectively, which was deemed significantly highest over the rest. The lowest nitrogen uptake for both the years and pooled was observed in C_2O_1 (Control) with values noted at 2.13 kg ha^{-1}, 2.24 kg ha^{-1} and 2.19 kg ha^{-1}, respectively, and was observed to be significantly at par with C_1O_1 (Control) (2.29 kg ha^{-1}, 2.44 kg ha^{-1} and 2.36 kg ha^{-1}). Further examination of the pooled data indicated an increased phosphorus uptake of 295.89% over C_2O_1 and 76.94% over C_2O_8 with the application of C_1O_7, while with the application of C_1O_3, an augmented phosphorus uptake of 271.69% over C_2O_1 and 66.12% over C_2O_8 were observed.

The above results may be because of the combined use of conservation practices and various organic sources in a balanced manner, which results in proper absorption, translocation, and assimilation of those nutrients, ultimately increasing the dry matter accumulation and nutrient contents of plants and thus showing more uptake of phosphorous. The findings conform with those of Age *et al*. (2019), Singh *et al.* (2020), Shilpa *et al*. (2023) and Chen *et al.* (2024).

Table 4.17(a): Effect of conservation practice and organic manures on nitrogen and phosphorus uptake in seed and stover

TREATMENTS	Nitrogen uptake (kg ha^{-1})						Phosphorus uptake (kg ha^{-1})					
	Seed			Stover			Seed			Stover		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	116.56	128.07	122.31	39.10	41.90	40.50	8.63	9.83	9.23	6.28	7.04	6.66
C_2 - Non-terrace	100.71	106.15	103.43	35.42	37.41	36.41	7.32	7.85	7.59	5.10	5.78	5.44
SEm±	0.06	0.37	0.19	0.08	0.17	0.09	0.02	0.04	0.02	0.03	0.04	0.03
CD (P=0.05)	0.37	2.25	0.73	0.47	1.05	0.37	0.10	0.24	0.08	0.16	0.27	0.10
CV	0.29	1.64	1.22	1.07	2.26	1.80	1.07	2.35	1.89	2.46	3.58	3.14
ORGANIC SOURCES												
O_1 - Control	47.29	48.88	48.08	16.31	16.54	16.42	3.27	3.46	3.36	2.21	2.34	2.27
O_2 - FYM @ 5 t ha^{-1}	111.33	118.99	115.16	38.75	41.22	39.99	8.40	9.20	8.80	5.84	6.44	6.14
O_3 - FYM @ 10 t ha^{-1}	125.56	138.96	132.26	41.93	46.00	43.96	9.55	10.66	10.11	6.71	7.97	7.34
O_4 - Poultry manure @ 2.5 t ha^{-1}	106.48	116.23	111.35	37.42	40.40	38.91	7.48	8.42	7.95	5.46	6.36	5.91
O_5 - Poultry manure @ 5 t ha^{-1}	120.09	127.47	123.78	41.19	43.39	42.29	8.73	9.60	9.17	6.30	6.90	6.60
O_6 - Vermicompost @ 2.5 t ha^{-1}	114.35	124.37	119.36	38.87	41.54	40.21	8.68	9.63	9.16	6.09	6.73	6.41
O_7 - Vermicompost @ 5 t ha^{-1}	131.99	145.58	138.79	43.74	47.21	45.47	10.31	11.76	11.04	7.07	8.36	7.71
O_8 - Enriched compost @ 2.5 t ha^{-1}	104.31	110.25	107.28	36.88	38.94	37.91	7.17	7.91	7.54	5.37	5.80	5.58
O_9 - Enriched compost @ 5 t ha^{-1}	116.29	123.28	119.79	40.25	41.66	40.95	8.17	8.91	8.54	6.18	6.76	6.47
SEm±	0.37	0.80	0.44	0.25	0.28	0.19	0.05	0.11	0.06	0.04	0.06	0.04
CD (P=0.05)	1.07	2.30	1.24	0.72	0.80	0.53	0.13	0.31	0.16	0.11	0.18	0.10
CV	0.83	1.67	1.35	1.64	1.72	1.68	1.39	2.94	2.38	1.66	2.36	2.08

Table 4.17(b): Interaction effect of conservation practice and organic manures on nitrogen and phosphorus uptake in seed and stover

TREATMENTS	Nitrogen uptake (kg ha^{-1})						Phosphorus uptake (kg ha^{-1})					
	Seed			Stover			Seed			Stover		
	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	48.02	49.58	48.80	17.03	17.10	17.06	3.36	3.55	3.45	2.29	2.44	2.36
C_1O_2	117.96	131.73	124.85	39.78	43.63	41.70	9.01	10.40	9.71	6.35	6.98	6.67
C_1O_3	137.08	151.97	144.52	44.52	48.56	46.54	10.46	11.82	11.14	7.35	8.94	8.14
C_1O_4	112.18	127.33	119.76	38.93	43.01	40.97	7.97	9.53	8.75	6.15	6.95	6.55
C_1O_5	128.85	139.65	134.25	43.67	45.80	44.73	9.34	10.64	9.99	7.03	7.64	7.33
C_1O_6	122.17	136.82	129.50	39.98	43.44	41.71	9.31	10.66	9.98	6.47	7.19	6.83
C_1O_7	146.10	163.57	154.83	46.49	51.03	48.76	11.58	13.55	12.57	7.91	9.42	8.67
C_1O_8	111.78	118.72	115.25	38.55	40.71	39.63	7.78	8.58	8.18	6.08	6.46	6.27
C_1O_9	124.87	133.30	129.08	42.96	43.82	43.39	8.83	9.72	9.28	6.87	7.36	7.11
C_2O_1	46.56	48.18	47.37	15.59	15.98	15.78	3.19	3.36	3.27	2.13	2.24	2.19
C_2O_2	104.71	106.24	105.47	37.73	38.80	38.27	7.79	8.00	7.90	5.33	5.90	5.62
C_2O_3	114.04	125.95	119.99	39.33	43.44	41.39	8.64	9.51	9.08	6.08	7.01	6.54
C_2O_4	100.77	105.13	102.95	35.92	37.79	36.85	6.99	7.31	7.15	4.77	5.76	5.26
C_2O_5	111.33	115.30	113.31	38.72	40.98	39.85	8.13	8.56	8.34	5.56	6.17	5.87
C_2O_6	106.54	111.92	109.23	37.76	39.64	38.70	8.06	8.60	8.33	5.71	6.28	6.00
C_2O_7	117.89	127.60	122.74	40.98	43.40	42.19	9.04	9.97	9.50	6.22	7.30	6.76
C_2O_8	96.84	101.78	99.31	35.20	37.16	36.18	6.57	7.24	6.91	4.65	5.14	4.90
C_2O_9	107.72	113.27	110.50	37.53	39.50	38.52	7.50	8.09	7.80	5.48	6.17	5.83
SEm±	0.52	1.13	0.62	0.35	0.39	0.26	0.06	0.15	0.08	0.05	0.09	0.05
CD (P=0.05)	1.51	3.25	1.76	1.02	1.13	0.75	0.18	0.43	0.23	0.16	0.25	0.15

4.5.2.3. Potassium uptake in seed and stover

The potassium uptake in seed and stover of soybean on the impact of conservation practices and organic sources are represented in Table 4.18(a) and 4.18(b). Here, it was seen that in addition to conservation practice, the incorporation of organic sources particularly vermicompost and FYM significantly influenced the treatments and further enhanced the potassium uptake.

