STUDY ON THE PREPARATION AND INFLUENCE OF ENRICHED COMPOST ON THE GROWTH, YIELD AND QUALITY OF PALAK (*Beta vulgaris* L.)

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Vegetable Science

By

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2025

DECLARATION

I, hereby declared that the presented work in the thesis entitled **"Study on the preparation and influence of enriched compost on the growth, yield, and quality of palak (*Beta vulgaris* L.)"** in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of Dr. Shivender Thakur, working as Assistant Professor, in the Department of Horticulture, School of Agriculture of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE-I

This is to certify that the work reported in the Ph.D. thesis entitled **"Study on the preparation and influence of enriched compost on the growth, yield, and quality of palak (*Beta vulgaris* L.)"** submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Horticulture, School of Agriculture, is a research work carried out by **Lokesh kumar, 12009899**, is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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CERTIFICATE-II

This is to certify that the thesis entitled **"Study on the preparation and influence of enriched compost on the growth, yield, and quality of palak (*Beta vulgaris* L.)"** submitted by **Lokesh kumar (Registration No. 12009899)** to the Lovely Professional University, Phagwara in partial fulfilment of the requirements for the degree of **Doctor of Philosophy (Ph.D.)** in the discipline of **Vegetable Science** has been approved by the Advisory Committee after the oral examination of the student, conducted in collaboration with an external examiner.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

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ABBREVIATIONS AND SYMBOLS USED

%	:	Per cent
@	:	At the rate
°C	:	Degree Centigrade
MEC_1	:	Mineral enriched compost
MEC_2	:	Microbial enriched compost
B:C	:	Benefit cost ratio
OC	:	Organic carbon
EC	:	Electrical conductivity
cm	:	Centimeter
e.g.	:	Exempli Gratia (for example
et al.	:	Et alia (and others)
Cu	:	Copper
FYM	:	Farm Yard Manure
Fe	:	Iron
Zn	:	Zinc
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
mg	:	Milligram
i.e.	:	Id Est (That is)
LDPE	:	Low density polyethylene
PP	:	Polypropylene
N	:	Nitrogen
Kg	:	Kilogram
K_2O	:	Potassium oxide
Kg/ha	:	Kilogram per hectare
Qtl/ha	:	Quintal per hectare
m	:	meter
m^2	:	Meter square

mg/100gm	:	Milligram per hundred grams
ml	:	Milliliter
ml/acre	:	Milliliter per acre
K	:	Potassium
NFB	:	Nitrogen Fixing Bacteria
No.	:	Number
P	:	Phosphorus
P_2O_5	:	Phosphorus Pentoxide
PGPR	:	Plant Growth Promoting Rhizobacteria
pH	:	$-\log [H^+]$
PLW	:	Physiological Loss in Weight
PSB	:	Phosphate Solubilizing Bacteria
RDF	:	Recommended Dose of Fertilizers
RF	:	Rainfall
RH	:	Relative Humidity
₹	:	Rupees
S	:	Sulphur
CD	:	Critical Difference
t/ha	:	Tonnes per hectare
dSm^{-1}	:	DeciSiemens per metre
Zn	:	Zinc
ppm	:	Parts per million

Abstract

The investigation entitled "Study on the preparation and influence of enriched compost on the growth, yield and quality of palak (*Beta vulgaris* L.)" was carried out over two consecutive cropping seasons of 2022 and 2023 at the Vegetable Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab. The variety "Harit Shobha" was used in this experiment. This research was organized using a three-replication, randomized completely block design and 10 treatment (T) combinations: T_1- fertilizers recommended dosage (RDFs) + Farm yard manure (FYM) (85:30:0 N: P: K kg/ha+ 20 tonnes/ha); T_2- fertilizers recommended dosage (RDFs) + Farm yard manure (FYM) (50% + 10 tonnes/ha); T_3- Farm yard manure (FYM) (20 tonnes/ha); T_4- mineral enriched compost (rock phosphate) (MEC_1) (5 tonnes/ha); T_5- microbial enriched compost (MEC_2) (5 tonnes/ha); T_6- vermicompost(VC) (5 tonnes/ha); T_7- MEC_1 @ 2.5 tonnes/ha + MEC_2 @ 2.5 tonnes/ha (50%+50%); T_8- MEC_1 @ 3.75 tonnes/ha + MEC_2 @ 1.25 tonnes/ha (75%+25%); T_9- MEC_1 @ 1.25 tonnes/ha + MEC_2 @ 3.75 tonnes/ha (25%+75%); T_{10}- absolute control (no application) for two years straight. Different enriched composts were prepared and were incorporated to soil according to the treatment combination during soil preparation. The treatment combination which comprised of RDF (T_1) resulted in plants having maximum height at 24, 40 and 55 DAS (22.36, 32.58 and 28.39 cm), number of leaves (9.06, 13.01 and 8.65), length of petiole (15.95, 22.36 and 15.98 cm), leaf area (51.76, 63.27 and 108.53 cm^2), diameter of petiole (0.66, 0.86 and 0.89 cm) and yield/plant/plot/ha (30.38 gm, 12.99 kg and 108.7 q. However, similar results were obtained by treatment T_7 having MEC_1 @ 2.5 tonnes/ha + MEC_2 @ 2.5 tonnes/ha (50%+50%) over the years suggesting shift towards organic cultivation which is the need of the hour. This treatment combination T_7 also resulted in good quality traits *viz*., highest ascorbic acid (88.54 mg/100g), phenols (22.52 mg/100g), antioxidant activity (4.46 %), minerals i.e., iron (16.67 mg), copper (4.60 mg) and zinc (8.56 mg) in palak leaves. After harvesting of the crop soil analysis also revealed maximum N:P: K availability i.e.147.50:65.73:225.95 kg/ha in treatment T_7 (MEC_1+ MEC_2 (50%+50%) as compared to recommended practice RDF. The two-year study's annual net return and the B:C ratio was also recorded significantly highest in the same treatment T_7. This treatment, T_7 recorded the best for all other soil parameters *viz*., soil pH (7.66), EC (0.37 dSm^{-1}) and OC (0.66 %). Over the two years, the annual net return of study was observed highest under treatment T_7 with benefit cost ratio of 2.72 and 2.73. Based on two-year study, it can be concluded that treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) resulted in best organic input to obtain greater yield, quality and better soil health.

Keywords: Rock phosphate, *Beta vulgaris* L, Biofertilizers, Enriched compost, Sustainable agriculture, Shelf life

CHAPTER-1 INTRODUCTION

Providing the necessary vitamins and minerals, vegetables play a significant role in a person's diet. One of the most popular vegetables in our nation is the leafy kind. Considered to have a high preventative food value, they are rich in nutrients. In addition to being used as a garnish for raw salads and cooked vegetables, leafy vegetables are rich in vitamins and minerals (Evers, 1989). Many diseases, including diabetes, cancer, and other conditions, can be prevented with a diet rich in leafy vegetables. Therefore, a substantial portion of a well-balanced diet should consist of green vegetables (Devi *et al.,* 2015).

Consumers around the world are increasingly concerned with food quality and safety. While our country has effectively adopted green revolution technology, resulting in food grain self-sufficiency, the intensive farming techniques linked with them have created serious issues (Doodhawal *et al.,* 2022). These behaviours not only harm soil and water quality, but they also endanger human health. Ensuring the protection and sustainable management of both our environment and human health through organic farming.

Organic farming practices prioritize using organic materials as inputs and the recycling of agricultural waste to provide nutrients, while crop rotation and soil biological processes are used to combat pests. They strictly prohibit the utilization of synthesized insecticides and fertilizers, which are known to have negative consequences connected with traditional farming practices (Meena *et al.,* 2022). Conventional farming frequently leads to increased concentrations of genetically modified organisms, heavy metals, hormones, antibiotic residue, nitrate, pesticide residue, and hormones in food, which have serious health consequences. Organic farming encourages agricultural diversification and the long-term production of healthful food. Furthermore, it can boost household income while addressing significant environmental issues. (Yadav *et al.,* 2020).

Spinach beet, officially known as *Beta vulgaris* var. *bengalensis,* has a chromosomal count of 2n=2x=18. It is also referred to as "Palak" in Hindi and "Indian spinach" in English (Ganvit *et al.,* 2023). It originated in the Indo-Chinese region (Nath,

1976) and is classified as *Beta vulgaris* in the Chenopodiaceae family. The word 'bengalensis' is presumably derived from its early use in Bengal. Other names for it include "Beet leaf" and "Desi palak",' and has close botanical links to beetroot and chard. Notably, palak's predecessor is sea beet (*Beta vulgaris var. maritima*). Although its delicate, succulent leaves are the main reason spinach beet is grown, it also offers substantial nutritional and culinary advantages (Jabeen *et al.*, 2018).

India has only covered 2% of its 140.1 million hectares with organic agriculture, making it a relatively new industry. States are extending their reach with three states- Madhya Pradesh, Rajasthan, and Maharashtra accounting for half of the nation's area dedicated to organic farming. The top 10 countries occupy 80% of the total organic farming area. In the Asia-Pacific region, China was the largest producer in 2021, with a production of more than 29.8 million metric tons of spinach. (Anonymous 2021a).

The continued use of pesticides and fertilizers that contain harmful chemicals in horticulture production has resulted in a reduction in soil fertility, altering both its physical and chemical properties. Organic techniques are critical for restoring soil fertility and maintaining consistent agricultural production (Manjunatha 2011). As a result, using organic sources including farmyard manure (FYM), vermicompost, biofertilizers, and other foliar sprays emerges as a viable option for promoting sustainable agricultural productivity (Sharma *et al.*, 2022).

Organic fertilizer sources include farmyard manure, animal waste, compost, and vermicompost, improve soil fertility and crop yield. However, growers are discouraged from fully utilizing these conventional organic materials because of their low nutrient content, bulkiness, handling issues, and labour-intensive application (Gajalakshmi and Abbasi 2008). Furthermore, the current composting technique for these biodegradable wastes is often financially unsustainable (Thakur *et al.*, 2023). Improving traditional composting methods to increase nutrient content can better mitigate nutrient depletion trends. In vegetables especially in leafy vegetables the toxic effect of chemical fertilizers is higher and it's very harmful to human beings. So today we need to enrich the traditional organic manures and compost to reduce inorganic fertilizers use and its application quantity, easy handling, and higher nutrient content of organic manures

(Shenbagavalli *et al.,* 2023). There are many inputs available for compost or manure enrichments are mentioned below.

Moreover, using mineral additions such as Rock Phosphate and Pyrites has shown advantageous in the composting process (Mwangi *et al.,* 2020). As a result, a method known as N-enriched phosphocompost has been created, which employs microbes that solubilize phosphate, specifically *Aspergillus awamori*, *Pseudomonas straita,* and *Bacillus megaterium* (Nath *et al.,* 2020). Also utilized phosphate rock, pyrite, and bio-solids to improve the nutrient content of farmyard manure (FYM) and compost (Opala,2023). Encouraging the creation and use of enhanced organic manure among a larger community of vegetable growers, catering to both organic and conventional crop cultivation approaches (Bordoloi *et al.,* 2018). Embracing diverse enrichment techniques and their application can stimulate the agricultural community to incorporate enrichment processes into current organic manure resources, reducing soil contamination and environmental degradation caused by fossil fuel use (Sindhu *et al.,* 2020). According to the study, constant application of larger dosages of enriched organic manures not only reduces the total requirement of organic manures but also improves their usage efficiency (Lida *et al.,* 2024).

The use of compost, particularly nutrient-rich compost, helps regulate seasonal changes in soil temperature, air, water, and nutrient availability, supporting consistent crop yield. Composting appears as an effective approach for regulating plant nutrients in a sustainable agricultural system (Meena *et al.*, 2021).

Spinach beet thrives best when fed a balanced diet. Manures are essential for addressing the nutritional requirements of plants to achieve optimal growth and output. Manure is defined as organic materials put into soil to improve fertility and plant health. It enriches the soil with important nutrients (Dewangan *et al.*, 2023). Its application not only improves soil fertility, structure, and water retention capacity, but it also increases soil organic matter levels, lowering crop production's reliance on synthetic fertilizers (Blay *et al.*, 2002).

In such cases, it becomes vital to seek alternative organic inputs to limit the dependency on chemical fertilizers while ensuring long-term soil fertility and crop output. Investigations at the local and national levels, have revealed that the poor nutrient content, bulkiness, handling challenges, and labour-intensive application of traditional organic manures prevent growers from fully utilizing them. As a result, many growers face difficulties in transitioning to organic farming. Given these challenges, there is an urgent need to improve traditional organic manures and compost to lessen reliance on chemical fertilizers and reduce the quantity of compost required. There has been little research on enriched compost, particularly for leafy vegetables and palak is grown throughout year normally in winter season i.e. the main season however, it can be grown in spring season also. With the objective to test its availability during spring season, the experiment was conducted for two consecutive years with the following objectives:

Objectives: -

1. To study the effect of biofertilizers and mineral compositions on the nutritional status of enriched compost.
2. To study the effect of enriched compost on the growth, yield, and quality attributes of Palak.
3. To study the effect of various packaging materials on the shelf life of Palak.
4. To study the economics of treatments.

CHAPTER-2 REVIEW OF LITERATURE

This chapter contains the relevant literature for the topic "Study on the preparation and influence of enriched compost on palak growth, yield, and quality (*Beta vulgaris* L.).

2.1 To study the effect of biofertilizers and mineral compositions on enriched compost's nutritional status.

2.2 To study the effect of enriched compost on Palak's growth, yield, and quality attributes.

2.3 To study the effect of various packaging materials on the shelf life of Palak.

2.4 Effect of biofertilizers and minerals on enriched compost's nutritional status.

Gajalakshmi and Abbasi (2008) highlighted composting as a highly adaptable and profitable way of handling biodegradable solid waste. Composting provides a sustainable solution for a wide range of waste types, including those of plant, animal, and synthetic origin. The resulting compost is a useful soil conditioner and fertilizer, with a steady market demand. Furthermore, compost is thought to help plants resist soil-borne illnesses while also delivering critical minerals such as nitrogen, phosphorus, and potassium. Considering these advantages, composting stands out as a promising solution to address the substantial volumes of biodegradable waste generated globally.

Mahajan *et al.,* (2010) investigated how agricultural waste may be used to make compost that meets the nutrient needs of plants. Their objective was to recycle organic waste and reduce the time required for organic matter to decompose, compared to vermicomposting, by using specific fungal species. These species, including *Aspergillus awamorie, Paecilomyces, Penicillium,* and *Trichoderma viridae,* were recognized for their capacity to enzymatically break down any raw material. Compost beds were created to accelerate the decomposition process, and the compost sample were analysed to measure the concentrations of key nutrients, such as zinc, iron, phosphorus, nitrogen, and potassium. A range of treatments was applied to examine the effects of different fungus species on the decomposition rate. Easy-to-access nutrients were added in the form of rock phosphate, urea, and single superphosphate. Their study found that the decomposition time of agricultural waste was reduced to about 35–40 days when all four fungal species were used.