4.5.2.3.1. Effect of conservation practice on potassium uptake in seed and stover

As per results from Table 4.18(a) the phosphorus uptake in seed and stover under different conservation practices was deemed significantly highest in C_1 (Bench terrace) during the experimental seasons with recorded values of 27.75 kg ha^{-1} and 34.17 kg ha^{-1} in 2021 and 30.57 kg ha^{-1} and 36.31 kg ha^{-1} in 2022, with a pooled average of 29.16 kg ha^{-1} and 35.24 kg ha^{-1}, respectively while the lowest phosphorus uptake in both seed and stover were recorded in C_2 (Non-terrace) with values logged at 24.07 kg ha^{-1} and 31.14 kg ha^{-1} in 2021; 25.33 kg ha^{-1} and 32.61 kg ha^{-1} in 2022 as well as 24.70 kg ha^{-1} and 31.87 kg ha^{-1} in pooled, respectively. An analytical examination of the pooled data revealed that conservation practice augmented nitrogen uptake in seeds and stover by 18.06% and 10.57% over C_2 (Non-terrace).

Conservation practices preserve soil organic matter, which is a significant source of potassium. By minimizing the disturbance of soil, it promotes the gradual decomposition of organic matter of the organic sources, thereby releasing potassium ions which are made available for plant uptake. Kumbhar *et al.* (2021) also reported that in conservation practices, the available K help restore high K in soil leading to an enhanced uptake of K by soybean, also the microbial release of nutrients enhanced the nutrient concentration in soil and hence more uptake by plants.

4.4.2.3.2. Effect of organic sources on potassium uptake in seed and stover

The effect of different organic sources on potassium uptake in seed and stover as presented in Table 4.18(a) revealed significant variations. The values ranged from (11.90 kg ha^{-1} to 31.79 kg ha^{-1}) and (13.33 kg ha^{-1} to 38.46 kg ha^{-1}) in the initial year, (12.18 kg ha^{-1} to 35.10 kg ha^{-1}) and (13.60 kg ha^{-1} to 41.28 kg ha^{-1}) in the succeeding year as well as (12.09 kg ha^{-1} to 33.44 kg ha^{-1}) and (13.46 kg ha^{-1} to 39.87 kg ha^{-1}) in pooled, respectively. During 2021 and 2022, the potassium uptake in seed was observed to be considerably highest in source O_7 (Vermicompost @ 5 t ha^{-1}) with recorded values of 31.79 kg ha^{-1} and 35.10 kg ha^{-1}, along with a pooled average of 33.44 kg ha^{-1} and was perceived to be significantly better over the rest. The second highest was seen in O_3 (FYM @ 10 t ha^{-1}) with a pooled value of 31.41 kg ha^{-1}. O_1 (Control) was reported to be significantly lowest with values recorded at 11.90 kg ha^{-1}, 12.18 kg ha^{-1} and 12.09 kg ha^{-1}, respectively. A critical investigation of the data further conveyed that application of O_7 (Vermicompost @ 5 t ha^{-1}) and O_3 (FYM @ 10 t ha^{-1}) augmented pooled potassium uptake in seed by 176.59% and 159.80% over O_1 (Control) and 31.45% and 23.47% over O_8 (Enriched compost @ 2.5 t ha^{-1}).

Regarding the potassium uptake in stover, a similar trend was observed whereby organic sources O_7 (Vermicompost @ 5 t ha^{-1}) was reported to be significantly highest with a recorded value of 38.46 kg ha^{-1} in the initial year, 41.28 kg ha^{-1} in the final year and 39.87 kg ha^{-1} in the pooled respectively, thus proving to be statistically superior to all the other organic sources. Again, in both years the least phosphorus uptake was reported in O_1 (Control) with a value of 13.33 kg ha^{-1} and 13.60 kg ha^{-1} along with a pooled average of 13.46 kg ha^{-1}, respectively thereby showing that it was statistically lowest amongst all the other sources. After a thorough examination, it was observed that potassium uptake in stover had an augmented pooled data of 196.21% over O_1 (Control) and 20.20% over O_8 (Enriched compost @ 2.5 t ha^{-1}) with the application of O_7 (Vermicompost @ 5 t ha^{-1}), respectively.

The increased K uptake in seed and straw might be due to the production of organic acids during the decomposition of organic matter, which releases the K associated with clay minerals and better availability from different sources (Laxmi *et al.,* 2015) and due to added supply of nutrients and proliferous root system developed under nutrient application resulting in better absorption of water and nutrients (Thakur *et al.,* 2023). Morshed *et al*. (2008) also attributed the uptake of nutrients to higher dry-matter production and higher seed yield per ha, owing to the continuous supply of essential plant nutrients to plants throughout the crop-growth period at higher fertility levels. Similar results were observed by Morya *et al*. (2018) and Mahmud *et al.* (2020).

4.5.2.3.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on potassium uptake in seed and stover is presented in Table 4.18(b). As was apparent from the table, significant variations were observed during the experimentation period and in pooled, with values ranging from (11.68 kg ha^{-1} to 35.27 kg ha^{-1}) and (12.83 kg ha^{-1} to 40.76 kg ha^{-1}) in 2021, (12.12 kg ha^{-1} to 39.59 kg ha^{-1}) and (13.15 kg ha^{-1} to 44.16 kg ha^{-1}) in 2022 and (11.90 kg ha^{-1} to 37.43 kg ha^{-1}) and (12.99 kg ha^{-1} to 42.46 kg ha^{-1}) in pooled, respectively.

In all the years and in pooled, the potassium uptake in seed was observed to be significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with values logged at 35.27 kg ha^{-1}, 39.59 kg $ha^{-1}$and 37.43 kg ha^{-1}, thus proving to be statistically superior over the rest. C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) was reported second highest with a pooled value of 34.16 kg ha^{-1}. The least potassium uptake in both the years and pooled was perceived in C_2O_1 (Control) with values of 11.68 kg ha^{-1}, 12.12 kg ha^{-1} and 11.90 kg ha^{-1}, respectively. Moreover, it was observed to be significantly at par with C_1O_1 (Control) with values logged at 12.13 kg ha^{-1}, 12.45 kg ha^{-1} and 12.29 kg ha^{-1}, respectively. A deeper analysis of the data further conveyed that the application of C_1O_7 augmented pooled potassium uptake in seed by 214.54% over C_2O_1 and 59.21% over C_2O_8 while the application of C_1O_3 augmented pooled potassium uptake of 187.06% over C_2O_1 and 45.30% over C_2O_8.

Nevertheless, the potassium uptake in stover was also observed to be comparatively higher in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) during the whole experimental period with values recorded at 40.76 kg ha^{-1} in the first year, 44.16 kg ha^{-1} in the second year and 42.46 kg ha^{-1} in pooled, thereby revealing to be statistically superior over the rest. The second best was observed in C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) with a pooled value of 40.78 kg ha^{-1}. The lowest phosphorus uptake was reported in C_2O_1 (Control) with values of 12.83 kg ha^{-1} and 13.15 kg ha^{-1} in 2021 and 2022, along with a pooled average value of 12.99 kg ha^{-1}, which was observed to be significantly at par with C_1O_1 (Control) (13.82 kg ha^{-1}, 14.05 kg ha^{-1} and 13.94 kg ha^{-1}). Critical examination of the pooled data further revealed augmented phosphorus uptake of 226.87% and 213.93% in seed with the application of C_1O_7 and C_1O_3 over C_2O_1 and 33.82% and 28.52% over C_2O_8.

The increase in total potassium uptake was due to the incorporation of decomposed material like FYM, vermicompost, poultry manure and enriched compost along with the usage of terraces, which is attributed to the greater capacity of organic colloids to hold K ions on the exchange sites thereby enhancing the availability of potassium is responsible for more uptakes. Shukla *et al.* (2023) noticed that the higher uptake by N, P and K under biowaste (farm waste) enriched vermicompost treatment could be ascribed as a result of superior grain and stover yields as well as more N, P and K contents in grain and straw of wheat. The results conformed with those of Age *et al.* (2019), Singh *et al.* (2020), Khatun *et al.* (2022), Shilpa *et al*. (2023) and Chen *et al.* (2024).

4.5.2.4. Sulphur uptake in seed and stover

The sulphur uptake in seed and stover concerning the effect of conservation practices and organic sources, including their interaction effect are represented in Table 4.18(a) and 4.18(b). Here, it was seen that in addition to the use of a bench terrace, the incorporation of organic manures particularly vermicompost and FYM significantly influenced the treatments and further enhanced the sulphur uptake.

4.5.2.4.1. Effect of conservation practice on sulphur uptake in seed and stover

The data on sulphur uptake in seed and stover on the effect of conservation practices as evident from Table 4.18(a) revealed C_1 (Bench terrace) to be significantly superior in both the years with recorded values of 4.79 kg ha^{-1} and 8.64 kg ha^{-1} in 2021 and 5.61 kg ha^{-1} and 9.43 kg ha^{-1} in 2022, along with the pooled average of 5.20 kg ha^{-1} and 9.03 kg ha^{-1}, respectively. Also, in both the experimental years, the sulphur uptake was recorded significantly lowest in C_2 (Non-terrace) with values logged at 4.01 kg ha^{-1} and 7.58 in kg ha^{-1} 2021; 4.41 kg $ha^{-1}$and 8.00 kg ha^{-1} in 2022 as well as 4.21 kg ha^{-1} and 7.79 kg ha^{-1} in pooled, respectively. A critical examination of the data revealed that with conservation practice an augmented pooled sulphur uptake in both seeds and stover of 23.51% and 15.92% over C_2 (Non-terrace).

Minimum disturbance of soil promotes the gradual decomposition of organic matter of the organic sources, attributing to greater availability of nutrients due to better soil properties. Higher levels of N, P, K and S through organic manures assured the availability of nutrients in adequate amounts, whereby more healthy and vigorous plant growth was evident *viz.,* taller plants, number of pods per plant, seed yield and dry matter production. A similar report was notified by Deng *et al.* (2021).

4.5.2.4.2. Effect of organic sources on sulphur uptake in seed and stover

The effect of different organic sources on sulphur uptake in seed and stover is presented in Table 4.18(a). Irrespective of the years the sulphur uptake in seed and stover revealed significant variations as a result of applications of organic sources with values ranging from (1.76 kg ha^{-1} to 5.87 kg ha^{-1}) and (5.26 kg ha^{-1} to 9.97 kg ha^{-1}) in the initial year, (1.87 kg ha^{-1} to 7.16 kg ha^{-1}) and (5.42 kg ha^{-1} to 11.00 kg ha^{-1}) in the succeeding year as well as (1.81 kg ha^{-1} to 6.51 kg ha^{-1}) and (5.34 kg ha^{-1} to 10.48 kg ha^{-1}) in pooled, respectively. As apparent from the data, the maximum sulphur uptake in seed (5.87 kg ha^{-1} in 2021 and 7.16 kg ha^{-1} in 2022) was reported in organic sources O_7 (Vermicompost @ 5 t ha^{-1}) during both seasons, along with the pooled average of 6.51 kg ha^{-1}, respectively. It was followed by O_3 (FYM @ 10 t ha^{-1}). O_1 (Control) was shown with the least sulphur uptake with values recorded at 1.76 kg ha^{-1}, 1.87 kg ha^{-1} and 1.81 kg ha^{-1} during 2021, 2022 and in pooled. Thus, O_7 (Vermicompost @ 5 t ha^{-1}) was perceived to be statistically superior over the rest of the organic sources. A deeper analysis of the data further conveyed that application of O_7 and O_3 augmented pooled sulphur uptake in seed by 259.67% and 223.76% over O_1 (Control) and 54.27% and 38.86% over O_8 (Enriched compost @ 2.5 t ha^{-1}).

Similar results were observed in stover, where the maximum sulphur uptake (9.97 kg ha^{-1} and 11.00 kg ha^{-1}) was perceived in O_7 (Vermicompost @ 5 t ha^{-1}) during 2021 and 2022 respectively, with pooled value of 10.48 kg ha^{-1} while the minimum sulphur uptake (3.64 kg ha^{-1}, 3.73 kg ha^{-1} and 3.68 kg ha^{-1}) was recorded in O_1 (Control). It was further observed that O_7 was statistically superior over the rest of the organic sources which was followed by O_3 (FYM @ 10 t ha^{-1}) (9.72 kg ha^{-1}). Further investigation of the data reported an increase in the pooled sulphur uptake of 184.78% over O_1 (Control) and 30.19% over O_8 (Enriched compost @ 2.5 t ha^{-1}).

The application of organic amendments enhances the release of ions in the soil and ultimately improves the seed and straw yield. The concentration of sulphur in plants was ultimately increased resulting in higher total sulphur uptake. Increased dry matter production and higher seed and stover yield might be responsible for higher nutrient uptake by soybean (Chaithra and Hebsur, 2018).

4.5.2.4.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on sulphur uptake in seed and stover is presented in Table 4.18(b). The data revealed significant variations among the treatments as a result of the interaction effect on the sulphur uptake in seed and stover during the experimentation period and pooled, with values ranging from (1.67 kg ha^{-1} to 6.74 kg ha^{-1}) and (3.47 kg ha^{-1} to 10.80 kg ha^{-1}) in 2021, (1.83 kg ha^{-1} to 8.34 kg ha^{-1}) and (3.51 kg ha^{-1} to 12.37 kg ha^{-1}) in 2022 and (1.75 kg ha^{-1} to 7.54 kg ha^{-1}) and (3.49 kg ha^{-1} to 11.58 kg ha^{-1}) in pooled, respectively.

During the experimental period, the sulphur uptake in seed was reported to be significantly highest in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with values recorded at 6.74 kg ha^{-1} and 8.34 kg ha^{-1}, respectively along with the pooled at 7.54 kg ha^{-1}, thereby revealing to be statistically superior over the rest of the treatments. C_1O_3 (Bench terrace + FYM @ 10 t ha^{-1}) was seen to be the second highest with a pooled value of 6.59 kg ha^{-1}. Meanwhile, the lowest sulphur uptake for both the years and pooled was observed in C_2O_1 (Control) with values noted at 1.67 kg ha^{-1}, 1.83 kg ha^{-1} and 1.75 kg ha^{-1}, respectively, which was observed to be significantly at par with C_1O_1 (Control) (1.84 kg ha^{-1}, 1.92 kg ha^{-1} and 1.88 kg ha^{-1}), respectively. Critical examinations of the pooled data further revealed that sulphur uptake in seed was enhanced by 330.86% and 276.57% with the application of C_1O_7 and C_1O_3 over C_2O_1 and 97.90% and 72.97% over C_2O_8.

Regardless of the season, sulphur uptake in stover was observed with a similar trend as that of the sulphur uptake in seed whereby C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was reported significantly maximum with recorded values of 10.80 kg ha^{-1}, 12.37 kg ha^{-1} and 11.58 kg ha^{-1} during 2021, 2022 and in pooled respectively. It was further deemed significantly and statistically highest over the rest. The lowest nitrogen uptake for both years was observed in C_2O_1 (Control) with values noted at 3.47 kg ha^{-1} and 3.51 kg ha^{-1} respectively, along with the pooled average of 3.49 kg ha^{-1}. It was perceived to be significantly at par with C_1O_1 (Control) (3.80 kg ha^{-1}, 3.95 kg ha^{-1} and 3.87 kg ha^{-1}). Further examination of the pooled data showed an increased sulphur uptake of 231.81% over C_2O_1 and 51.97% over C_2O_8 with the application of C_1O_7, while with the application of C_1O_3, an augmented sulphur uptake of 202.87% over C_2O_1 and 38.71% over C_2O_8 were observed.