Kanwal *et al.,* (2011) conducted a study in Rawalpindi, Pakistan, focusing on the aerobic composting of water lettuce to create phosphorus-enriched organic manures. The findings of their research revealed that the compost enriched with rock phosphate (RP-compost) exhibited significantly higher levels of both total and available phosphorus when compared to regular compost. Furthermore, they observed that when effective microorganisms were introduced as part of the composting process, it led to a substantial increase in the total phosphorus, available phosphorus, and other essential nutrient contents in the compost. These included nutrients like nitrogen, potassium, zinc, and boron. This underscores the positive impact of using effective microorganisms in enhancing the nutrient quality of the compost, making it a valuable organic resource for agriculture.

Manjunatha, (2011) carried out an experiment and results indicated decrease in pH in case of rock phosphate-enriched USWC (Urban solid waste compost) 8.02 as compared to unenriched urban solid waste compost 8.29. The results showed that the concentrations of phosphorus in enriched USWC (urban solid waste compost), vermicompost and FYM were recorded as 2.87, 2.43 and 1.16 per cent, respectively which were higher than those in unenriched USWC, vermicompost and FYM having values of 0.90, 0.82, and 0.28 per cent, respectively. Similarly, compared to unenriched compost, enriched compost had greater concentrations of all major, secondary, and micronutrients.

Rai *et al.,* (2012) discovered that adding rock phosphate to compost at a rate of 1% of total wheat or rice biomass resulted in a significant improvement in numerous key compost properties. They observed a considerable rise in the percentages of organic carbon (C) and total nitrogen (N). Furthermore, the compost included higher quantities of several critical elements such as zinc (Zn), copper (Cu), iron (Fe), potassium (K), calcium (Ca), magnesium (Mg), and manganese (Mn). Through this study, they suggested that even a small addition of rock phosphate during composting has a noteworthy favourable influence on the nutritional makeup of the finished compost.

These results have substantial ramifications for improving the quality of compost designed for agricultural use.

Borah *et al.,* (2014) investigated overall nutritional content and microbial population count of farmyard manure and vermicompost after the addition of microbial cultures. In their study bacteria that solubilize phosphate (PSB), *Azotobacter*, and *Azospirillum*, cultures were implanted at 0.2% concentrations into farmyard manure (FYM) or vermicompost consortia. These mixes were then cultured for thirty days in a laboratory experiment with a completely randomized layout and a moisture level of approximately 251% (w/w). Their results revealed that during the 30-day incubation period with various consortia, there was a considerable rise in the population of *Azotobacter*, *Azospirillum*, and PSB in the composts, ranging from 35% to 133%. Furthermore, after 30 days of incubation, the C: N proportion in both farmyard manure and vermicompost declined dramatically, owing to a large fall in total carbon concentration.

Qureshi *et al.,* (2014) presented an intriguing approach to composting by enriching it with rock phosphate. They achieved this by mixing rock phosphate with a combination of farmyard manure, poultry manure, and sugar press mud, all while incorporating effective microorganisms into the process. The results of their experiment indicated an overall increase in nutrient content during the composting procedure. When it comes to the major nutrients, there were substantial enhancements, with total nitrogen, phosphorus, and potassium levels increasing to 2.5%, 2.89%, and 1.93%, respectively. In terms of micronutrients, the compost displayed notably higher concentrations of iron and zinc at 1012 and 166 ppm, respectively. Their approach demonstrated its potential for not only boosting the nutrient content of compost but also enriching it with essential elements that can benefit agricultural soil and plant health.

Meena *et al.,* (2015) examined the effects of *Aspergillus awamori*, rice straw, and low-grade minerals such as rock phosphate (RP) on phosphatase activity, proportions of phosphorus (P) and microbial biomass phosphorus (MBP) in a wheat-soybean cropping system between 2009 and 2010 at IARI in New Delhi. Findings revealed that after wheat harvest, the application of rock phosphate enriched compost at a rate of 5 t/ha, in conjunction with 50% of the recommended dose of chemical fertilizers (RDF), significantly increased the amount of MBP 5.62 and 4.28 mg/kg soil in both surface at 0-15 cm and sub-surface at 15-30 cm of soil, respectively, compared to the control plot. Surface soil had larger changes in P fractions and microbial activity than sub-surface soil.

Surekha *et al.*, (2016) conducted field experiments over two years at the Indian Institute of Rice Research in Hyderabad to assess and compare the impact of field-fortified poultry manure applications on selected microbiological soil attributes. Their results revealed that soil dehydrogenase, soil phosphatase activity, and soil microbial carbon are affected by plots treated alone with inorganic fertilizers. In all, MEC treated plots (mineral enriched compost) compared to control and RDF, soil microbial biomass Cμg/g dry soil wt, soil enzyme such as μg p-nitrophenol/g soil/ha alkaline phosphate was found highest.

Rady *et al.,* (2016) reported the outcomes of the experiment, the physico-chemical properties of the soil were enhanced by the addition of OMF (Organo mineral fertilizer) compost. When compared to the control, the application of OMF compost @ rate of 20 tons/ha also improved all identified physio-biochemical features and evaluated soil properties. In summary, using locally accessible recycled organic materials to manufacture the researched OMF compost, the benefits of this compost proved the viability and potential of sustainable agronomic performance of common beans as a partial substitute for chemical fertilizers.

Meena *et al.,* (2017) measured various soil parameters and nutrient availability under different treatment conditions. The results indicated that pH, electrical conductivity (EC), and organic carbon content attained their peak levels in three distinct treatments viz. application of 100% RDF, 75% RDF combined with 6 tons of enriched compost, and 100% RDF supplemented with 20 tons of Farm Yard Manure (FYM) per hectare. The values for pH, EC and organic carbon were recorded as 7.57, 0.28 dSm^{-1} and 0.60%, respectively. In terms of nutrient availability, the highest levels of potassium (K), and nitrogen (N), measuring 253.69 and 245.13 kg/ha, respectively, were recorded when 100% RDF was combined with 20 tons of FYM per hectare.

Phosphorus (P) and sulphur (S) availability, on the other hand, peaked at 22.66 and 19.26 kilograms per hectare, respectively, in the treatment involving 75% RDF and 6 tons of Enriched Compost per hectare in the post-harvest soil. Their findings provide valuable insights into optimizing soil conditions and nutrient availability for crop production.

Bordoloi *et al.,* (2018) underscore the intricate, diverse, and precarious nature of agricultural production systems in northeast India, emphasizing the critical necessity for a robust nutrient management strategy to sustain these systems. They advocated for the utilization of nutrient-enriched compost, notably phospho-sulpho-nitro (PSN) compost, which is meticulously crafted through a waste recycling process utilizing locally sourced organic materials such as crop residue, weed biomass, and animal dung, with minimal incorporation of mineral additives. This approach holds significant potential for implementing effective nutrient management to sustain agricultural production in northeast India. A successful standardized manufacturing methodology for phospho-sulpho-nitro compost was established and tested at the Division of Natural Resources Management and ICAR Research Complex in India. By altering the sorts of animal manure slurry, four various varieties of PSN compost were created. Notably, PSN compost created from poultry, pig, and cow dung slurries had higher nutrient-supplying capability and chemical characteristics than those made from plain soil slurry. Their results revealed that overall, 2.5 tonnes per hectare of PSN compost is expected to offer approximately 73 kg nitrogen, 123 kg phosphorus, 46 kg potassium, and 16 kg sulphur per hectare. Also, incorporating PSN compost into an integrated nutrient management framework dramatically increased crop productivity, including paddy, maize, soybean, groundnut, ginger, turmeric, and seasonal produce. These are proven in diverse regions of Meghalaya and Nagaland. They suggested that continued use of PSN compost resulted in incremental increases in soil quality and also commercial compost production demonstrated a favorable benefit-to-cost ratio ranging from 1.8:1 and 2.0:1.

Kumar *et al.,* (2018) studied the compost enrichment through the residues of the crops including urea (1.5% to 4.5%), wheat straw (WS) + rock phosphate (6 - 12%) + sulphide (1.5% to 3% using gypsum) and cotton shredding stalk + urea (1.5% - 4.5%)

+ rock phosphate (6 - 12%) + sulphide (1% to 3% using gypsum). They discovered the positive effects on compost quality in terms of total concentrations of nitrogen, phosphorus solubility in citrate and aqueous solutions, potassium, sulphur, and micronutrients through increasing levels of gypsum and RP. Composting with gradual decomposition reduced organic carbon, microbial breath, and the carbon-to-nitrogen ratio (C: N ratio). In the first 60 to 70 days, the number of microbials (such as bacteria, fungi, and actinomycetes) increased rapidly and thereafter reduced.

Jagadeesha *et al.*, (2019a) experimented to find out the features of the compost enhanced with rock phosphate. Their results showed decreased value for pH in rock phosphate-enriched USWC (Urban solid waste compost) 8.02 compared to unenriched USWC 8.29. Their results also showed that the concentrations of phosphorus in enriched USWC, vermicompost and FYM were recorded as 2.87, 2.43, and 1.16 per cent, respectively which were higher than those in unenriched USWC, vermicompost and FYM 0.90, 0.82, 0.28 per cent, respectively. Also, enriched compost recorded more concentrations of all major, secondary, and micronutrients as compared unenriched compost.

Das *et al.*, (2019) conducted a study on organic farming systems, particularly focusing on the supply of phosphorus (P) to soils through the recycling of on-farm organic materials. Including compost, animal manure, and green crops manure. Their research highlighted the significance of sustainable soil P management, particularly when dealing with P limitations. One key aspect they explored was the preparation of phospho-compost, that plays a pivotal role in increasing soil P sustainability. The primary raw material for producing soluble P fertilizers is rock phosphate, characterized by the chemical formula $Ca_3(PO_4)_2$. They suggested that rock phosphate can be applied directly to the soil and can solubilize within the soil, thus making phosphorus readily available to crops. The actual effectiveness of this process, however, depends on a variety of factors, including soil properties, climate conditions, cropping systems, and nutrient management practices. Their findings shed light on the potential of phosphocompost in addressing P availability in organic farming systems.

Beura *et al.,* (2019) conducted a study that showed significant findings. The results, based on laboratory analyses of both soil and plant samples, pointed to a promising treatment method. Specifically, the treatment involving rock-phosphate enriched compost at a rate of 100% of the required phosphorus dose, along with the addition of phosphorus-solubilizing bacteria and mycorrhiza, emerged as the most effective approach. This treatment was shown to have a substantial positive effect on maintaining a higher nutrient status in the soil. These findings underscore the potential benefits of this treatment method in agricultural practices aimed at enhancing soil fertility and overall crop health.

Meena *et al.,* (2019) executed a *kharif*-season field trial at the Rajasthan College of Agriculture's Instructional Farm (Agronomy) in Udaipur, Rajasthan. The study's findings revealed important information on soil quality. One notable observation was a drop in soil pH and electrical conductivity as the experiment progressed and more enriched compost was added. This shows that adding enriched compost improved soil acidity and electrical conductivity, thus generating a more favourable environment for crop growth. Furthermore, the study also found significant increases in organic carbon and the accessibility of critical nutrients including primary nutrients and zinc in the soil by the crop's harvest stage. They suggested that using enriched compost brought about a notable increase in field soil nutrient content, which most likely contributed to increased crop output.

Mwangi *et al.,* (2020) conducted experiment to assess the effectiveness of lemon and pineapple juices in releasing nearly half of the readily available phosphorus from phosphate rock (PR) and to determine the necessary concentration and duration for achieving this release. Second, to evaluate (b) the impact of various rock phosphate oversight methods on carrot yields, nutrient absorption, and phosphorus utilization efficiency. Their results revealed that the lemon juice was found successful in solubilizing rock phosphate and giving out 63% of the whole applied phosphorus into an accessible form, as opposed to 11% with pineapple juice and only 6% with water. Compost and rock phosphate dissolved in the juice of lemon during planting significantly improved nutrient absorption and enhanced the yields of carrots. Their outcomes are comparable to the field application of triple superphosphate (TSP).

Andrade *et al.*, (2021) aimed to investigate the efficacy of enriching compost with arbuscular mycorrhizal fungi and bacteria when used in conjunction with Brachiaria as the host plant. A control group, compost containing *brachiaria* alone, compost containing *brachiaria* and mycorrhizal fungus, compost containing *brachiaria* and mycorrhizal fungus, *Azorhizobium* sp., *Azoarcus* sp., *Bacillus subtilis*, and *Azotobacter* sp. were among the seven treatments that were applied. *Brachiaria* shoots biomass, nitrogen and phosphorus concentrations, mycorrhizal colonization, and compost chemical properties were measured over a period of 183 days. Mycorrhizal colonization attained up to 53% even though the compost had a high P availability of 951-2927 mg/kg.

2.2.1 Effect of enriched compost on growth, yield, and quality

Gairola *et al.,* (2009) carried out a study on *Beta vulgaris* L. cv. Pusa Bharti in the Jamia Hamdard Herbal Garden in New Delhi. Through this study, they investigated the impact of potassium supplementation in combination with other fertilizers on the growth, nitrate production, and leaf quality. Their findings demonstrated that while nitrate level decreased, potassium supplementation enhanced chlorophyll content index (CCI), leaf area, nitrate reductase activity (NRA), and dry weight %. Remarkably, the outcomes from a 2:1 nitrogen/potash ratio were statistically equivalent to those from a 1:1 nitrogen/potash ratio. Moreover, compared to other fertilizer treatments, potassium-deficient fertilizer treatments produced lower NRA levels and greater nitrate contents in the leaves. Their study suggested using potassium to reduce the health risks associated with nitrate toxicity because potassium treatments increased NRA while lowering nitrate levels. They also concluded that for optimal effects, a balanced 1:1 mix of potassium and nitrogen fertilizer combined with FYM (farm yard manure) is advised.

Bharad *et al.,* (2010) through their study analysed the effect of natural manure and the number of harvestings on the development, productivity, and quality of palak at the Horticulture Department, Dr. Panjab Rao Deshmukh Krishi Vidyapeeth, Akola. The experiment demonstrated that administering 50 kg N/ha of urea to the leaves resulted in the greatest growth concerning plant height (37.20 cm), leaf area indexes (114.20 cm^2), and number of leaves (16.28) and maximum leaf yield (250.94) qtl/ha.

In addition, the leaves had more ascorbic acid (74.23 mg/100g), moisture (89.53), and chlorophyll (1.91 mg/g).

Joshi and Vig (2010) in a pot experiment studied the impact of vermicompost on growth, and yielding attributes of Tomato (*Lycopersicum esculentum* L). Their results revealed that the germination percentage decreased with the vermicompost @ 15 tonnes/ha treatment, while the subsequent treatments showed a similar trend. However, nearly all growth, yield, and quality metrics showed an increase compared to the control, although the increase within the treatments was not found to be statistically significant.

Bindiya *et al.*, (2012) carried out a study in 2007 and 2008, on gherkin (*Cucumis anguria* L.) cv. Ajax. Their goal of the research was to ascertain how biofertilizers and organic manures affected the output and quality of gherkin. The application of the fertilizers recommended dose of N: P: K @ 150: 75: 150 kg/ha produced higher growth and yield attributes than control, this was also comparable to treatment having vermicompost @ 18 t/ha plus Azotobacter @ 2 kg/ha plus phosphate solubilizing bacteria @2 kg/ha. Also, the pooled data analysis showed that, when the RDF was applied, better growth and yield characteristics were seen. Similarly, these results were comparable to those obtained when vermicompost @ 18 t/ha plus Azotobacter @2 kg/ha plus phosphate solubilizing bacteria @2 kg/ha were applied, as compared to the control.

Singh *et al.,* (2014) through their study determined how biofertilizers could increase broccoli productivity and quality. Their results revealed that treatment having inoculation of Azospirillum and Azotobacter @ 50 per cent each significantly increased the size and yield of curd with values recorded as 15.17 cm diameter and 1.17 kg, with guard leaves of broccoli, respectively when compared to other treatment combinations. Their results also showed that Azospirillum, PSB, Azotobacter @ 100% all performed better when compared to RDF. Except for Azospirillum+Azotobacter @ 50% each, all other treatment combinations performed poorly.

Roy *et al.,* (2014) carried out a study using commercial manure (CM), poultry manure (PM), as well as a mixture of CM and PM (@10 tons/hectare) in Indian spinach

(*Basella alba*). Their study was having four different treatments i.e. control (T_1), which did not include any manure, CM (T_2), PM (T_3), and CM+PM (T_4). Their results showed that organic manure addition to soil enhanced fresh weight of root, number of leafs, shoot and root length, and other metrics related to vegetative development. Furthermore, the levels of potassium and other secondary nutrients in all plant sections increased two to three times over the control, independent of the presence of organic additives.

Meena *et al.,* (2015) carried out a field investigation and yielded impressive results, with the highest grain production of 9.68 quintals per hectare and straw output of 39.23 quintals per hectare. These excellent yields were attained by combining the dose of 75% of the recommended fertilizer (RDF) with 6 tons of rock phosphate-enriched compost. This strategy outperformed the control group and all other treatments, demonstrating its usefulness in increasing crop productivity.

Devi *et al.,* (2015) investigated to evaluate the impacts of fly ash, biochar and vermicompost on the growth, yielding attributes and quality of palak cv. All Green. Their results showed that treatment T_4 (RDF + Vermicompost) had the highest growth metrics compared to the other treatments. Furthermore, T_4 demonstrated early plant emergence, with only 1.50 days required. The RDF + Vermicompost treatment produced the maximum leaf yield per hectare (208.33 quintals/ha). Furthermore, T_4 (RDF + Vermicompost) had the highest quality metrics, vitamin C (83.60 mg/100 g), zinc level (12.11), and dry matter (13.77%).

Kumar *et al.,* (2015) experimented to examine the impact of both biofertilizers and organic manures on cabbage at the Assam Agricultural University's horticulture farm in Jorhat in 2009 and 2010. The application of both PSB + AZB biofertilizers and organic manures produced higher yield that was similar to the RDF (control). Their results revealed that enriched compost having PSB and Azotobacter showed similar results as obtained by RDF. Treatment having organic manures with biofertilizers (PSB + AZB) recorded higher ascorbic acid, leaf P and K, ash content, and mineral content. On the other hand, leaf N, moisture, and protein levels were higher when fertilizers were applied at the approved dosage (120N:60P:60 kg/ha). The treatments that applied biofertilizers (PSB + AZB) in conjunction with organic manures had significantly longer storage lifetimes than the typical room-temperature treatment.

Rady *et al.,* (2016) investigated the effects of an inventive organo-mineral fertilizer (OMF) on *Phaseolus vulgaris* L. plants that experience salt stress in terms of soil characteristics, growth metrics, physio-biochemical characteristics, and Cd^{+2} and NO^{-3} concentrations. The OMF compost was applied at rates of 10, 20, and 30 tons per hectare, with the 50% suggested NPK level being used instead. Furthermore, a control group received 100% NPK application as a comparison. The investigation sought to evaluate the effects of this compost on plant development traits, quantitative abilities, and overall growth, as an alternative to mineral-NPK fertilizers.

Xu *et al.,* (2016) conducted a study using salt and nutrient shortage on spinach. Their results revealed that vitamin deficits and salinity both reduced the nutritional quality of spinach. Regardless of salt level, an increase in reduction power was caused by inadequate nutrients. Lower levels of carotenoids and flavonoids, higher levels of anthocyanin and total phenolic contents, and increased antioxidant capacity in the absence of salt were all caused by lack of nitrogen. Phosphorus deficiency increased the amounts of carotenoids and flavonoids when there was no salt present; when there was salt stress, it increased the overall phenolic content and decreased the contents of amino acids and FICA. Their results suggested that minimal fertilizer or mild salt stress cultural practices could increase the nutritional content of spinach while very slightly decreasing yield.

Anwar *et al*., (2017) performed a study to evaluate uptake and spinach growth of nutrients in co-composting soils modified with cow manure. Digested spinach shooting samples and determined the nutrients in the shoots. The co-composted manure greatly increased the spinach's growth and nutrient availability. In spinach shoots, the ratios of leaf litter to dry biomass, P, and K varied: 1:0 <1:1 <1:2 <1:3. On the other hand, as the amount of leaf litter increased, the manure amendment decreased the amounts of N, Zn, Fe, Cu, and Cd in spinach shoots.

Pascual *et al.,* (2017) investigated a study to utilize the enriched compost. They utilized Trichoderma T-77 (Th-78) and tested it for the biostimulant, biofertilizer, and repressive effect on the muskmelon crop since the nursery in the field under bio greenhouse conditions as a growing medium and organic change. They showed that enriched compost Th-78 recorded the highest fresh weight and lowest incidence of pathogens both at the nursery environment under artificial plant pathogens. The change in the soil of this advanced compost also reduced the percentage of natural infection in melons and enhanced melon yields under natural conditions. In addition, muskmelon plants cultivated in advance showed a lower incidence of pathogens in the above compost combination.

Gogoi *et al.,* (2016) evaluated how organic materials and a community of microorganisms affected knolkhol yield and quality at the Department of Horticulture's experimental farm in Jorhat. Their results revealed that treatment T_8 [RDF (80:60:60 kg NPK + FYM 10 tonnes/ha)] recorded maximum knob yield (191.45 quintals per hectare), followed by T_7 [RDF N, P, K (80:60:60 kg + FYM10 tonnes/ha)] with 169.73 quintals per hectare (enriched compost 5 tonnes/ha). In the case of quality analysis also results showed that the enriched compost 5 tonnes/ha and consortium treatments (T_2) had significantly greater levels of ascorbic acid (63.54 mg per 100 g), carbohydrate content 6.74 per cent, calcium 2.06 per cent, phosphorus 0.69 per cent, and potassium 4.62 per cent in comparison to other treatment combinations.

Pangaribuan *et al.,* (2017) studied the influence of enriched compost and chemical fertilizer on *Zea mays* L. growth and yielding attributes. In their study, the compost was improved by adding chicken dung and dolomite. Their outcomes demonstrated that using the full recommended nitrogen fertilizer dose recorded higher yields than other treatment combination. Through this study, they revealed that using enriched rice straw compost could be a good idea for modest-scale agricultural development within red acid soil ultisol.

Meena *et al.,* (2017) carried out a field investigation and discovered a technique of composting low-grade Indian rock phosphate with paddy straw, that increased the solubilization of inaccessible phosphorus in rock phosphate, converting it into usable forms. This technique improved the delivery of phosphorus, nitrogen, potassium, and sulphur (NKS) to green gram (*Vigna radiata* L.). Their results showed that 75% RDF

+ enriched compost @ 6 tonnes recorded higher grain production i.e. 9.68 q/ha when compared to control and other treatments.

Jabeen *et al.,* (2018) conducted a experiment at SKUAST-K Shalimar's Vegetable Experimental Field during the rabi season and found that the vermicompost treatment produced the maximum height of plant and leaf blade mass (1.13, 2.55, and 3.54 g). In contrast, the treatment with mustard cake applied at a rate of 1.2 tons per acre yielded the lowest results for growth indices. Similarly, the vermicompost treatment recorded the highest yield metrics, including the leaf yield/plant 17.62, 29.27, and 29.26 g, 58.73, 97.58, 97.88 q/ha, leaf area, and number of leafs.

Pradeep *et al.,* (2017) did a meta-analysis to investigate how the nutrients affect the agricultural productivity. They examined several tests comparing nutrition sources, both organic and inorganic for tropical crop yields. In their research, they chose contrasted ten plants, including Amaranthus, brinjal, chilli., okra, tomato, bitter gourd, coleus, and cowpea. The study compared organic and conventional crops, with an emphasis on cucumber. Manure and poplar leaf litter, which were among the organic sources tested by them. They suggested that the extended viability of sustainable nourishment in vegetable crops was dependent on parameters such as the amount and quality of organic manures applied, crop productivity, produce quality, and pricing in the market.

Baliah *et al.,* (2017) experimented with the nursery to find out the efficacy of microbe-enriched vermicompost. They discovered that using microbially enriched vermicompost has a substantial impact on the growth of okra plants. Their results varied according to the type of microorganisms employed for enrichment, with enriched samples showing better responses than the control. Also, vermicompost enhanced with *Azospirillum brasilense* showed greater levels of total chlorophyll, carotene, protein, and amino acids. In addition, glucose content and activity were higher in vermicompost enhanced with *Pseudomonas fluorescens*.

Barik *et al.,* (2018) carried out a study during the kharif season to find out the impact of organic inputs in ridge gourd performance. Their results revealed that the growth and yield characteristics, i.e. fruits per vine (19.92), yield (1.95 kg/vine), average fruit weight (97.86 g), fruit length (19.79 cm), and length of vine (6.02 m) were noted maximum under RDF treatment combination (T_1). Conversely, the combination treatment T_5 (rock phosphate + biofertilizer consortium + vermicompost@ 5t/ha) was recorded as the largest fruit girth (12.78 cm) at a rate. Treatments including organic sources of nutrients outperformed the usual treatment in terms of quality metrics. While the (T_6) enriched compost @ 2.5 tonnes/ha recorded the highest ascorbic acid concentration (4.51 mg/100g) and the enriched compost @ 5 t/ha (T_7) recorded the maximum ash content (7.62%), total sugar (5.43%), and reducing sugar (4.02%) respectively.

Vethamoni *et al.,* (2018a) carried out field experiment to find out how organic manuring techniques affected the growth and productivity of palak. The organic approach, which applied vermicompost (4 t/ha) to the soil, *Azospirullum* (200 ml/acre) as a liquid nitrogen biofertilizer, and vermiwash (3%) as a foliar spray, produced the plants which were having maximum plant height i.e. (46.69 cm), leaf numbers (23.6), length of leaf (23.21 cm), width of leaf (15.83 cm), and canopy spread in both east-west and north-south directions (47.09 cm and 47.84 cm), on 65 days after sowing compared to control treatment. Additionally, the treatment produced the lowest growth and yield characters, such yield per hectare (7732.87 kg/ha), when treatment with straight fertilizer applied at 100% RDF.

Vethamoni *et al.,* (2018b) carried out a study in the Coimbatore district's Sandaya Koundampalayam, Thondammutur block, to find out how amendment of organic manures affected the quality parameters of palak. They observed that significant gains in quality parameters were demonstrated by the organic approach, which included applying liquid nitrogen biofertilizer, treating the soil with vermicompost, and spraying vermiwash on the leaves. Also, the amounts of ascorbic acid (64.35 mg/100g), total phenolic content (23.01mg/100g), carotenoids content (3.96 mg/100g), calcium (344.77 mg/100g), iron (15.8 mg/100g), antioxidant activity (3.43 mg/100g), and post-harvest life were recorded more in the treatments amended with organic manures than in the inorganic treatments. Furthermore, the amounts of nitrate and oxalate were lower in the organic treatments.

Saikia *et al.,* (2018) observed the effects of the biofertilizer consortia on the yield and biochemical attributes on French beans (*Phaseolus vulgaris* L.) crop. Through their study, they revealed that the yield-related characteristics including pod per plant (28.57), length of pod (15.07 cm), pod dia. (0.96 cm), seed/pod (6.73), yield of pod (11.27 t/ha), and harvest index (67.67%) demonstrated a considerable increase with the application of the necessary fertilizer treatment T_1 (FYM 20 t/ha+ NPK @ 30:40:20 kg/ha (RDF)). Treatment T_3 i.e. Enriched compost @ 3t/ha showed similar results as that of treatment T_1. Also, T_1 reported the least dry matter content (6.87%), crude fibre content (7.15%), and the highest quantity of crude protein (22.63%). The treatment combination treatment T_4 (Vermicompost @ 3 t/ha) recorded a substantially higher ascorbic acid content (11.67 mg100g/FW) than the other organic treatments.

Tanuja *et al.,* (2019) researched to find out the effects of fish silage-enriched vermicompost on cowpea growth, yield, and quality components. They found that cowpeas performed best when cultivated with enriched vermicompost, resulting in a higher average yield of fruits per plant. They suggest enrichment of vermicompost with fish silage appears to be a potential technique for increasing its nutritional value. Their results indicated that cowpea showed best results with enriched vermicompost for parameters like height of plant (114.2 cm), total number of branches per plant (13.4), weight per fruit (4.41 g), and number of seeds per fruit (10.5). Through their study, they suggested that this novel strategy has the potential to boost agricultural productivity by recycling fish waste into a useful resource.

Jagadeesha *et al.,* (2019) carried out a field experiment to study the impact of compost enriched with rock phosphate on the yield characteristics of the finger millet-cowpea cropping system. They revealed that the finger millet yields of grain (45.15) and straw (60.36 q/ha) were recorded highest when the RDF dose nitrogen and potassium + 75% P was applied by enriched USWC (Urban solid waste compost) (T_5). The haulm yields (29.98 q/ha) and grain yields (14.62) of the leftover cowpea were significantly found at par with the recommended amounts of N and K + 75% P provided by enriched vermicompost (T_8).

Hashimi *et al.*, (2019) carried out a pot trial to examine the properties of the soil and the growth traits of spinach (*Spinacia oleracea* L.) by using different treatment combination of cow manure (CM) and inorganic fertilizer alone, and in combination both. According to their study T_7 (200 kg N/ha) recorded best spinach production followed by treatment T_8 (3 t CM + 90 kg N/ha) coming in second with 4.2 and 4.1 t/ha, respectively. The yield of the control treatment pot was notably lower than that of the other treatments. When nourished with T_7 (N 200 kg/ha), T_8 (3 tonnes CM + N 90 kg/ha), and T_6 (N 150 kg/ha), in that order, the crop reached the largest plant heights. Except for T_2 (CM 6 t/ha), plant heights in every treatment were considerably greater than those in the control treatment.