The results conform with that of Age *et al.* (2019), whereby the significantly highest sulphur uptake in respect of seed and straw was associated with organic and inorganic fertilizers in conjunction with conservation practices due to a better supply of nutrients throughout the crop growing period. Our finding corroborates with that of Singh *et al.* (2020), Aher *et al.* (2021), Khatun *et al.* (2022), Shilpa *et al*. (2023) and Chen *et al.* (2024).

Table 4.18(a): Effect of conservation practice and organic manures on potassium and sulphur uptake in seed and stover

TREATMENT	Potassium uptake (kg ha^{-1})						Sulphur uptake (kg ha^{-1})					
	Seed			Stover			Seed			Stover		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	27.75	30.57	29.16	34.17	36.31	35.24	4.79	5.61	5.20	8.64	9.43	9.03
C_2 - Non-terrace	24.07	25.33	24.70	31.14	32.61	31.87	4.01	4.41	4.21	7.58	8.00	7.79
SEm±	0.04	0.09	0.05	0.10	0.18	0.10	0.02	0.03	0.02	0.03	0.04	0.02
CD (P=0.05)	0.24	0.58	0.20	0.63	1.07	0.40	0.11	0.16	0.06	0.18	0.23	0.09
CV	0.79	1.77	1.40	1.65	2.64	2.23	2.06	2.71	2.45	0.79	1.77	1.40
ORGANIC SOURCES												
O_1 - Control	11.90	12.28	12.09	13.33	13.60	13.46	1.76	1.87	1.81	3.64	3.73	3.68
O_2 - FYM @ 5 t ha^{-1}	26.55	28.39	27.47	33.80	35.41	34.61	4.34	4.92	4.63	8.19	8.67	8.43
O_3 - FYM @ 10 t ha^{-1}	29.78	33.04	31.41	37.05	40.37	38.71	5.36	6.37	5.86	9.36	10.08	9.72
O_4 - Poultry manure @ 2.5 t ha^{-1}	25.31	27.67	26.49	33.01	35.16	34.09	4.02	4.57	4.29	7.95	8.69	8.32
O_5 - Poultry manure @ 5 t ha^{-1}	28.38	30.10	29.24	36.22	37.93	37.07	4.94	5.36	5.15	8.94	9.74	9.34
O_6 - Vermicompost @ 2.5 t ha^{-1}	27.33	29.78	28.55	34.00	35.90	34.95	4.76	5.35	5.05	8.38	8.97	8.67
O_7 - Vermicompost @ 5 t ha^{-1}	31.79	35.10	33.44	38.46	41.28	39.87	5.87	7.16	6.51	9.97	11.00	10.48
O_8 - Enriched compost @ 2.5 t ha^{-1}	24.71	26.18	25.44	32.46	33.87	33.17	4.02	4.42	4.22	7.75	8.35	8.05
O_9 - Enriched compost @ 5 t ha^{-1}	27.42	28.99	28.20	35.55	36.62	36.08	4.52	5.09	4.80	8.77	9.21	8.99
SEm±	0.06	0.18	0.09	0.23	0.30	0.19	0.04	0.06	0.04	0.05	0.08	0.05
CD (P=0.05)	0.17	0.52	0.27	0.66	0.86	0.53	0.13	0.16	0.10	0.14	0.23	0.13
CV	0.57	1.57	1.22	1.71	2.12	1.93	2.46	2.76	2.64	0.57	1.57	1.22

Table 4.18(b): Interaction effect of conservation practice and organic manures on potassium and sulphur uptake in seed and stover

TREATMENTS	Potassium uptake (kg ha^{-1})						Sulphur uptake (kg ha^{-1})					
	Seed			Stover			Seed			Stover		
	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	12.13	12.45	12.29	13.82	14.05	13.94	1.84	1.92	1.88	3.80	3.95	3.87
C_1O_2	28.00	31.39	29.69	34.90	37.43	36.17	4.64	5.52	5.08	8.56	9.45	9.01
C_1O_3	32.31	36.02	34.16	38.98	42.58	40.78	5.99	7.20	6.59	10.10	11.04	10.57
C_1O_4	26.66	30.33	28.50	34.40	37.55	35.97	4.24	5.00	4.62	8.54	9.52	9.03
C_1O_5	30.31	32.88	31.60	38.04	40.22	39.13	5.32	6.02	5.67	9.58	10.42	10.00
C_1O_6	29.17	32.79	30.98	34.93	37.60	36.26	5.14	6.02	5.58	8.82	9.64	9.23
C_1O_7	35.27	39.59	37.43	40.76	44.16	42.46	6.74	8.34	7.54	10.80	12.37	11.58
C_1O_8	26.45	28.29	27.37	34.15	35.07	34.61	4.33	4.94	4.63	8.17	8.80	8.49
C_1O_9	29.45	31.39	30.42	37.52	38.17	37.84	4.88	5.57	5.22	9.35	9.70	9.53
C_2O_1	11.68	12.12	11.90	12.83	13.15	12.99	1.67	1.83	1.75	3.47	3.51	3.49
C_2O_2	25.10	25.39	25.25	32.71	33.39	33.05	4.04	4.32	4.18	7.82	7.89	7.86
C_2O_3	27.26	30.06	28.66	35.13	38.15	36.64	4.73	5.54	5.13	8.62	9.12	8.87
C_2O_4	23.97	25.02	24.49	31.63	32.77	32.20	3.80	4.14	3.97	7.37	7.87	7.62
C_2O_5	26.44	27.33	26.88	34.39	35.63	35.01	4.56	4.69	4.62	8.29	9.07	8.68
C_2O_6	25.50	26.77	26.13	33.07	34.21	33.64	4.38	4.68	4.53	7.93	8.29	8.11
C_2O_7	28.31	30.61	29.46	36.17	38.41	37.29	5.01	5.97	5.49	9.15	9.62	9.38
C_2O_8	22.97	24.06	23.51	30.78	32.68	31.73	3.72	3.90	3.81	7.34	7.91	7.62
C_2O_9	25.39	26.58	25.99	33.57	35.08	34.33	4.17	4.60	4.39	8.20	8.72	8.46
SEm±	0.09	0.25	0.13	0.32	0.42	0.27	0.06	0.08	0.05	0.07	0.11	0.07
CD (P=0.05)	0.24	0.73	0.38	0.93	1.21	0.75	0.18	0.23	0.14	0.19	0.32	0.18

4.6. Economic analysis

The two-year experimental data and pooled average on the cost of cultivation, gross return, net return and benefit-cost ratio as a result of the impact on conservation practices and organic sources including their interaction are presented in Tables 4.19(a) and 4.19(b).

4.6.1. Total cost of cultivation

4.6.1.1. Effect of conservation practice on the total cost of cultivation

An inquisition on two years' data and average data of two years as per Table 4.19(a) on the impact of conservation practices showed that C_1 (Bench terrace) recorded the highest cost of cultivation with values noted at ₹ 66971.74 ha^{-1} in all the season and in pooled. C_2 (Non-terrace) was observed with the lowest cost of cultivation with values recorded at ₹ 66171.74 ha^{-1} in all the season and in pooled. In addition to chemical fertilizers, the high cost of organic sources particularly enriched compost and the labour charges expensed due to the conversion of slope land into bench terrace, increased the overall cost of cultivation in C_1 treatment.