Machado *et al.*, (2020) investigated the influence of growing plants using nitrogen fertilizer and organic compost. They discovered that applying organic compost to soil that has been not fertilized, improved fresh spinach beet production of areas 2.3 to 4.81 kg/m^2 and shoot dry weight from 0.60 to 1.31 gm/plant. Furthermore, carotenoid content (31.14 mg 100g fresh weight) boosted significantly with the addition of inorganic nitrogen, culminating in greater amounts in plants treated using composted organic matter. However, the addition of nitrogen significantly reduced leaf-blade ferric lowering antioxidant activity.

Zafar-ul-Hye *et al.*, (2020) carried out a study to evaluate the impact of compost mixed with biochar and PGPR on spinach plants exposed to intentionally generated PB toxicity. They found a considerable increase in root fresh weight of (47%), weight of dry root (31%), and potassium (11%) in spinach plants. Their findings showed promise for future use in the development and implementation of soil additives based on Rhizobacteria and compost mixed with biochar.

Ros *et al.*, (2020) evaluated the potential benefits of spraying compost tea (CT) derived from vineyard and onion composts, either alone or in combination with *Trichoderma harzianum*. Their results showed that the foliar application of compost tea plus *Trichoderma harzianum* exhibited the maximum yield, phenolic content and antioxidant capability levels. The also found that nitrate levels in the compost tea and compost tea + *Trichoderma harzianum* treatments were within acceptable amount and were much lower than those in the control.

Mu *et al.,* (2020) through their study found that the compost treatments with larger percentages often increased the levels of elements such as nitrogen, phosphorus, potassium, sodium, manganese, zinc, and magnesium within the crops. They also recorded that higher compost ratios resulted in enhanced yields for leafy crops, with the highest yield reported at a 70% compost concentration. Conversely, root vegetables produced the most at a medium compost treatment rate of 50 %. Furthermore, they also suggested that at the compost concentration of 70%, compost may replace more than half of total synthetic fertilizer usage.

Jamoh, (2021) evaluated the palak performance concerning organic inputs and microbial consortiums. Their two-year pooled research revealed that treatment T_8 (FYM@ 20 t/ha + NPK@ 80: 60: 0 kg/ha) had the highest plant height (35.90 cm), most leaves per plant (21.43), largest leaf area (292.91 cm^2), total plant weight (51.26 g), and highest yield (2.97 kg m^2). On the other hand, T_7 (Enriched compost@ 3 t/ha) showed a similar pattern, with the same treatment exhibiting the best leaf blade petiole ratio. Regarding the quality measures, T_7 produced the highest levels of ascorbic acid (70.54 mg/100g), iron (15.71 mg/100g), total carotenoid content (3.87 mg/100g), and total phenol (23.29 mg/100g). T_8 had the highest percentage of moisture (89.76%), crude fibre (11.53%), and chlorophyll (1.63 mg/100g) also.

Sultana *et al.,* (2021) used synthesized fertilizers (urea, TSP (Triple superphosphate), MOP, gypsum, and zinc sulfate) and four types of compost made from municipal solid waste (MSW), three of which were enriched and one unenriched. They found that the application of composts increased soil nutrient levels. Their findings also revealed that the optimal treatment was a blend of 50% chemical fertilizers and 10 tons per hectare of enriched compost (MSW + MOC (mustard oil cake) + SPM (sugarcane press mud) ratio of 5:2:3), which resulted in the highest fruit yield (edible portion) and concentrations of nitrogen, phosphorus, potassium, and sulfurin brinjals, together with elevated nutrient availability in the soil.

Meena *et al.,* (2022) studied the impact of enriched compost and zinc on growth and yield traits of black gram. Their outcome showed that the, pod number per plant, number of seeds per pod, yield of seed in black gram seed increased significantly with treatment combinations that was having higher level of phosphorus enrichment in compost and zinc (phosphorus enriched compost @ 4 t/ha and Zn @ 4 kg/ha). In contrast, the zinc application dramatically reduced the amount of phosphorus in the stover and seed as compared to the control. However, it was shown that applying zinc @ 6 kg/ha and phosphorus-enriched compost at 6 t/ha together increased the production of both seeds and stover.

Doodhwal *et al.,* (2022) determined the fertility levels and phosphorus-enriched compost affected the yield and grade of corn (*Zea mays* L.) grown in the Typic Haplustepts soil of Rajasthan's Aravalli region and sub-humid southern hills. Their results revealed that 100% RDF + foliar Zn @ 0.5% + phosphorus-enriched compost @ 6 t/ha recorded significant increase in yield of maize and its protein content.

Kulal and Pillewad (2023) investigated the production of nutrient-rich compost and its effects on chickpea development, nutrient dynamics, yield, and yield characteristics. Their findings revealed that applying 75% of the recommended dose of fertilizers (RDF) (N: $P_2 O_5$: K_2O) with 50% nutrient-enriched compost, followed by 75% RDF with 25% nutrient-enriched compost produced the greatest outcome with regards to all macro and micro nutrients during chickpea harvesting. Conversely, the absolute control group had the lowest nutritional values.

Prabavathi and Ramesh (2023) carried out a study at Puliyanthoppu village, Krishnagiri District, Tamil Nadu, to find out how finger millet growth and productivity were affected by foliar nutrition and organic compost. According their results, the pot containing enriched poultry manure compost @ 750 kg/ha (M_3) showed a significant increase in growth and yield. This was evident in the values *viz.* height of plant (103.64 cm), leaf area index (5.71), number of tillers (161.27 m^{-2}), dry matter production (9156 kg/ha), grain yield (3504 kg/ha) and straw yield (6597 kg/ha).

2.4.1 Effect of different packaging material

Piagentini and Güeme (2002) examined how chemical treatment and packaging film type affected the fresh-cut spinach storage life. In the experiment, fresh-cut spinach treated with citric and ascorbic acid solutions before being packaged in LDPE or polypropylene (PP) bags. Spinach packed in PP bags had a short shelf life due to the packaging film's influence on the development of off-odors, rather than any significant changes in visual quality or microbiological counts. In contrast, the standard and durability of spinach packaged in LDPE bags were indicated by changes in overall emergence or a rise in the number of microorganisms, contingent on the chemical process used.

Reddy *et al.,* (2014) studied the impact of different packaging materials on the shelf life of amaranthus leaves. Packing material used for amaranthus leaves included brown paper pouches, PET jars, polypropylene bags (25 and 40 micron), Low- and high-density polyethylene bags (with or without vents). The leaves were packed with or without stems. Their result revealed that amaranthus leaves with tender stems could be stored for up to six days in polypropylene 150-gauge pouches with vents, retaining 84.36 per cent of moisture, losing 21.01 per cent of their physiological weight, and decomposing 9.01 percent. Also in comparison, a four-day shelf life was achieved using polypropylene 100-gauge pouches, which showed 86.32 per cent moisture retention, 1.27 per cent physiological loss in weight, 16.98 and 14.52 per cent decaying, and yellowing, respectively.

Nyaura *et al.,* (2014) studied the post-harvest management which is one of the most suitable techniques for palak storage due to its brief duration and financial benefits. The palak leaves should be handled and packed carefully for a higher rate of profit. An approximate of 30 % is lost as a result of inadequate handling and storage conditions.

Kakade *et al.,* (2015) performed a study to find out the prolonged durability of fresh-cut spinach and reported that, under ambient and cold storage conditions, the maximum durability of spinach was determined to be 3 days and 14 days, respectively, when stored in LDPE bags with 5% perforation.

Ambrose *et al.*, (2017) studied to examine the convenience and marketability of fruits and vegetables, with a special emphasis on the advantages of little processing for retail consumption. Their study sought to investigate the feasibility of newly processing and packaging *Moringa oleifera* leaves utilizing a variety of packing materials and storage conditions. The method entailed mechanically removing the leaflets from the branches of freshly harvested moringa leaves, which were then cleaned with chlorinated water and air-dried. The leaves were packed in a variety of materials, including low-density polyethylene (LDPE) of 40 and 80-micron thickness, as well as polypropylene of 40- and 60-micron thickness, with ventilation levels ranging from 0% to 2%. The packed leaves were stored at both room temperature (29–33 °C, 50–70% RH) and chilled settings (5±2 °C, 90-95% RH). Measurements of weight loss, wilting percentage, and variations in nutritional content (iron, vitamin C, vitamin A, and chlorophyll levels) were made regularly during the storage period. The results of the investigation showed that packing with 40-micron polypropylene thickness and 1% ventilation performed best for recently processed Moringa leaves kept at room temperature. On the other hand, LDPE with a thickness of 80 microns and 1% ventilation turned out to be the best choice for chilled storage.

Prasad *et al.*, (2018) investigated a study for proper packaging and chemical treatment which will extend the duration of spinach preservation after harvesting under room temperature settings. After being harvested, the spinach plants received a treatment of a variety of chemicals, such as distilled water, 0.3 per cent ascorbic acid, 0.3 per cent citric acid, 0.5 per cent common salt, 0.5 per cent sugar, and 0.005 per cent benzoic acid. Following treatment, these plants were either left unpacked or packaged in a variety of ways, including perforated low-density polyethylene (LDPE) packing and newspaper packaging. The T_3P_3 (0.005 per cent benzoic acid + LDPE packing) group demonstrated the lowest rate of respiration (52.28 ml/kg/hr) and the longest half-life (6.5 days) to accomplish 50% colour change and 50% rotting. With the lowest physiological weight loss (78.80g/100g), maximum production of ethylene (8.41 nl/g/hr), and greatest content of dry matter (22.96g/100g), T_1P_3 (0.3% ascorbic acid + Low-density packing) had the longest shelf life (up to 5 days).

CHAPTER-3 MATERIALS AND METHODS

The investigation titled "Study on the preparation and influence of enriched compost on the growth, yield, and quality of palak (*Beta vulgaris* L.)" was carried out over two consecutive cropping seasons of 2022 and 2023 at the Vegetable Farm, Department of Horticulture, Lovely Professional University, Phagwara, Punjab.

3.1 EXPERIMENTAL SITE

3.1.1 Location and Climate

The Lovely Professional University, Phagwara, Punjab is located at 31.22ºN latitude and 75.7°E longitude at an altitude of 252 m higher than the mean sea level. Phagwara (Jalandhar) has a humid subtropical climate with hot summers and winds from April-July followed by a hot humid rainy season and cold winters associated from December- January.

The Meteorological Observatory of LPU, Phagwara provided the temperature, precipitation, and relative humidity data, which were then carefully documented during spring-summer experimental periods of February 2022 to April 2022 and February 2023 to April 2023 (Appendix-Ia and Ib). The mean temperature ranged between 19.13°C (min.) to 28.51 (max.) during the first season, while in the second season, conversely, the mean temperature varied between 14.88°C and 28.54°C. During the cropping period of the first and second seasons, relative humidity varies between 42.6 to 53.15 per cent and 44.17 to 73.80 per cent, respectively.

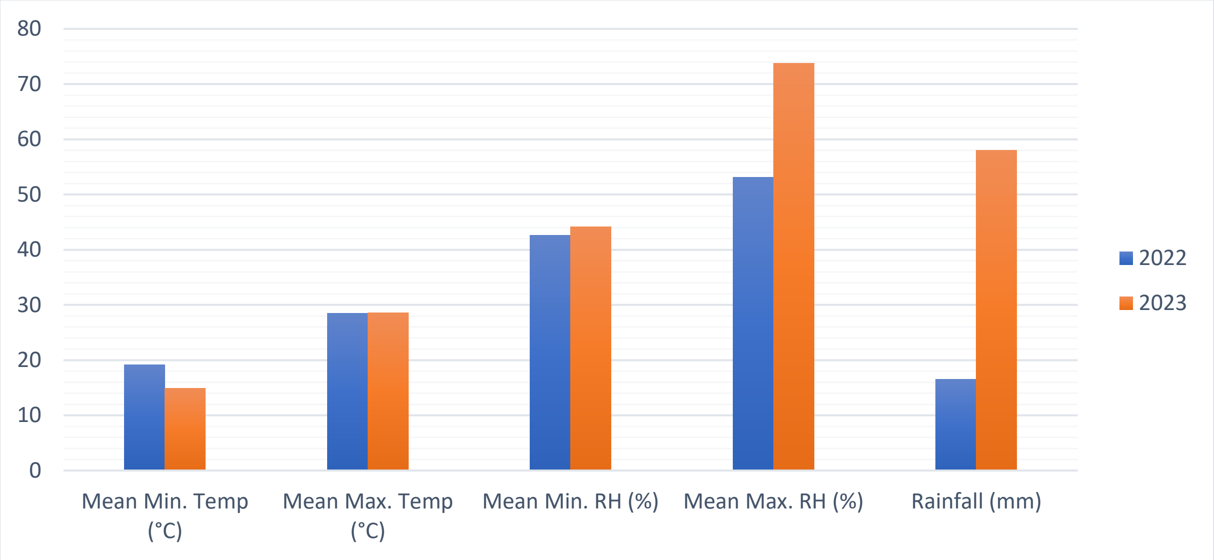


Fig 3.1 Meteorological data during the period of experiment 2022 and 2023

3.1.2 Soil characteristics

Before the commencement of the investigation, random soil samples were taken and collected from various locations within the experimental area, ranging in depth from 0 to 15 cm. After combining these samples to create a composite sample, different physicochemical properties of the soil were investigated. Different methods that were employed for various physicochemical characteristics (initial) of the soil and their results obtained have been summarized in Table 3.1.

Table 3.1 Physical and chemical characteristics of the study location

Specifics	**Values attained**		**The methods adopted**	**Soil status**
Physical properties %				
1. Sand 2. Silt 3. Clay	58.97 % 17.10 % 23.93 %		Piper's method, 2019	Sandy clay loam
Chemical properties	1st year	2nd year		
1. Soil pH	8.5	7.9	pH digital meter	Alkaline
2. Soil EC (dSm^{-1})	0.65	0.58	The digital conductivity meter	Normal

3.	Organic Carbon %	0.35	0.39	Walkley and Black's, 1934	Low
4.	Available N(kg/ha)	138.25	138.54	Subbiah and Asija (1956) method	Low
5.	Available P(kg/ha)	48.12	49.32	Olsen (1954), Olsen method	High
6.	Available K(kg/ha)	219.23	221.15	The standard method Merwin and Peech, (1951)	Moderate

3.1.3 EXPERIMENTAL DETAILS

In the field experimental trial during a two-years study i.e. 2022 and 2023, the cultivar of palak (*Beta vulgaris* L.) Harit Shobha was grown with three replications in a randomized block design consisting ten treatments. During the year 2021, after compost enrichment, analysis was done on physiochemical data of enriched compost, and observations were recorded based on morphological yield traits as well as biochemical data of palak. The cultivar grown in the field was further evaluated for shelf-life studies for both consecutive years i.e. 2022 and 2023. Palak harvested from the field trial was stored under ambient storage conditions with different packaging materials for one week of observation within the post-harvest lab and the details of the packaging material used are mentioned below:

1. LDPE (Low-density polyethylene) bags
2. PP (Polypropylene) bags

3.1.4 Cultivar

The cultivar used for this experiment was Harit Shobha. It is an open-pollinated, multi-cut cultivar with bigger leaves at the plant's base and smaller leaves further up the flowering stem. Direct seed sowing in lines was done on 24th and 25th February during both the years and plant population was maintained at a spacing of 25 cm ×10 cm in 3.5 × 3.0 m^2 sized plots.

3.1.5 Seed source

The seeds were procured from the Agri Store of Lovely Professional University and the cultivar was produced by UPL ADVANTA Ltd.

3.1.6 Organic manures

3.1.6.1 Enriched compost

Enriched compost has higher levels of organic matter and nutrients. Additives used to enrich compost have a direct positive impact on a variety of metrics, including compost quality, maturity, nutrient and heavy metal concentrations, and nutrient bioavailability. Furthermore, it has an impact on the environmental footprint of the composting process by reducing the emission of greenhouse gases and other volatile compounds such as nitrogen oxides, sulphur compounds, and organic pollutants.

3.1.6.1.1 Mineral enriched compost

Several layers of rock phosphate were added to the pit while it was being filled with diverse farm waste to improve the compost. The degradation of the trash mixture resulted in mineral-enriched compost. In the first-year analysis of this mineral-enriched compost N, P, and K content was found to be 1.25, 1.35, 0.86 per cent, and in the second year 1.26, 1.34, 0.85 per cent, respectively.

3.1.6.1.2 Microbial enriched compost

After the trash mixture had decomposed and the final product emerged from the pit, biofertilizers and biopesticides were added to the compost. To increase microbial activity in the enriched compost, it was placed in the shade for fifteen days. In the first-year analysis of this microbial-enriched compost N, P, K content was found to be 1.12, 0.50, 0.79 per cent, and in the second year 1.13, 0.55, 0.77 per cent, respectively.

3.1.6.1.3 Mineral + microbial enriched compost

This compost is a combination of mineral and microbially enriched compost. It contains fifty percent mineral-enriched compost and fifty percent microbial-enriched compost. In the first-year analysis of this mineral + microbial enriched compost N, P, and K content was found to be 1.73, 2.13,1.14 per cent and in the second year 1.74, 2.18, 1.16 per cent, respectively.

3.1.6.1.4 Enrichment of compost

A few additions were used to enrich compost and improve its quality. These additives were divided into three primary categories:

- Organic substances.
- Mineral supplements.
- Microbial additions.

3.1.6.1.5 Organic substances

Regarding organic inputs, we made use of a wide variety of organic substrates that were found on and off the farm. These organic substances of mature composts, leftover straws, grass clippings, pallets of crushed wood, hardwood materials, weed and crop residues, fruit and vegetable peels, and livestock wastes were used. By carefully using organic additions according to their carbon-to-nitrogen (C/N) ratio, the goal was to accelerate the breakdown of organic material and stop nitrogen leaching during the composting process.

3.1.6.1.6 Mineral supplements

Most of the time, mineral additions like rock phosphate were utilized to enhance compost. The benefits of using mineral additives for compost enrichment include their great availability and low cost, their ability to absorb heavy metals, their potential to reduce greenhouse gas emissions during composting, and large-scale production of rock phosphate is done from rocks that contain phosphorus, like tricalcium phosphate. It is mostly used to make phosphatic fertilizer, though it can also be used to give P_2O_5 to severely acidic soil under specific circumstances.

Table 3.2: Composition of nutrients in rock phosphate

Sr. No.	Specifics	Content
1.	Phosphorus (%)	20.0
2.	Potassium (%)	0.13
3.	Sulphur	0.40
4.	Calcium (%)	9.0

5.	Magnesium (%)	3.48
6.	Iron (mg/kg)	5870
7.	Manganese (mg/kg)	904
8.	Zinc (mg/kg)	213
9.	Copper (mg/kg)	40

(Biswas and Narayanasamy 2006)

3.1.6.1.7 Microbial additions

Composting material was inoculated with various types of microorganisms (Rhizobium, Azotobacter, and Phosphate solubilizing bacteria) and biopesticides (*Trichoderma*, *Pseudomonas*) for enriching the compost (Jamoh *et al.,* 2021).

3.1.6.1.8 Composting process

Pits or trenches were filled in layers (five to six). Tree leaves, agricultural debris, crop residues, and animal feed wastes were among the biodegradable organic materials that were strewing across the trench floor in a layer that was roughly 20 cm deep. On top of the biodegradable organic material, a layer of rock phosphate (120 kg/ton) was applied. The rock phosphate layer was then covered with a slurry made from 10 kg/ton of cattle dung and water. Until all the biodegradable components were included, layering was repeated. Throughout the composting process, the moisture content was kept at 60% of its water-holding capacity. Aeration was provided by periodic turning, monthly. After a month of composting, the exterior of the composting mass was covered with a slurry of dirt and cow dung to protect it from precipitation. An appropriate polyethylene sheet was used to cover the exterior of the composting trench or pit. It took 90–100 days to complete of composting process and then used for field application. The final product was then inoculated with nitrogen-fixing microorganisms @100gm, phosphate, and potassium solubilizing microbes @100gm, and biopesticide *Pseudomonas* spp., *Trichoderma* spp. @100 and then kept in a shady area to increase microbial activity in compost (Rao, 2018).

3.1.6.1.9 Postharvest processing of compost

After collecting the compost from the pit, excess moisture, and undesirable materials such as stone, cake, plastics, and metals were removed with the help of spade. The final product has a moisture content of 35-50 per cent. To achieve a uniform size, the compost was dried in the shade and was sieved through a 1-inch mesh (Nath *et al*., 2020).

3.1.6.2 Farmyard manure (FYM)

Farmyard manure (FYM) is made up of decomposing cattle dung, stable bedding, and various other straw and plant stalk remains. High-quality, well-rotted FYM was obtained from the Department of Horticulture, Lovely Professional University in Phagwara, Punjab.

3.1.6.3 Vermicompost

Vermicomposting is the process of decomposing organic materials using worms. Worm casting, also known as vermicompost, is the last byproduct of vermicomposting. It has water-soluble nutrients, micronutrients, beneficial microorganisms, and plant growth hormones and enzymes. The NPK (N-1.5%, P-0.9%, and K-1.5%) was available in vermicompost. It has been scientifically demonstrated to be a wonderful growth promoter and a plant protector against illnesses and pests. Numerous humic compounds are also present in vermicompost, and studies have indicated that some of these substances' effects on plant growth are comparable to those of hormones or plant growth regulators given to the soil. The vermicompost was sourced from the Agri store of Department of Horticulture, Lovely Professional University, Phagwara, Punjab.

3.1.7 Bio-fertilizers

3.1.7.1 Rhizobium (RZB)

This aerobic bacterium fixes atmospheric nitrogen into ammonia, a natural fertilizer for plants, in association with certain plants, such as legumes. The organic materials that the plant produces through photosynthesis are subsequently fed to the bacterium. This mutually beneficial relationship exists among all rhizobia; the genus Rhizobium is a well-known example.

3.1.7.2 Azotobacter

Among the biofertilizers are azotobacter, which are live organisms that, when applied to the soil's surface or seeds, aid in populating the rhizosphere, or the internal portions of plants, and also aid in growth by making more primary nutrients available to plants. A gram-negative, free-living bacteria with an oval or spherical form is called an azotobacter. This is a significant biofertilizer that increases soil fertility by fixing nitrogen, which in turn increases crop productivity by allowing plants to absorb biologically active chemicals through biosynthesis.

3.1.7.3 Phosphate Solubilising Bacteria (PSB)

Beneficial microorganisms that can convert inorganic phosphorus from insoluble compounds are known as phosphate-solubilizing bacteria. Among the most crucial aspects of nourishment from phosphates in plants is the ability of rhizosphere bacteria to solubilize phosphate. The Agri store of Department of Horticulture, Lovely Professional University in Phagwara, Punjab provided microbes i.e. *Rhizobium*, *Azotobacter*, and Phosphate-Solubilizing Bacteria (PSB).

3.1.8 Bio-pesticides

3.1.8.1 *Pseudomonas fluorescens*

Common aerobic gram-negative bacteria called *Pseudomonas fluorescens* is present in agricultural soils and develops in the rhizosphere. Numerous characteristics of this rhizobacterium enable it to function as a biocontrol agent and enhance plant growth.

3.1.8.2 *Trichoderma viride*

Trichoderma viride appears as coils around pathogens, breaking down the formation of fungal pathogen cell walls by generating chitinases and celluloses, among other enzymes. Mycoparasitism is the term for this process, in which a fungus inhibits the growth and metabolic capacity of another fungus to cause its death.

The bio-pesticides i.e. *Pseudomonas* and *Trichoderma* were made available by the Agri store of Department of Horticulture, Lovely Professional University, Phagwara, Punjab from authentic source.

3.1.9 Chemical fertilizers

To apply the recommended fertilizer dosages (RDF), urea was used for the application of nitrogen, and single super phosphate (SSP) for phosphorus.

3.1.10 Packaging Material

3.1.11 Low-density polyethylene (LDPE)

Polyethylene is the most basic and least expensive plastic produced by adding ethylene to polymerize it. Packaging film with low density is the most widely used type. Water vapor may pass through LDPE well, but oxygen, carbon dioxide, and many flavour and odor molecules cannot get through. LDPE is typically utilized in circumstances requiring heat sealing and film applications because of its relative clarity. In terms of cost per mass unit, LDPE is often the least expensive plastic film (Mangaraj *et al.,* 2009). Because of its high CO_2: O_2 permeability ratio, LDPE allows for selective oxygen permittivity without causing an excessive buildup of CO_2 inside the package (Said *et al.,* 2014).

3.1.12 Polypropylene (PP)

Among commodity plastics, polypropylene (PP) has the lowest density (0.89 to 0.91 g/cm^3) and is more transparent and tougher than polyethylene. PP resists chemicals and water vapor quite well. PP's barrier qualities are like HDPE's (Mangaraj *et al.,* 2009). Because of its high melting point, it can be used in applications that call for heat resistance. Since it can be heat-sealed at a temperature of up to 170°C, it is typically coated with a PE/PVDC/PVC copolymer to make the process easier (Said *et al.,* 2014).

3.2 EXPERIMENTAL DETAILS

The field was split up into three sections, each holding ten plots. A random number table was used to randomly assign treatments inside each plot.

3.2.1 Details of experiment-I

Crop	:	Palak
Cultivar	:	Harit Shobha
Design	:	Randomized block design (RBD)
Treatments	:	10

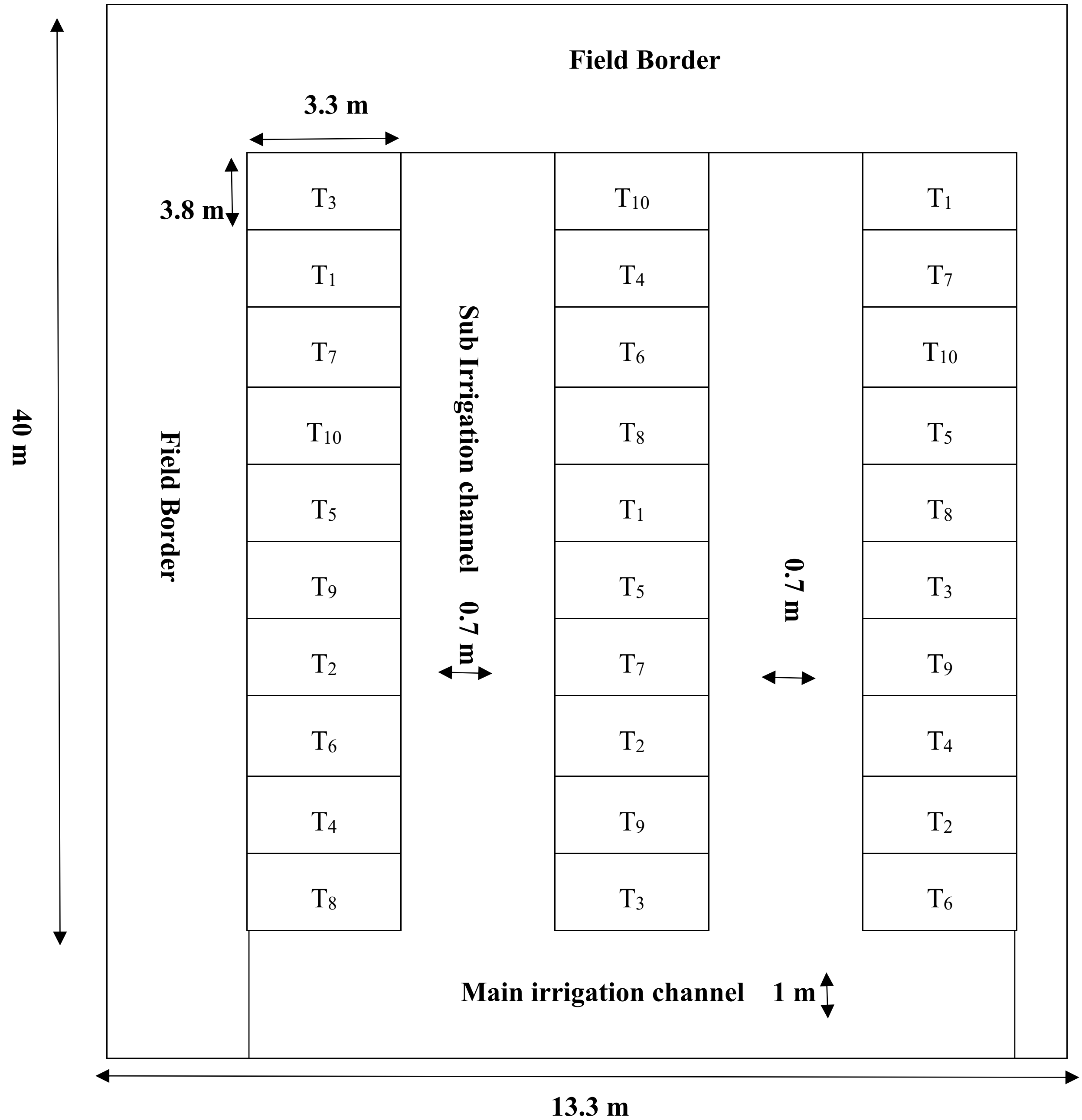
Replications	:	3
Number of plots	:	30
Size of plot	:	$(3.5 \times 3.0)\ m^2$
Plant to Plant spacing	:	10 cm
Row-to-row spacing	:	25 cm
Sowing dates	:	24 Feb. 2022
		25 Feb. 2023

3.2.1.1 Treatment details of experiment-I

Sr. No	Treatment
T_1	RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
T_2	RDF 50% + 50% FYM (10 tonnes/ha)
T_3	FYM (20 tonnes/ha)
T_4	Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
T_5	Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)
T_6	Vermicompost (5 tonnes/ha)
T_7	50% Mineral enriched compost (2.5 tonnes) + 50% Microbial Enriched Compost (2.5 tonnes)
T_8	75% Mineral enriched compost (3.75 tonnes) + 25% Microbial enriched compost (1.25 tonnes)
T_9	25% Mineral enriched compost (1.25 tonnes) + 75% Microbial enriched compost (3.75 tonnes)
T_{10}	Control (no application)