4.6.1.2. Effect of organic sources on the total cost of cultivation

The effect of different organic sources on the total cost of cultivation is presented in Table 4.19(a). From the data, it was observed that the highest cost of cultivation (₹ 174071.74 ha^{-1}) was found in O_9 (Enriched compost @ 5 t ha^{-1}), and the lowest cost of cultivation (₹ 24071.74 ha^{-1}) was found in O_1 (Control).

Besides the labour charges and RDF cost, this higher cost of cultivation was due to the higher cost of each organic source. In particular, enriched compost was deemed the highest as compared to the other organic sources, as its cost per kg was ₹ 30. On the other hand, O_1 (Control) treatment was reported lowest due to the non-addition of organic sources.

4.6.1.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the total cost of cultivation is presented in Table 4.19(b). As per data, the highest and lowest cost of cultivation was recorded in C_1O_9 (Bench terrace + Enriched compost @ 5 t ha^{-1}) (₹ 174471.74 ha^{-1}) and C_2O_1 (Control) (₹ 23671.74 ha^{-1}) interactions, respectively.

C_1O_9 interactions gave the highest cost of cultivation as it involved the application of enriched manure in addition to chemical fertilizers. It also required additional labour for the conversion of the slope land to bench terraces, which added to the cost of cultivation.

4.6.2. Gross return

4.6.2.1. Effect of conservation practice on the gross return

A perusal of the data on the effect of conservation practice as per Table 4.19(a), reported C_1 (Bench terrace) with the highest gross return with the values recorded at ₹ 134129.64 ha^{-1}, ₹ 146340.15 ha^{-1} and ₹ 140234.90 ha^{-1} for 2021, 2022 and pooled, respectively. Meanwhile, C_2 (Non-terrace) was reported least with the lowest gross return of ₹ 118530.76 ha^{-1} in 2021, ₹ 123800.31 ha^{-1} in 2022 and ₹ 121165.54 ha^{-1} in pooled.

The C_1 treatment resulted in the highest gross returns as it produced higher grain and stover yield as compared to C_2.

4.6.2.2. Effect of organic sources on the gross return

The effect of different organic sources on the gross return is presented in Table 4.19(a). Here, it was observed that O_7 (Vermicompost @ 5 t ha^{-1}) recorded the highest gross return (₹ 149153.96 ha^{-1}, ₹ 162732.47 ha^{-1} and ₹ 155943.21 ha^{-1} for 2021, 2022 and pooled, respectively) followed by O_3 (FYM @ 10 t ha^{-1}) and O_5 (Poultry manure @ 5 t ha^{-1}), and the lowest gross return was found in O_1 (Control) with values logged at ₹ 67086.54 ha^{-1} in 2021, ₹ 68994.66 ha^{-1} in 2022 and ₹ 68040.60 ha^{-1} in pooled, respectively.

The higher gross return in O_7 treatment was due to the production of higher seed and straw yield in addition to that it was also because of the addition of vermicompost into the soil. Our findings corroborate with those of Meena *et al.* (2023a) and Keerthana *et al.* (2024).

4.6.2.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the gross return is presented in Table 4.19(b). Here, the highest gross return was recorded in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) with the highest gross return value of ₹ 163115.15 ha^{-1} in 2021, ₹ 180903.79 ha^{-1} in 2022 and ₹ 172009.47 ha^{-1} in pooled, respectively and the lowest was recorded in C_2O_1 (Control) interaction with values logged at ₹ 66068.90 ha^{-1}, ₹ 68110.80 ha^{-1} and ₹ 67089.85 ha^{-1} in 2021, 2022 and pooled.

C_1O_7 interactions gave the highest gross return due to higher yield (seed + stover) as a result of nutrient management and effective soil conservation.

4.6.3. Net return

4.6.3.1. Effect of conservation practice on the net return

A perusal of the data as per Table 4.19(a) recorded the highest net return in C_1 (Bench terrace) with values logged at ₹ 67157.90 ha^{-1}, ₹ 79368.41 ha^{-1} and ₹ 73263.16 ha^{-1} in 2021, 2022 and in pooled, respectively, and the lowest net return was observed in C_2 (Non-terrace) with the minimum gross return of ₹ 52359.03 ha^{-1} in 2021, ₹ 54800.93 ha^{-1} in 2022 and ₹ 53579.98 ha^{-1} in pooled.

C_1 (Bench terrace) treatment gave the highest net returns despite incurring the highest cost of cultivation because it resulted in superior seed and stover yields. Meanwhile, the lowest net return, which was recorded in C_2 (Non-terrace) treatment in both the two years of experimentation and the average data of two years, might be due to the lower yield of soybean as a result of lower soil fertility. The above finding is similar to that of Chen *et al.* (2024).

4.6.3.2. Effect of organic sources on the net return

The effect of different organic sources on the net return is presented in Table 4.19(a). The highest net return in both seasons and pooled was observed in O_7 (Vermicompost @ 5 t ha^{-1}) with the recorded highest net return of ₹ 100082.22 ha^{-1} in 2021, ₹ 113660.73 ha^{-1} in 2022 and ₹ 106871.48 ha^{-1} in pooled, respectively followed by O_3 (FYM @ 10 t ha^{-1}) and O_6 (Vermicompost @ 2.5 t ha^{-1}). The lowest net return was found in O_9 (Enriched compost @ 5 t ha^{-1}) with the minimum recorded net return of ₹ -41254.71 ha^{-1}, ₹ -34525.40 ha^{-1} and ₹ -37890.05 ha^{-1} in 2021, 2022 and in pooled, respectively as the cost of inputs and expenditure were higher than the overall net return.

Organic sources, O_7, O_3 and O_6 had better yield levels, which resulted in larger net returns. Sindhuja *et al.* (2021) and Keerthana *et al.* (2024) reported similar findings. However, O_9 and O_8 treatment failed to achieve the maximum net returns throughout the season, due to the higher expenditure on the purchase of enriched compost, *i.e.,* per bag (1 kg) of enriched compost cost ₹ 30. These high cost are due to the careful utilisation and selection of the organic materials (quality ingredients) as well as higher labour-intensive processes (to ensure nutrient balance and effectiveness), sustainable production practices and packaging.

4.6.3.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the net return is presented in Table 4.19(b). C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was recorded with the highest net returns with the values of ₹ 113643.41 ha^{-1} in 2021, ₹ 131432.05 ha^{-1} in 2022 and ₹ 122537.73 ha^{-1} in pooled, respectively. This was followed by C_1O_3 (Bench terrace + FYM @10 t ha^{-1}).

The C_2O_9 (Non-terrace + Enriched compost @ 5 t ha^{-1}) interaction recorded the lowest net return of ₹ -49122.41 ha^{-1} in 2021, ₹ -43909.46 ha^{-1} in 2022 and ₹ -46515.94 ha^{-1} in pooled, which might be due to due to the higher cost of cultivation due to higher labour expenditures in addition to the higher cost of organic sources (enriched compost). Whereas, C_1O_7 and C_1O_3 interactions recorded the highest net returns due to higher grain and stover yield.

4.6.4. Benefit Cost (B: C) ratio

4.6.4.1. Effect of conservation practice on B: C ratio

From Table 4.19(a), it was revealed that forms of conservation practices significantly influenced the benefit: cost ratio in both seasons and in pooled, whereby the highest B: C ratio was recorded in C_1 (Bench terrace) with values noted at 1.00 in 2021, 1.19 in 2022 and 1.09 in pooled, respectively, and the lowest B: C ratio was documented in C_2 (Non-terrace) with recorded values of 0.79 in 2021, 0.83 in 2022 and 0.81 in pooled, respectively.