3.2.2 Details of experiment-II

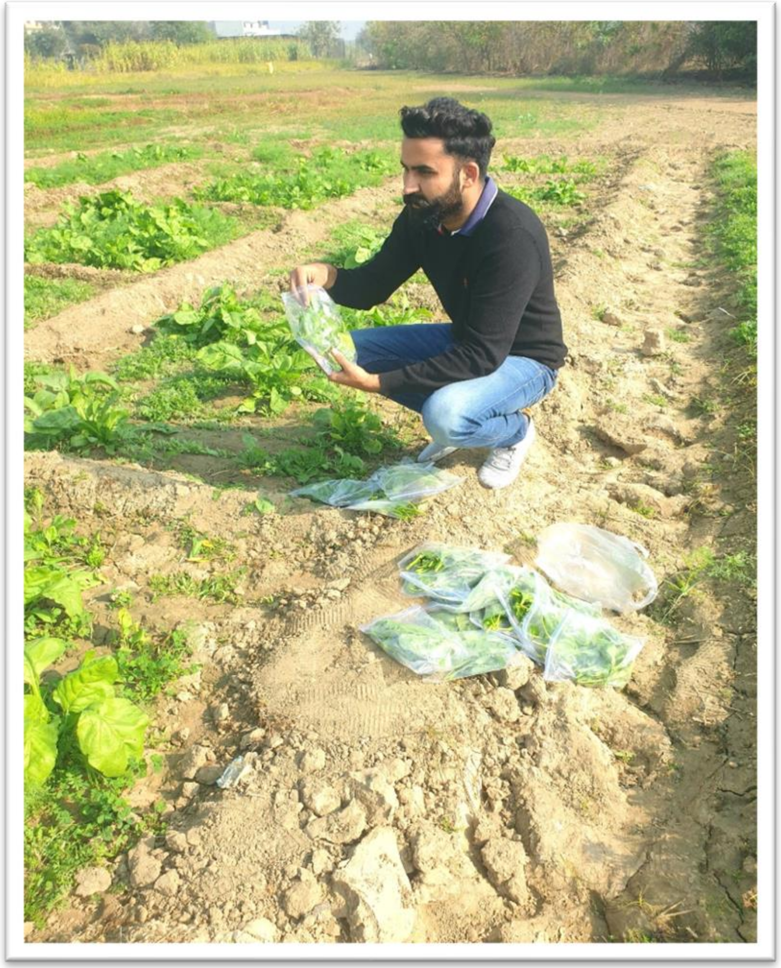
Experimental site	:	Post Harvest Laboratory
Design	:	Completely Randomized Design (CRD)
Experimental materials	:	Different packaging material
Variety	:	Harit Shobha
Replications	:	4
Treatments	:	7



Total Length: - 40 m
Total width: - 13.3 m
Total experimental area: - 532 m^2
Net plot size: - 3.5 x 3.0 = 10.5 m^2
Net area: - 10.5 x 30 = 315 m^2

Plate 1. Layout of experimental field

Plate 2. General view of experimental site (Experiment I)



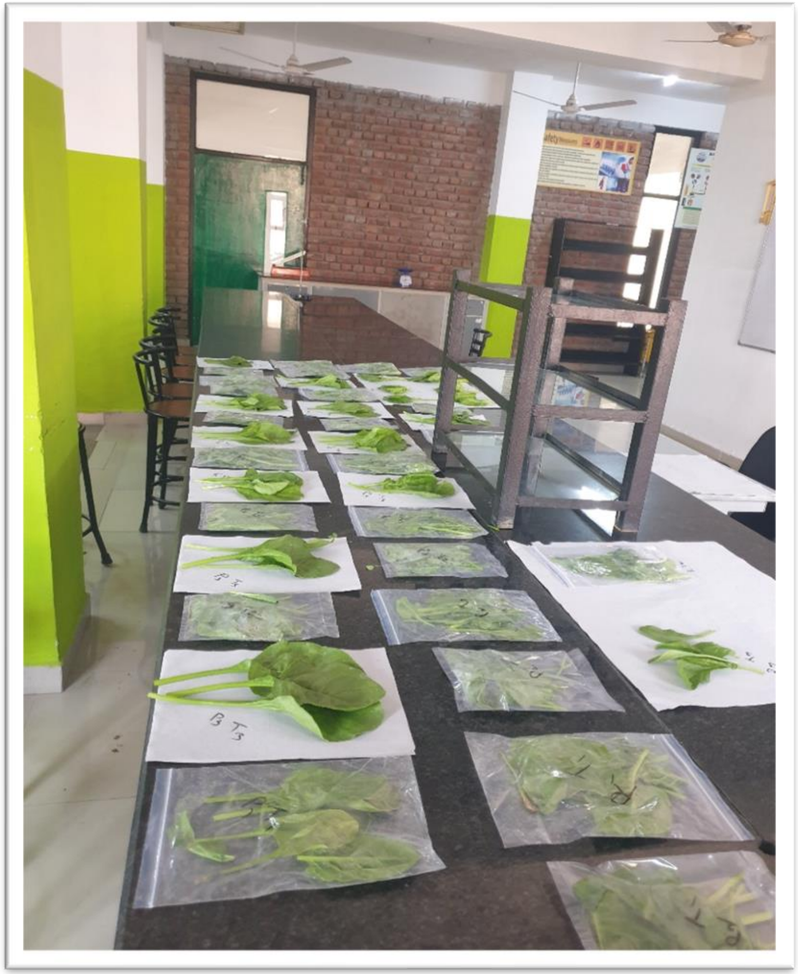


Plate 3. General view of post-harvest work into field and lab (Experiment II)

3.2.2.1 Treatment details of experiment-II

Sr. No	Treatment
T_1	LDPE 40 microns with 0 % vent.
T_2	LDPE 40 microns with 1 % vent.
T_3	LDPE 40 microns with 2 % vent.
T_4	PP 40 microns with 0 % vent.
T_5	PP 40 microns with 1 % vent
T_6	PP 40 microns with 2 % vent.
T_7	Control (No packaging)

LDPE: Low-density polyethylene

PP: Polypropylene

VENT: Ventilation

3.3 CULTURAL MANAGEMENT

3.3.1 Preparation of field

The experimental field was completely tilled by a tractor ten days before the seeds were sown. Stones and leftover crop debris were cleared away. The experimental field was leveled and adequate drainage was provided. Following that, the experiment plots of size 3.5×3.0 m^2 were made and treatments were distributed by the plan of arrangement. The field was left as it was at the end of the first research year, and following individual plot ploughing the following year, the same plots were prepared using the same treatment combinations. The first irrigation was carried out just after sowing and later twice a week.

3.3.2 Application of manures and fertilizers

The NPK was given according to the standard protocol, which contained urea (46% nitrogen) and single super phosphate (16% phosphorus). The recommended dose of fertilizers (RDF) for the palak crop in the present investigation was; 85: 30: 0 kg/ha NPK + FYM 20 tonnes/ha. Half dose of nitrogen and full dose of phosphorus was applied before sowing of the crop and remaining half dose of nitrogen was applied 30 days after sowing. During the soil preparation, all enriched compost and manures were physically added to the different plots based on their treatment.

3.3.3 Seed sowing and intercultural operations

For proper germination of seeds, the palak seeds were soaked for 24 hours. Direct seed sowing was done in the field on 24th and 25th of February during both the years i.e. 2022 and 2023 with immediate irrigation to have fast germination. Seeds were sown in flat beds @ 25-30 kg/ha for which row spacing was 25 cm and plant to plant spacing of 10 cm was given for the palak crop.

Different intercultural operations i.e. irrigation, hoeing, weeding and strategies for protecting plants for the palak crop were done according to the Package of Practices for vegetables given by Punjab Agricultural University, Ludhiana, Punjab (Anonymous, 2021b), to produce a healthy crop.

3.3.4 Irrigation

The first irrigation was given immediately after sowing of the seeds in all plots. Later on the irrigations were given at twice a week interval till the harvest.

3.3.5 Harvesting

After 25, 40, and 55 DAS, the plants from each plot were harvested and weighed individually.

3.4 OBSERVATIONS RECORDED

The data were evaluated to check the performance of palak under variations/treatments into form of growth, yield, and quality attributes. Data were collected from ten randomly marked plants in each replication, and the means for the two years that followed 2022 and 2023 were calculated for statistical analysis.

3.4.1 GROWTH AND YIELD ATTRIBUTES

3.4.1.1 Plant height (cm)

Using a meter scale, the height of plant was measured from the bottom to the top of the largest leaf at 25, 40 and 55 days after sowing (DAS). A calculation was made and the average height of the plant was stated in centimeters.

3.4.1.2 Number of leaves per plant

The aggregate number of leaves from ten randomly tagged plants at 25, 40 and 55 DAS were counted separately from same plants and summed up, then the mean value per plant was computed.

3.4.1.3 Length of petiole (cm)

The mean petiole length was worked out from the observations of ten tagged plants at 25, 40 and 55 DAS of each treatment.

3.4.1.4 Average leaf area per plant (cm^2)

Ten leaves were selected randomly of observational plant from each treatment at 25, 40 and 55 DAS. The average leaf area of leaves was calculated using an electronic area meter.

3.4.1.5 Diameter of the petiole (cm)

The petiole girth was measured using a vernier calliper at 25, 40 and 55 DAS and the mean values were calculated.

3.4.1.6 Average leaf yield per plant (g)

The leaf yield of each plant was estimated at the 1st, 2nd and 3rd cuttings i.e., after 25, 40 and 55 DAS, by weighing all the leaves separately and summing them up to calculate the average.

3.4.1.7 Average leaf yield per plot (kg)

Each plot leaf yield measured at 1st, 2nd and 3rd cuttings (after 25, 40 and 55 DAS) were separately and summed up to calculate average leaf yield per plot.

3.4.1.8 Leaf yield (q/ha)

Leaf yield per hectare was computed in quintals using the kilogram leaf yield obtained from each plot.

3.4.2 QUALITY ATTRIBUTES

3.4.2.1 Moisture content (%)

Moisture percent was calculated by taking a 100 g sample of palak leaves from each treatment and recording the fresh weight and oven dry weight at 80^0C for 48 hours at the third cutting. It was estimated as

$$Moisture\ \% = \frac{Fresh\ Leaves\ Weight - Dry\ Leaves\ Weight}{Fresh\ Leaves\ Weight} \times 100$$

3.4.2.2 Dry matter content (%)

After harvesting the leaves, the fresh weight of ten observation plants was measured and dried in an oven and the mean dry weight was calculated.

3.4.2.3 Ascorbic acid content (mg/100g)

The amount of ascorbic acid was determined utilizing the 2,6-dichlorophenol indophenols visual titration procedure. (A.O.A.C., 1975). A 5g sample of palak leaves was pulverized in a mortar and pestle, followed by the addition of 50 ml of 4% oxalic acid and filtering. After filtering, 5 millilitres of the solution were obtained and titrated against the dye solution. Using the dye factor, the amount of ascorbic acid was determined and represented as mg /100g using the formula:

$$Ascorbic\ acid = \frac{Titration\ value \times Dye\ factor \times Volume\ made\ up}{Analiquot\ of\ extract \times Volume\ of\ sample\ taken\ for\ estimation} \times 100$$

3.4.2.4 Total carotenoids content (mg/100g)

5g of palak samples with 3g celite powder was ground with 50 ml cold acetone and filter through Whatman No. 4 filter paper. 40 ml of petroleum ether (PE) was taken in a 500 ml separatory funnel and acetone extract was added in the funnel (Ranganna 1986). Thereafter, move the paste to a Buchner flask of 250 ml fitted with a sintered funnel (5 µm) and vacuum filter. The material was subjected to this procedure three times until it lost all colour. After adding 40 ml of petroleum ether to the extract, a 500 ml separatory funnel was used. The acetone was progressively removed by gently adding ultrapure water to prevent the formation of an emulsion. The watery phase was disposed of. Until no more solvent was left, this procedure was repeated four times. Next, a funnel was used to transfer the extract into a volumetric flask of 50 ml that had 15 g of anhydrous sodium sulfate. Petroleum ether made up the volume, and samples were measured at 450 nm. The following formula was used to get the total carotenoid content:

$$Total\ Carotenoids\ \left(\frac{mg}{100g}\right) = \frac{Absorbance \times Volume\ (ml) \times 10000}{Absorbance\ coefficient\ (2592) \times Sample\ weight\ (g)}$$

3.4.2.5 Total phenol content (mg/100g)

The total phenol content in ten randomly picked palak leaves from each treatment was estimated using Malick and Singh (1980) methodology. A blue complex called molybdenum blue is created when phenol and phosphomolybdic acid combine in the Folic-Ciocalteau reagent in an alkaline medium. This blue complex can be detected spectrophotometrically at 650 nm. Multiple times, phenol was extracted using 80% ethanol in a 1:10 (w/v) ratio. The supernatants were then collected and centrifuged, the pooled materials were evaporated until dry, and the residue was dissolved in a known volume of distilled water. Pipetting out differential aliquots allowed for the final volume to be adjusted to 3 ml using pure water. Add the Folin-Ciocalteau reagent (0.5 ml). Next, fill each tube with 2 milliliters of the 20% Na_2CO_3 solution. After one minute of boiling water, remove the tubes, let them cool, and compare the absorbance at 650 nm to the reagent black. A range of catechol concentrations was used to generate the standard curve. The test sample's total phenol concentration was expressed as mg catechol per 100g of material.

3.4.2.6 Antioxidant activity (%)

The antioxidant activity of palak samples estimated on the basis of 1, 1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging activity. 0.1 ml of sample extract and 3.9 ml of 6×10-5mol/L DPPH that was made in methanol were added to a test tube. After that, the sample was kept in the dark for thirty minutes, and its wavelength was measured at 515 nm (Brand and Williams, 1995). As a blank, the methanol solution was employed. The following formula was used to calculate the antioxidant activity.: -

$$Antioxidant\ activity\ (\%) = \frac{Blank_{(AB)} - Sample_{(AS)}}{Blank_{(AB)}} \times 100$$

Were,

$Ab_{(B)}$ = Absorption of the blank

$Ab_{(S)}$ = Absorption of the sample

3.4.2.7 Minerals content (mg/100g)

The total iron, copper, and zinc content in the plant in each treatment were estimated using DTPA extractable by AAS (Lindsay and Novell, 1978).

3.4.2.8 Chlorophyll index

The amount of chlorophyll of palak was determined using the SPAD meter (502 plus) (Konica Minolta, Inc.), which measures leaf absorbance in the red and near-infrared areas. Two LEDs emit light at peak wave lengths of 650 and 940 nm.