Higher crop yield and net returns were achieved when the crop was cultivated in a bench terrace as in in C_1 treatment, thereby giving the highest B: C ratio. This is in line with the findings of. The B: C ratio of C_1 treatment reflected the overall effect of the expense of manual labour required beside the application of inorganic nutrients *i.e.,* RDF.

4.6.4.2. Effect of organic manures on B: C ratio

The effect of different organic sources on the B: C ratio is presented in Table 4.19(a). An inquisition on the two years' data and average data of two years among organic sources, it was observed that O_2 (FYM @ 5 t ha^{-1}) recorded the highest B: C ratio (2.80, 3.04 and 2.92 in 2021, 2022 and in pooled, respectively) followed by O_6 (Vermicompost @ 2.5 t ha^{-1}) and O_3 (FYM @ 10 t ha^{-1}), while the lowest B: C ratio (-0.24, -0.20 and -0.22 in 2021, 2022 and in pooled, respectively) was found in O_9 (Enriched compost @ 5 t ha^{-1}).

O_7 (Vermicompost @ 5 t ha^{-1}), despite giving the highest yield did not outperform the rest of the organic treatments *viz.*, O_2, O_6 and O_3 in terms of B: C ratio due to the higher cost incurred in purchasing the products of the organic sources. Similar findings were reported by Singh (2018). The B: C ratio's behaviour under various treatments could be explained by variations in economic return and marginal cost.

4.6.4.3. Interaction effect

The interaction effect of conservation/non-conservation practices and different organic amendments on the B: C ratio is presented in Table 4.19(b). As per data the highest B: C ratio was recorded in C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}), with values recorded at 2.94 in 2021, 3.38 in 2022 and 3.16 in pooled, followed by C_1O_6 (Bench terrace + Vermicompost @ 2.5 t ha^{-1}) interaction and the lowest B: C ratio was recorded in C_2O_9 (Non-terrace + Enriched compost @ 5 t ha^{-1}) interaction with values logged at -0.28 in 2021, -0.25 in 2022 and -0.27 in pooled, respectively.

C_1O_2 and C_1O_6 interactions gave the highest B: C ratio because of the lower cost of cultivation and lower cost in procuring the organic manures, even though the overall yield and net returns were not higher in these interactions. The treatment C_2O_9 interaction had the lowest B: C ratio because of the higher cost of cultivation and higher cost of material inputs.

Table 4.19(a): Effect of conservation practice and organic manures on the economics of soybean

TREATMENT	Total cost of cultivation (₹ ha⁻¹)			Gross Return (₹ ha⁻¹)			Net Return (₹ ha⁻¹)			B: C ratio		
FORMS OF CONSERVATION PRACTICES	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**	**2021**	**2022**	**POOLED**
C_1 - Bench terrace	66971.74	66971.74	66971.74	134129.64	146340.15	140234.90	67157.90	79368.41	73263.16	1.00	1.19	1.09
C_2 - Non-terrace	66171.74	66171.74	66171.74	118530.76	123800.31	121165.54	52359.03	54800.93	53579.98	0.79	0.83	0.81
ORGANIC SOURCES												
O_1 - Control	24071.74	24071.74	24071.74	67086.54	68994.66	68040.60	43014.80	44922.92	43968.86	1.79	1.87	1.83
O_2 - FYM @ 5 t ha^{-1}	34071.74	34071.74	34071.74	129494.96	137506.63	133500.80	95423.22	103434.89	99429.06	2.80	3.04	2.92
O_3 - FYM @ 10 t ha^{-1}	44071.74	44071.74	44071.74	142293.79	155944.35	149119.07	98222.06	111872.62	105047.34	2.23	2.54	2.38
O_4 - Poultry manure @ 2.5 t ha^{-1}	54071.74	54071.74	54071.74	124448.68	135151.94	129800.31	70376.94	81080.20	75728.57	1.30	1.50	1.40
O_5 - Poultry manure @ 5 t ha^{-1}	84071.74	84071.74	84071.74	136845.24	144136.33	140490.78	52773.50	60064.59	56419.05	0.63	0.71	0.67
O_6 - Vermicompost @ 2.5 t ha^{-1}	36571.74	36571.74	36571.74	132677.39	143241.41	137959.40	96105.65	106669.67	101387.66	2.63	2.92	2.77
O_7 - Vermicompost @ 5 t ha^{-1}	49071.74	49071.74	49071.74	149153.96	162732.47	155943.21	100082.22	113660.73	106871.48	2.04	2.32	2.18
O_8 - Enriched compost @ 2.5 t ha^{-1}	99071.74	99071.74	99071.74	122154.23	128377.92	125266.08	23082.50	29306.18	26194.34	0.23	0.30	0.26
O_9 - Enriched compost @ 5 t ha^{-1}	174071.74	174071.74	174071.74	132817.03	139546.34	136181.69	-41254.71	-34525.40	-37890.05	-0.24	-0.20	-0.22

Table 4.19(b): Interaction effect of conservation practice and organic manures on the economics of soybean

TREATMENTS	Total cost of cultivation (₹ ha^{-1})			Gross Return (₹ ha^{-1})			Net Return (₹ ha^{-1})			B: C ratio		
	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED	2021	2022	POOLED
C_1O_1	24471.74	24471.74	24471.74	68104.19	69878.53	68991.36	43632.45	45406.79	44519.62	1.78	1.86	1.82
C_1O_2	34471.74	34471.74	34471.74	135769.75	150995.11	143382.43	101298.02	116523.38	108910.70	2.94	3.38	3.16
C_1O_3	44471.74	44471.74	44471.74	153314.00	168549.46	160931.73	108842.26	124077.72	116459.99	2.45	2.79	2.62
C_1O_4	54471.74	54471.74	54471.74	130285.72	147171.19	138728.46	75813.98	92699.46	84256.72	1.39	1.70	1.55
C_1O_5	84471.74	84471.74	84471.74	145178.86	156186.71	150682.79	60707.13	71714.98	66211.05	0.72	0.85	0.78
C_1O_6	36971.74	36971.74	36971.74	140482.73	156647.34	148565.04	103510.99	119675.61	111593.30	2.80	3.24	3.02
C_1O_7	49471.74	49471.74	49471.74	163115.15	180903.79	172009.47	113643.41	131432.05	122537.73	2.30	2.66	2.48
C_1O_8	99471.74	99471.74	99471.74	129831.64	137398.80	133615.22	30359.91	37927.06	34143.48	0.31	0.38	0.34
C_1O_9	174471.74	174471.74	174471.74	141084.73	149330.41	145207.57	-33387.01	-25141.33	-29264.17	-0.19	-0.14	-0.17
C_2O_1	23671.74	23671.74	23671.74	66068.90	68110.80	67089.85	42397.16	44439.06	43418.11	1.79	1.88	1.83
C_2O_2	33671.74	33671.74	33671.74	123220.17	124018.15	123619.16	89548.43	90346.41	89947.42	2.66	2.68	2.67
C_2O_3	43671.74	43671.74	43671.74	131273.59	143339.25	137306.42	87601.85	99667.51	93634.68	2.01	2.28	2.14
C_2O_4	53671.74	53671.74	53671.74	118611.64	123132.68	120872.16	64939.90	69460.95	67200.42	1.21	1.29	1.25
C_2O_5	83671.74	83671.74	83671.74	128511.62	132085.94	130298.78	44839.88	48414.20	46627.04	0.54	0.58	0.56
C_2O_6	36171.74	36171.74	36171.74	124872.04	129835.48	127353.76	88700.31	93663.74	91182.02	2.45	2.59	2.52
C_2O_7	48671.74	48671.74	48671.74	135192.76	144561.15	139876.96	86521.03	95889.41	91205.22	1.78	1.97	1.87
C_2O_8	98671.74	98671.74	98671.74	114476.82	119357.05	116916.94	15805.09	20685.31	18245.20	0.16	0.21	0.18
C_2O_9	173671.74	173671.74	173671.74	124549.33	129762.27	127155.80	-49122.41	-43909.46	-46515.94	-0.28	-0.25	-0.27

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSION

The present study entitled "**Effect of conservation practice and organic manures on soil properties and performance of soybean (*Glycine max* L.)**" was conducted during the *Kharif* season of 2021 and 2022 at the experimental farm of the School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus with the following objectives:

1. To assess the effect of conservation practice and organic manures on soil properties
2. To evaluate the effect of conservation practice and organic manures on yield and yield attributes of soybean
3. To evaluate the benefit-cost ratio of different treatment combinations.