3.4.2.9 Crude fiber content (%)

The procedure outlined below was used to calculate the sample's crude fibre by Rangana (1986). Surface moisture-free samples weighing 2g were digested with 200ml of 1.25 percent H_2SO_4 (v/v) for 30 minutes. The acid solution was decanted, and the item was rinsed with hot water to remove the acid. Solid particles were digested with 200ml of 1.25 percent NaOH for 30 minutes. After decanting the top layer, solid particles were screened using the Whatman 14 no. filter paper. The remaining residue was cleansed of alkali by washing with 10 percent hot potassium sulphate solution, followed by repeated washing with hot water, ethyl alcohol, and finally ether. The materials were in an oven to dry at 110°C for five hours before being weighed. Finally, the material was placed in a silica crucible and cooked in a muffle furnace at dull red heat for several hours before cooling and being weighed (Wa). The weight differential (We-Wa) corresponds to the following formula.

$$Crude\ fibre\ (\%) = \frac{W_e - W_a}{Weight\ of\ the\ sample} \times 100$$

Where, W_e = the oven-dried sample's weight (g)

W_a = the sample's weight after cooling (g)

3.4.2.10 Leaf nitrate content (mg/kg)

As per Cataldo *et al.* (1975), the amount of nitrate in various samples was determined using a quick colorimetric measurement of nitrate in plant tissue through salicylic acid nitration.

3.5 OBSERVATIONS RECORDED FOR SHELF-LIFE STUDIES

The crop grown in the field under different treatment was further checked for shelf-life studies for both years 2022 and 2023. The crop was harvested from each treatment and stored under ambient storage conditions with different packaging materials and observations were recorded as follows.

3.5.1 Physiological loss in weight (%)

The leaves initial weight and its weight after storage were subtracted to determine the amount of physiological weight loss, which was then expressed as a percentage (Koraddi *et al.,* 2009). Each statement's % weight reduction was determined utilizing the formula below:

$$PLW(\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100$$

3.5.2 Shelf life (days)

100 gm of palak leaves were used for all the treatments under study. They were stored in ambient storage conditions with different packaging materials. Observations were recorded for alternate days from the date of storage. The number of days required for palak leaves to lose weight in an acceptable physiological manner was stated in days.

3.5.3 Days to 50 per cent color change

The total number of days taken to 50 per cent colour change in the palak samples was recorded based on visual appearance from the first day to 7th day of storage.

3.5.4 Days to 50 per cent rotting

The total number of days taken to 50 per cent rotting of the palak samples was recorded based on visual appearance from the first day to 7th day of storage.

3.6 ENRICHED COMPOST ANALYSIS

3.6.1 Characterization of compost

Various enriched composts i.e. mineral enriched compost, microbial enriched compost, and mineral + microbial enriched composts were analyzed for chemical properties by standard procedures as mentioned below:

3.6.1.1 pH and EC (dSm^{-1})

The pH of the compost samples was measured with an electrical digital pH meter on a 1:25 water suspension ratio. A conductivity meter was used to measure electrical conductivity through the supernatant extract from the suspension mixture (1:25) according Jackson (1973). 25 g of different compost samples were taken in 100 ml beaker. After 50 ml of distilled water added suspension mixed with glass rod and kept stable for two to three hours. For pH determination the meter electrode calibrated through acidic, alkaline or neutral buffer solution. Electrodes inserted in suspension and measured the pH of compost samples. In electrical conductivity determination, first standardized the conductivity meter with standard KCL solution thereafter dipped the cell into solution and EC measured.

3.6.1.2 Organic carbon (%)

A pre-weighed silica crucible was filled with 10 g of compost samples to measure the amount of carbon in the compost sample. The samples were kept for two hours at 600°C in a furnace. The crucibles were quickly cooled and weighed to a constant (ash weight) after being transferred to desiccators. The percentage of organic matter was then divided by 1. 724 to determine the amount of organic carbon (Jackson, 1973).

3.6.1.3 Total nitrogen (%)

Total nitrogen of compost was estimated by Kjeldahl's method as described by Jackson (1973). To prepare soil samples, mixed 1g of soil sample with 5-7g of digestion mixture and 20ml of concentrated sulphuric acid. Loaded 20 samples into a digestion block, heated at 375^0 C for 2-3 hours, and removed tubes with exhaust led intact. Cooled to room temperature. For the distillation process, added 4% boric acid to a 250 ml conical flask, mixed with indicator, and distilled with 40 ml sodium hydroxide, collecting 150 ml of the resulting distillate. Removed the conical flask from the distillation chamber, and allowed it to cool down to room temperature. Titrated the distillate with 0.1 N hydrochloric acid or sulphuric acid until the colour changed from green to red/pinkish red. Ran a blank sample without a compost sample.

3.6.1.4 Total phosphorus (%)

The total phosphorus was taken out utilizing 0.5 N $NaHCO_3$ at 8.5 pH and measured utilizing spectrophotometry according Olsen, (1954). Took 2.5 g of compost samples in 150 ml conical flask and added about 1 g of phosphorus free activated charcoal and 50 ml of 0.5N sodium bicarbonate solution. Shook the contents on mechanical shaker for 30 minutes and filter them immediately through Whatman filter paper 40. Pipette out 10 ml of aliquot in 50 ml volumetric flask, added 10 ml of 1. 5 percent ammonium molybdate and about 2-3 ml of distilled watered, shook well, added 1 ml of working stannous chloride and made up the volume to 50 ml with distilled watered, the blue colour was developed. Read the OD at 660 nm wavelength on spectrophotometer within 10-20 minutes.

3.6.1.5 Total potassium (%)

A flame photometer was used to determine the digested compost sample's total potassium content following the proper dilution (Jackson, 1973). 5 g of compost samples was taken in 100 ml conical flask and added 25 ml of ammonium acetate solution. Shook the contents on the mechanical shaker for 20-30 minutes, filtered and the made up the volume to 25 ml and determined potassium on flame photometer.

3.6.1.6 Calcium and Magnesium (%)

As per Piper (2019), to analyze calcium and magnesium of compost samples, a 5 g of compost sample taken in 150 ml flask, added 25 ml neutral normal ammonium acetate solution, filter through Whatman No.1 paper and shaken for five minutes. Added carbamate crystals, ammonium chloride-ammonium hydroxide buffer solution, and Eriochrome black T indicator. Titrated the solution with 0.01N versenate until the color changes to bright blue or green and no wine red colour remains.

3.6.1.7 Total sulphur (%)

Page *et al.* (1982) state that the 420 nm turbidity was measured using a spectrophotometer after precipitating the sulphate with barium chloride to determine the quantity of sulphur in compost samples. Weighed 20 g of compost sample, added 100 ml of monocalcium phosphate extracting solution, filter, and dilute in a 25ml volumetric flask. Added 2.5 ml of HNO_3 and acetic-phosphoric acid, shook, and added $BaSO_4$ seed suspension and added 1ml of gum acacia-acetic acid solution. Invert the flask 10 times and measured the turbidity intensity at 440 nm. Allowed the mixture to stood for 15 minutes before adding the solution. Ran a blank sample side by side.

3.6.1.8 Estimation of Micro Nutrients (mg/kg)

Lindsay and Norwell (1978) used an Atomic Absorption Spectrophotometer (AAS) and the appropriate dilution to identify the micronutrients (Cu, Zn, Fe, and Mn) in the digested compost sample. Weighed 10 g of compost samples and transferred to a 100-ml narrow mouth polyethylene bottle. Added 20 ml DTPA solution and put stopper. Shaken on an electric shaker for 2 hours at 25^0 C. Filtered the contents through Whatman No.1 or Whatman No 42 filter paper. Also, run a blank sample with only DTPA solution and no compost.

3.7 SOIL ANALYSIS

Before the start of the experiment the soil samples were taken from multiple locations of experimental area for estimation of initial soil properties. Upon the experiment was completed, samples of field soil were collected from every treatment plot and examined for various soil properties. The procedures used to assess the various physicochemical parameters are described in the appropriate sections.

3.7.1 pH and EC (dSm^{-1})

The pH of the compost samples was measured with an electrical digital pH meter on a 1:25 water suspension ratio. A conductivity meter was used to measure electrical conductivity through the supernatant extract from the suspension mixture (1:25) according Jackson (1973). 25 g of different compost samples were taken in 100 ml beaker. After 50 ml of distilled water added suspension mixed with glass rod and kept stable for two to three hours. For pH determination the meter electrode calibrated through acidic, alkaline and neutral buffer solution. Electrodes inserted in suspension and measured the pH of compost samples. In electrical conductivity determination, first standardized the conductivity meter with standard KCL solution thereafter dipped the cell into solution and EC was measured.

3.7.2 Organic carbon content (%)

The organic carbon content was measured using Walkley and Black's (1934) ferrous ammonium sulphate titration and dichromate oxidation technique. Weighed 2 g of soil passed through 0. 2 mm sieve in 500 ml conical flask, added 10 ml of potassium dichromate with pipette, and shaken well. Added slowly 20 ml of concentrated sulphuric acid by swirling the flask during addition. When the content was cooled at room temperature, added 200 ml of distilled watered and 10 ml of 85% orthophosphoric acid and shaken the contents, added 10 drops of diphenylamine indicator which imparts violet colour to the contents. Titration done with 0.5 N ferrous ammonium sulphate till the colour was changes from violet to bright green. In the last the volume of the ferrous ammonium sulphate was noted.

3.7.3 Available nitrogen (kg/ha)

The soil's accessible nitrogen was assessed using Subbiah and Asija's alkaline potassium permanganate technique (1956). Weighed 20 g of soil sample in an 800 ml Kjeldahl flask and moisturise the soil with about 10 ml of distilled water. Also added 100 ml of 0.32% KMnO4 solution, glass beads or rods, and 2-3ml of paraffin liquid to avoid contact with the upper part of the flask's neck. Measured 20 ml of 2% boric acid containing mixed indicator in a 250 ml conical flask and placed it under the receiver tube. Added 100 ml of 2. 5% NaOH solution and immediately attach to the rubber stopper fitted in the alkali trap. Titration of the distillate against 0.02 M H_2So_4 taken in burette until pink colour started appearing also ran a blank sample without soil.

3.7.4 Available phosphorus and potassium (kg/ha)

The accessible phosphorus was taken out utilizing 0.5 N $NaHCO_3$ at 8.5 pH and measured utilizing spectrophotometry according Olsen, (1954). The total phosphorus was taken out utilizing 0.5 N $NaHCO_3$ at 8.5 pH and measured utilizing spectrophotometry according Olsen, (1954). 2.5 g of soil samples taken in 150 ml conical flask and added about 1 g of phosphorus free activated charcoal and 50 ml of 0.5N sodium bicarbonate solution. Shaken the contents on mechanical shaker for 30 minutes and filtered immediately through Whatman filter paper 40. Pipette out 10 ml of aliquot in 50 ml volumetric flask, added 10 ml of 1. 5 percent ammonium molybdate and about 2-3 ml of distilled watered, shook well, added 1 ml of working stannous chloride and made up the volume to 50 ml with distilled watered, the blue colour was developed. Read the OD at 660 nm wavelength on spectrophotometer within 10-20 minutes.

The available potassium was extracted using typical neutral ammonium acetate and measured using a flame photometer according Merwin and Peech, (1951). 5 g of soil samples was taken in 100 ml conical flask and added 25 ml of ammonium acetate solution. Shook the contents on the mechanical shaker for 20-30 minutes, filtered and the made up the volume to 25 ml and determined potassium on flame photometer.

3.8 ECONOMICS OF THE TREATMENTS

The cultivation cost was calculated using the current input costs at the time of use. The cultivation cost was determined for each treatment. Calculating net return per hectare was done by deducting the cost of cultivation from total revenue.

Total cost of cultivation: Total variable cost + Total fixed cost.

Gross return: Total yield (kg) × Market price of the produce (Rs. /kg).

Net return: Gross return - total cost of cultivation.

Benefit-cost ratio: Net return/ total cost of cultivation.

3.9 STATISTICAL ANALYSIS

Statistical analyses were done on the recorded data as per standard statistical procedure at a level of 5 per cent significance for both the cropping seasons of 2021-2022 and 2022-2023 using the software OPSTAT. The three replications for field experimental using RBD (randomized block design) and four replications for laboratory trials using CRD (completely randomized design) were laid out to verify the influence of different variables. As suggested by Panse and Sukhatme (2000), the mean value of the data was subjected to analysis of variance (randomized complete block design) using MS-Excel and OPSTAT according Sheoran *et al.*, (1998).

Variation source	**DF**	**Sum of Squares**	**Mean Squares**	**F Value**
Replication (r)	(r-1)	S_r	$S_r/(r-1) = M_r$	M_r/M_e
Treatment (t)	(t-1)	S_t	$S_t/(t-1) = M_t$	M_t/M_e
Error	(r-1) (t-1)	S_e	$S_e/(r-1)\ (t-1) = M_e$	
Total	(rt-1)	S_T	S_T	

Where,

r = Replication numbers

t = Treatment numbers

At the significance level of 5%, the obtained "F" value and the "F" table value were compared. The treatment effects were deemed significant, i.e., one of the treatment pairs differed considerably, and CD was obtained when the "F" calculated value was more than the "F" table value.

$$CD = SE \times t_{(0.05)} \text{ (error df)}$$

$$CD = \frac{\sqrt{2 \times Me}}{\sqrt{r}}\, t_{(0.05)} \text{ (error df)}$$

Pooled analysis of variance (ANOVA) was performed for both the years as follows:

Variation source	**DF**	**Sum of Squares**	**Mean Squares**	**F Value**
Replication (r)	(r-1)	S_r	$S_r/(r-1) = M_r$	M_r/M_e
Years	(a-1)	S_b	$S_a/(a-1) = M_a$	M_a/M_e
Treatments	(b-1)	S_a	$S_b/(b-1) = M_b$	M_b/M_e

Treatments × Years	(a-1) (b-1)	S_{ab}	S_{ab}/(a-1) (b-1) = M_{ab}	M_{ab}/M_e
Error	(ab-1) (r-1)	S_e	S_e/(r-1) (t-1) = M_e	
Total	rab-1	S_T		

Where,

r = Replication numbers

a = Total years

b = number of treatments

At the significance level of 5%, the obtained and tabulated "F" values were compared. When the computed "F" value exceeds the table value, it is deemed significant, meaning that one of the pairs differed significantly and a CD was calculated.

In order to compare the means of any two treatments, the critical difference (CD) and standard error of mean SE (m) were estimated as follows:

$$SE(m) = \pm (M_e/r)^{1/2}$$

$$SE(d) = \pm (2M_e/r)^{1/2}$$

Critical difference (CD) = SE (d) × t (5 %) value at error df.

$$SE(d)_y = \frac{\sqrt{2} \times \sqrt{M_e}}{\sqrt{ra}}$$

$$SE(d)_y = \frac{\sqrt{2} \times \sqrt{M_e}}{\sqrt{rb}}$$

$$SE(d)_{y \times t} = \frac{\sqrt{2} \times \sqrt{M_e}}{\sqrt{rb}}$$

CHAPTER-4 RESULTS AND DISCUSSION

The investigation entitled "**Study on the preparation and influence of enriched compost on the growth, yield and quality of palak (*Beta vulgaris* L.)"** was carried out over two consecutive cropping seasons of 2022 and 2023 at the Vegetable Farm, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab. The collected data on Different characteristics were statistically examined and it was verified that the results were relevant. This chapter presents the results for various growth, yield, quality and shelf-life characteristics. The results have also been reviewed, together with possible explanations and evidence to determine the cause-and-effect link between various treatments and sort out information of practical significance.