The experiment comprising eighteen different treatment combinations was replicated thrice in a split plot design (SPD). The main plot treatments consisted of two forms of conservation practice *viz.,* C_1: Bench terrace and C_2: Non-terrace with the sub-plot treatments consisting of nine organic manures *viz.,* O_1: Control, O_2: FYM @ 5 t ha^{-1}, O_3 FYM @ 10 t ha^{-1}, O_4: Poultry manure @ 2.5 t ha^{-1}, O_5: Poultry manure @ 5 t ha^{-1}, O_6: Vermicompost @ 2.5 t ha^{-1}, O_7: Vermicompost @ 5 t ha^{-1}, O_8: Enriched compost @ 2.5 t ha^{-1} and O_9: Enriched compost @ 5 t ha^{-1}. Soybean variety DSB-19 was sown using a seed rate of 60 kg ha^{-1} and a spacing of 2.5 cm x 1.5 cm. The soil of the experimental site was acidic with high soil organic carbon, available N, K and low content of available P. Recommended package of practice was followed for the cultivation of the soybean crop. The response of soybean to various forms of treatment with growth attributes, yield attributes and yield, nutrient content, nutrient uptake by crop, soil physicochemical and biological properties before sowing and after harvest; protein and oil content in seed and available nutrients before sowing and after harvest of the crop including the economics were recorded following the standard field techniques and analyzed using appropriate statistical methods during the period of investigation. The salient findings of the present investigation have been summarized below as follows:

5.1 Effect of conservation practice and organic manures on soil properties

Conservation practice was seen to influence the overall soil's physicochemical and biological properties during the years of the experimentation as compared to non-conservation practice. In addition to that application of organic manures was observed to equally influence and increase the performance of the soil properties.

1. Under the chemical properties, the soil organic carbon and CEC were found to be significantly higher in C_1 (Bench terrace). However, the soil pH was observed to decrease in C_1 (Bench terrace) and increase with C_2 (Non-terrace). From the organic sources, O_7 (Vermicompost @ 5 t ha^{-1}) was observed with the highest soil organic carbon and CEC while in pH, O_1 (Control) was observed the highest. Among the treatment combinations, the highest soil organic carbon and CEC were observed in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) and for pH, the highest was observed in C_2O_1 (Control).

2. Among the macro and micronutrients, the available N, P, K and S were found to be significantly higher in C_1 (Bench terrace) while the lowest was observed in C_2 (Non-terrace). With the application of O_7 (Vermicompost @ 5 t ha^{-1}), higher available N, P, K and S were observed, thus statistically being superior over the rest. From the treatment combinations, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was observed with the highest available nutrients (N, P, K and S) in soil when compared to the rest.

3. In the case of physical properties, C_1 (Bench terrace) also recorded a significantly higher bulk density, hydraulic conductivity, mean weight diameter

and water-holding capacity in both years when compared to C_2 (Non-terrace). From the various organic sources, O_7 (Vermicompost @ 5 t ha^{-1}) was observed with the highest bulk density, hydraulic conductivity, mean weight diameter and water-holding capacity while the lowest was observed from O_1 (Control). Regarding the treatment combinations, the highest bulk density, hydraulic conductivity, mean weight diameter and water-holding capacity were perceived in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) and the lowest was noted in C_2O_1 (Control).

4. However, the particle density showed no significant variation as a result of the impact of conservation practices and organic sources in both the years and in pooled. Similarly, their interaction effect was recorded as non-significant.

5. When compared to C_2 (Non-terrace), C_1 (Bench terrace) was recorded with the highest soil microbial biomass carbon. Amongst the organic sources, O_7 (Vermicompost @ 5 t ha^{-1}) was observed with the highest soil microbial biomass while O_1 (Control) was observed the lowest. In regards to the treatment combinations, the highest soil microbial biomass carbon was perceived in C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) and the lowest soil microbial biomass was noted in C_2O_1 (Control).

5.2 Effect of conservation practice and organic manures on the growth attributes of soybean

1. Plant height of the soybean crop at all growth stages *viz*., 35 DAS, 70 DAS and at harvest was significantly influenced by the conservation practices. C_1 (Bench terrace) was observed with the highest plant height and the lowest plant height was observed in C_2 (Non-terrace). In the context of organic sources, O_7 (Vermicompost @ 5 t ha^{-1}) was perceived with the maximum plant height in all the growth stages, and O_1 (Control) was observed with the minimum plant

height. The treatment combination C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was perceived with the maximum plant height in all the growth stages while the plant height was reported as minimum in C_2O_1 (Control).

2. The growth parameters, *viz.*, nodule weight $plant^{-1}$, number of nodules $plant^{-1}$ and diameter of nodules were not significantly influenced by the impact of conservation practices and organic sources.

5.3 Effect of conservation practice and organic manures on yield and yield attributes of soybean

1. Among the yield attributes, the number of seeds per pod and test weight were not significantly affected by the impact of conservation practices or organic manures.

2. Based on the data analysis, the conservation practices significantly influenced the number of pods per plant during the period of study with C_1 (Bench terrace) recording the maximum number of pods $plant^{-1}$ and the lowest recorded at C_2 (Non-terrace). Organic sources were also found to significantly influence the number of pods per plant whereby, O_7 (Vermicompost @5 t ha^{-1}) was found to be significantly superior over the rest, while O_1 (Control) was recorded as significantly lowest. The treatment combination C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) recorded a significant maximum number of pods per plant while Control (C_2O_1) recorded the lowest.

3. C_1 (Bench terrace) was recorded with a significantly higher seed yield and stover yield when compared to C_2 (Non-terrace). Among the different organic sources, O_7 (Vermicompost @ 5 t ha^{-1}) exhibited the highest seed yield and stover yield and was statistically superior over the rest. Meanwhile, O_1 (Control) was reported with a significant minimum seed yield and stover yield in both years. The treatment combination, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) recorded a significant maximum seed yield and stover yield and was

statistically superior over the rest while Control (C_2O_1) was recorded with the lowest seed yield and stover yield.

4. As per data it was revealed that C_1 (Bench terrace) recorded a significantly higher biological yield and harvest index as compared to C_2 (Non-terrace). The biological yield and harvest index differed significantly in both seasons among the different organic sources under study. O_7 (Vermicompost @ 5 t ha^{-1}) exhibited the highest biological yield and thereby higher harvest index. Meanwhile, the lowest biological yield was reported in O_1 (Control) and the lowest harvest index was observed in O_8 (Enriched compost @ 2.5 t ha^{-1}). From the treatment combinations, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was observed with the highest biological yield and harvest index and was statistically superior over the rest while C_2O_1 (Control) was recorded with the lowest biological yield and C_2O_8 (Non-terrace + Enriched compost @ 2.5 t ha^{-1}) with the lowest harvest index.

5. Conservation practices had a significant influence on the protein and oil content. The highest protein content and oil content were observed from C_1 (Bench terrace). In the case of different organic sources, the maximum protein and oil content was recorded in O_7 (Vermicompost @5 t ha^{-1}) and the minimum was observed in O_1 (Control). The treatment combination C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was recorded with the highest protein content as well as oil content while C_2O_1 (Control) was recorded as the lowest.

6. The nutrient content of N, P, K and S in seed and stover was significantly influenced by the impact of conservation practices and organic sources. C_1 (Bench terrace) was observed with the significantly highest N, P, K and S content in seed and stover while C_2 (Non-terrace) was recorded lowest. The nutrient concentration in the seed and stover was observed to increase with higher doses of organic amendments. Amongst the organic sources, O_7 (Vermicompost @ 5 ha^{-1}), was recorded with the highest N, P, K and S content

in the seed and stover and the least N, P, K and S content was observed in O_1 (Control). Among the treatment combinations, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was recorded with the significantly highest N, P, K and S content in both seed and stover while the lowest was recorded C_2O_1 (Control).

7. N, P, K and S uptake in seed and stover under different conservation practices reported C_1 (Bench terrace) with the significantly highest N, P, K and S uptake in both seed and stover over C_2 (Non-terrace). From the organic sources, O_7 (Vermicompost @ 5 ha^{-1}) was reported with the highest N, P, K and S uptake in seed as well as stover, while the lowest was observed in O_1 (Control). The treatment combination, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) recorded the significantly highest N, P, K and S uptake in both seed and stover while C_2O_1 (Control) was recorded significantly lowest.

5.4 Benefit-cost ratio of different treatment combinations

From the data, it can be observed that C_1 (Bench terrace) recorded the highest total cost of cultivation, gross returns, net returns, and benefit: cost ratio as compared to C_2 (Non-terrace) in both years. Among the organic sources, the maximum total cost of cultivation was observed in O_9 (Enriched compost @ 5 t ha^{-1}), while the highest gross return and net return were observed in O_7 (Vermicompost @ 5 ha^{-1}) and the highest B: C ratio was recorded in O_2 (FYM @ 5 t ha^{-1}) during both years of study. Regarding the treatment combinations, C_1O_9 (Bench terrace + Enriched compost @ 5 t ha^{-1}) was recorded with the highest cost of cultivation, C_1O_7 (Bench terrace + Vermicompost @ 5 t ha^{-1}) was recorded with the highest gross return and net return, and finally C_1O_2 (Bench terrace + FYM @ 5 t ha^{-1}) was recorded with the highest B: C ratio.

From the findings of the present investigation, the following conclusions can be drawn:

1. Conservation practice in the form of Bench terrace was found to be the best form of conservation practice as it prevents soil erosion, conserves moisture, and improves the soil properties, growth parameters, yield attributes and yield of soybean during both the research years.
2. Concerning organic sources, Vermicompost @ 5 t ha^{-1} was found best as it greatly improves the overall soil properties and enhances the soil fertility which thereby improves the growth parameters, yield attributes and yield of soybean. It was followed by FYM @ 10 t ha^{-1}.
3. The treatment combination, C_1O_7 *i.e.,* Bench terrace + Vermicompost @ 5 t ha^{-1} was found best followed by C_1O_3 *i.e.,* Bench Terrace + FYM @ 10 t ha^{-1} regarding crop growth and yield as well as soil productivity, proving that conservation practice when incorporated with organic sources improves the soil fertility and provides essential nutrients for crops.
4. On the economic aspect, C_1O_9 *i.e.,* Bench terrace + Enriched compost @ 5 t ha^{-1} was recorded with the highest cost of cultivation, while C_1O_7 *i.e.,* Bench terrace + Vermicompost @ 5 t ha^{-1} was recorded with the highest gross return and net return. However, the B: C ratio was highest in C_1O_2 *i.e.,* Bench terrace + FYM @ 5 t ha^{-1}.

Recommendation

Based on the results of two-year field experimentation, it can be recommended that soybean cultivation using Bench terrace in conjunction with Vermicompost @ 5 t ha^{-1} performed best followed by Bench terrace + FYM @ 10 t ha^{-1} for the overall improvement in the soil health and fertility which thereby enhances the growth, yield, and productivity of the crop. Though high cost of cultivation and high labour charges were observed in conservation practice, the overall economic feasibility was observed in Bench terrace + FYM @ 5 t ha^{-1} which could be recommended to the farmers for earning good revenue while at the same time improving the soil and crop productivity.

Future Prospects

Based on the results of the present investigation, the short-term as well as the long-term impact of addition of different organic sources on soil health and performances of soybean at various degree of slope gradients may be undertaken at different parts of Nagaland to formulate a proper recommendation for sustainable production of soybean.

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APPENDICES

APPENDIX - I

Common Cost of Cultivation

SL. No.	Particulars	Input/Quantity	Rate (₹ $unit^{-1}$)	Cost (₹ ha^{-1})
1.	**Field preparation**			
	a. Forest clearing	5 man days	400/man/day	2000
	b. Bed preparation and sowing	6 man days	400/man/day	2400
2.	**Manures and fertilizer**			
	a. Nitrogen (Urea)	42.9 kg	₹ 245/50 kg bag	210.21
	b. Phosphorus (SSP)	500 kg	₹ 266/50 kg bag	2660
	c. Potassium (MOP)	66.67 kg	₹ 320/50 kg bag	426.688
	d. Gypsum	170.21 kg	₹ 200/50 kg bag	680.84
	e. Application of manures and fertilizer	2 man days	400/man/day	800
3.	**Seed**	60 kg	30	1800
4.	**Plant protection**			
	a. Labour charges	10 man days	400/man/day	4000
	b. Insecticide			
	Chloropyriphos	2 litre	550/500ml	1100
	c. Fungicide			
	Bavistin Carbendazim 50% WP	1 kg	500/1kg	500
	d. *Rhizobium japonicum*	1.2 kg	245/1kg	294
	5. Harvesting, threshing drying and winnowing	12 man days	400/man/day	4800
Total				**20471.738**

APPENDIX – II

Cost of cultivation for conservation practices and organic sources

	Inputs	Inputs/Quantity	Rate (₹ unit^{-1})	Cost (₹ ha^{-1})
Factor 1	**Forms of conservation practices**			
C_1	Bench terrace	10 labours	₹ 400	4000
C_2	Non-terrace	8 labours	₹ 400	3200
Factor 2	**Organic sources**			
O_1	Control	0	0	0
O_2	FYM @5 t ha^{-1}	5000 kg ha^{-1}	₹ 2 kg^{-1}	10000
O_3	FYM @10 t ha^{-1}	10000 kg ha^{-1}	₹ 2 kg^{-1}	20000
O_4	Poultry manure @2.5 t ha^{-1}	2500 kg ha^{-1}	₹ 12 kg^{-1}	30000
O_5	Poultry manure @5 t ha^{-1}	5000 kg ha^{-1}	₹ 12 kg^{-1}	60000
O_6	Vermicompost @2.5 t ha^{-1}	2500 kg ha^{-1}	₹ 5 kg^{-1}	12500
O_7	Vermicompost @5 t ha^{-1}	5000 kg ha^{-1}	₹ 5 kg^{-1}	25000
O_8	Enriched compost @2.5 t ha^{-1}	2500 kg ha^{-1}	₹ 30 kg^{-1}	75000
O_9	Enriched compost @5 t ha^{-1}	5000 kg ha^{-1}	₹ 30 kg^{-1}	150000