4.1 CHARACTERIZATION OF ENRICHED COMPOST FOR ITS CHEMICAL PROPERTIES

The enriched compost used for the experiment *viz.* Mineral (Rock phosphate) enriched compost(E_1), Microbial (N, P, K biofertilizer and biopesticides) enriched compost(E_2) and mineral + microbial enriched compost(E_3) was analyzed after enrichment in December 2021 and 2022, respectively for their chemical properties and presented in Table 4.1.

4.1.1 pH, EC and Organic carbon

The pH of enriched composts i.e. E_1(mineral compost), E_2(microbial compost) and E_3(mineral + microbial compost) for both years were recorded as 7.90, 7.80, 7.40 and 7.89, 7.79, 7.39, respectively. The pH of enriched compost ranges between 7.39 – 7.90 i.e. slightly neutral in the nature that is most suitable for plant growth and development. Compost E_3 had a slightly lower pH than other enriched compost due to the formation of organic acids and compounds containing phenols during the incubation process. However, pH was balanced after a while due to the buffering characteristic of humic compounds. Comparable outcomes were according to Mahajan *et al.*, (2010).

Electrical conductivity (EC) of enriched composts i.e. E_1(mineral compost), E_2(microbial compost) and E_3(mineral + microbial compost) for both years were recorded as 3.4, 3.1, 2.1 dSm^1 and 3.41, 3.05, 2.12 dSm^1, respectively. An increase in electrical conductivity is due to increased concentration of salts because of decomposition of organic matter. The release of various mineral ions, including phosphate, ammonium, and potassium, during the incubation of these mineral enriched composts may be the cause of the increase in electrical conductivity. (Yadav and Garg, 2011; Jamoh 2021).

The organic carbon content of enriched composts i.e. E_1(mineral compost), E_2(microbial compost) and E_3(mineral + microbial compost) for both years were recorded as 12.5, 13.1, 13.5 per cent and 12.51, 13.09, 13.60 per cent, respectively. The increased organic carbon content was noted because of better decomposition that of the different organic sources used in compost enrichment. In line with our investigations, Preethu *et al.*, (2007) and Jagadeesha *et. al.,* (2019a) also recorded similar results.

4.1.2 Primary nutrients (N, P, K)

The available nitrogen (N) in enriched composts i.e. E_1(mineral compost), E_2(microbial compost) and E_3(mineral + microbial compost) for both years were recorded as 1.25, 1.12, 1.73 per cent and 1.29, 1.15, 1.78 per cent, respectively. The improved nitrogen content might result from decomposition of complex N-Compounds effected by breakdown of organic carbon molecules that are labile, which reduces the weight of composting mass and increases the microbial activity (Bernai *et al.,* 1998).

The phosphorus (P) content in enriched composts i.e. E_1(mineral compost), E_2(microbial compost) and E_3(mineral + microbial compost) for both years were noted as 1.35, 0.50 and 2.13 per cent and 1.34, 0.55, 2.18 per cent, respectively. The increase in phosphorus content in all enriched composts might result from enrichment with microbial consortium that resulted in efficient mineralization of rock phosphate which led to enhance the phosphorus content in E_3 (mineral + microbial) compost. Comparable outcomes were attained by Mahajan *et al.,* (2010).

Potassium (K) content in enriched composts i.e. E_1(mineral compost), E_2(microbial compost) and E_3(mineral + microbial compost) for both years were recorded as 0.86, 0.76 and 1.14 per cent and 0.85, 0.77, 1.16 per cent, respectively.

Higher amount of K in enriched compost E_3 might result from rapid microbial activity resulting in a material volume reduction observed (Manjunatha, 2011).

Table 4.1. Chemical characteristics of several enriched composts for two years utilized in the research

Parameters	Season 2021-22			Season 2022-23		
	E_1	E_2	E_3	E_1	E_2	E_3
pH	7.90	7.80	7.40	7.89	7.79	7.39
EC (dSm^{-1})	3.40	3.10	2.10	3.41	3.05	2.12
Organic carbon (%)	12.50	13.10	13.50	12.51	13.09	13.60
N (%)	1.25	1.12	1.73	1.29	1.15	1.78
P (%)	1.35	0.50	2.13	1.34	0.55	2.18
K (%)	0.86	0.76	1.14	0.85	0.77	1.16
Ca (%)	5.40	4.22	7.33	5.30	4.20	7.39
Mg (%)	0.61	0.70	0.81	0.63	0.72	0.83
S (%)	0.36	0.34	0.46	0.35	0.33	0.47
Cu (mg/kg)	76.84	130.50	222.00	76.83	131.52	222.12
Zn (mg/kg)	383.20	383.00	317.20	383.22	383.10	317.30
Fe (mg/kg)	15400	10570	18100	15412	10571.10	18120.13
Mn (mg/kg)	352.20	470.90	446.90	353.10	471.80	447.80

Note * E_1= Mineral enriched compost
*E_2= Microbial enriched compost
*E_3= Mineral + microbial enriched compost

4.1.3 Secondary nutrients (Ca, Mg and S)

Among further nutrients, calcium and magnesium content in enriched composts i.e. E_1(mineral compost), E_2(microbial compost) and E_3(mineral + microbial compost) for first year were recorded as 5.40, 4.22, 7.33 per cent and 0.61, 0.70, 0.81 per cent, respectively. For second year Ca and Mg in E_1, E_2 and E_3 was recorded as 5.30, 4.20, 7.39 and 0.63, 0.72, 0.83 per cent, respectively. Increase in Ca and Mg in enriched composts may be due to enrichment of compost with rock phosphate because it contains higher amount of Calcium and Magnesium. The sulphur (S) content in enriched composts i.e. E_1(mineral compost), E_2(microbial compost) and E_3(mineral + microbial compost) for both years were recorded as 0.36, 0.34, 0.46 per cent and 0.35, 0.33, 0.47 per cent, respectively and it was observed that there was no such increment in the sulphur content after enrichment of compost. Increased S concentration in enriched composts is mostly due to decomposing of organic materials (Anand, 2016 and Jamoh, 2021).

4.1.4 Micro Nutrients (Cu, Zn, Fe and Mn)

The micronutrients content in enriched composts i.e. E_1(mineral compost) for both years recorded as 76.84, 383.20, 15400.00, 352.20 mg kg^{-1} and 76.83, 383.22, 15412.00, 353.10 mg kg^{-1} for Cu, Zn, Fe and Mn, respectively. In case of E_2(microbial compost) for both years it was recorded as 130.50, 383.00, 10570.00, 470.90 mg kg^{-1} and 131.52, 383.10, 10571.10, 471.80 mg kg^{-1} for above mentioned micronutrients. Similarly, in E_3(mineral + microbial compost) the results followed for micronutrients content for both years were obtained as 222.00, 317.20, 18100.00, 446.90 mg kg^{-1} and 222.12, 317.30, 18120.13, 447.80 mg kg^{-1}, respectively. Increased micronutrient content in enriched composts might be due to micronutrient chelation that is occurring biologically (Jagadeesha *et al.*, 2019a; Murthy and Upendra, 2008).

4.2 GROWTH AND YIELD ATTRIBUTES

4.2.4 Plant height (cm)

A plant species' ecological strategy is highly influenced by its height. Height is essential to a species carbon gain strategy since it influences a plant's ability to compete for light and is correlated with traits like canopy area, leaf mass per area, leaf nitrogen per area, and leaf mass fraction. (Moles *et al.*, 2009).

The data referring to plant height of palak reported in Table 4.2 and Fig 4.1 confirms noteworthy variance in plant height. The height of plant at 25 DAS in different treatment combinations in the present studies ranged from 9.73 to 22.38 cm having a mean of 18.07 cm during the first year (2022) and the values ranged from 10.17 to 22.33

cm having a mean of 18.57 cm during second year. The pooled mean values for plant height ranged from 9.95 to 22.66 cm.

In the both years, the maximum height of plant was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 22.38 and 22.33 cm at 25 DAS. The plant height for control i.e. treatment (T_{10}) was found to be 9.73 and 10.17 cm that was least among all treatment combination, respectively.

Also, in pooled data analysis of both the years the maximum plant height was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with value of 22.36 cm which was statistically at par with treatment combinations T_7 (50% mineral enriched compost + 50% microbial enriched compost) and T_2 RDF 50% + FYM (10 tonnes/ha) with values of 21.80 and 21.58 cm at 25 DAS, respectively. The absolute control (T_{10}) during pooled data analysis recorded the lowest plant height (9.95 cm).

Significant differences were confirmed by data revealing the plant height of palak, as seen through Table 4.2 and Fig 4.2. The plant height at 40 DAS in different treatment combinations in the present studies varied from 18.39 to 32.50 cm having a mean value of 28.22 cm during the first year (2022) and the values varied from 19.39 to 32.67 cm having a mean value of 28.16 cm during second year. The pooled mean values for plant height varied from 18.89 to 32.58 cm.

In both years, the maximum height of plant was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 32.50 and 32.67 cm at 40 DAS. The plant height for control i.e. treatment (T_{10}) was found to be 18.39 and 19.39 cm that was least among all treatment combination, respectively.

Also, in pooled data over the years the maximum plant height was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 32.58 cm at 40 DAS. Treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and T_2 **(**RDF 50% + FYM (10 tonnes/ha) showed similar results with values of 31.51 and 30.39 cm and statistically at par with treatment T_1. The plant height for control i.e. treatment (T_{10}) was found to be 18.89 cm that was least among all treatment combination, respectively.

Plant height variation is confirmed to be significant, as indicated by the data on plant height of palak displayed in Fig. 4.3 and Table 4.2. Height of the plant at 55 DAS in different treatment combinations in the present studies ranged from 13.55 to 28.25 cm with a mean value of 22.88 cm during the first year (2022) and the values ranged from 14.35 to 28.52 cm with a mean value of 23.28 cm in the second year. Plant height pooled mean values ranged from 13.95 to 28.39 cm.

In the both years, the maximum height of plant was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the values of 28.25 and 28.52 cm at 55 DAS. The plant height for control i.e. treatment (T_{10}) was found to be 13.55 and 14.35 cm that was least among all treatment combination, respectively.

Also, in pooled data analysis the maximum plant height was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 28.39 cm at 55 DAS. Treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and T_2 **(**RDF 50% + FYM (10 tonnes/ha) showed similar results with values of 27.39 and 27.64 cm and statistically at par with treatment T_1. The plant height for control i.e. treatment (T_{10}) was found to be 13.95 cm that was least among all treatment combination, respectively.

During first year of the experiment, the increased plant height might be due to higher nutrients application to the soil under treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha). Higher photosynthetic activity compared to other treatments may be directly linked to easily accessible nutrients from chemical fertilizers, as well as quicker absorption and translocation by plants. Also, protoplasm production leads to cell division and expansion, that depends on nitrogen, the primary component of proteins. Similar outcomes were mentioned by Hashimi *et al.,* (2019) for palak.

Table 4.2 Effects of various treatments on the plant height of palak at 25, 40 and 55 DAS (cm)

Treatments	Plant height at 25 DAS (cm)			Plant height at 40 DAS (cm)			Plant height at 55 DAS (cm)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	22.38	22.33	22.36	32.50	32.67	32.58	28.25	28.52	28.39
T_2	21.82	21.35	21.58	30.47	30.31	30.39	27.64	27.64	27.64
T_3	16.43	14.84	15.63	27.92	21.72	24.82	20.47	18.35	19.41
T_4	19.57	19.94	19.75	30.13	30.31	30.22	22.99	27.02	25.01
T_5	17.46	18.15	17.80	27.85	28.53	28.19	21.61	21.09	21.35
T_6	18.45	19.94	19.19	28.52	30.12	29.32	22.41	22.04	22.22
T_7	21.32	22.27	21.80	31.33	31.69	31.51	27.33	28.25	27.79
T_8	18.34	19.26	18.80	29.80	29.11	29.46	22.99	23.73	23.36
T_9	15.19	17.44	16.32	25.24	27.72	26.48	21.53	21.79	21.66
T_{10}	9.73	10.17	9.95	18.39	19.39	18.89	13.55	14.35	13.95
Mean	**18.07**	**18.57**	**18.32**	**28.22**	**28.16**	**28.19**	**22.88**	**23.28**	**23.08**
CD($p \leq 0.05$)	**0.52**	**0.77**	**0.85**	**1.34**	**1.03**	**1.55**	**1.02**	**0.73**	**1.14**
CV %	**1.70**	**2.42**	**2.10**	**2.78**	**2.13**	**2.48**	**2.60**	**1.83**	**6.30**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)

*T_2= RDF 50% + FYM (10 tonnes/ha)

*T_3= FYM (20 tonnes/ha)

*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)

*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)

*T_6= Vermicompost (5 tonnes/ha)

*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost

*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost

*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost

*T_{10}= Control

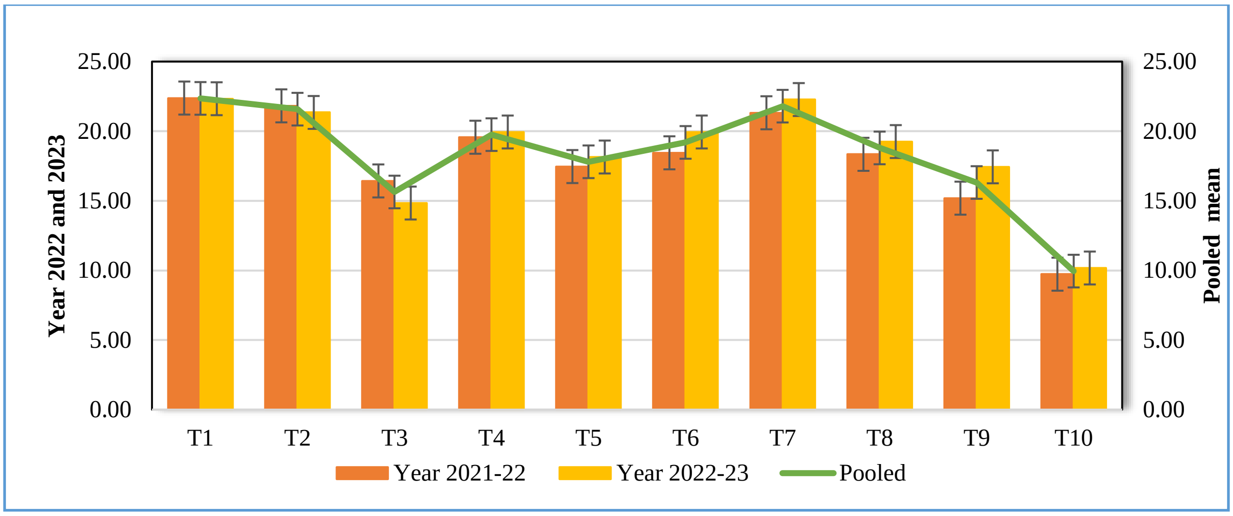


Fig. 4.1 Effects of various treatments on plant height of palak at 25 DAS (cm)

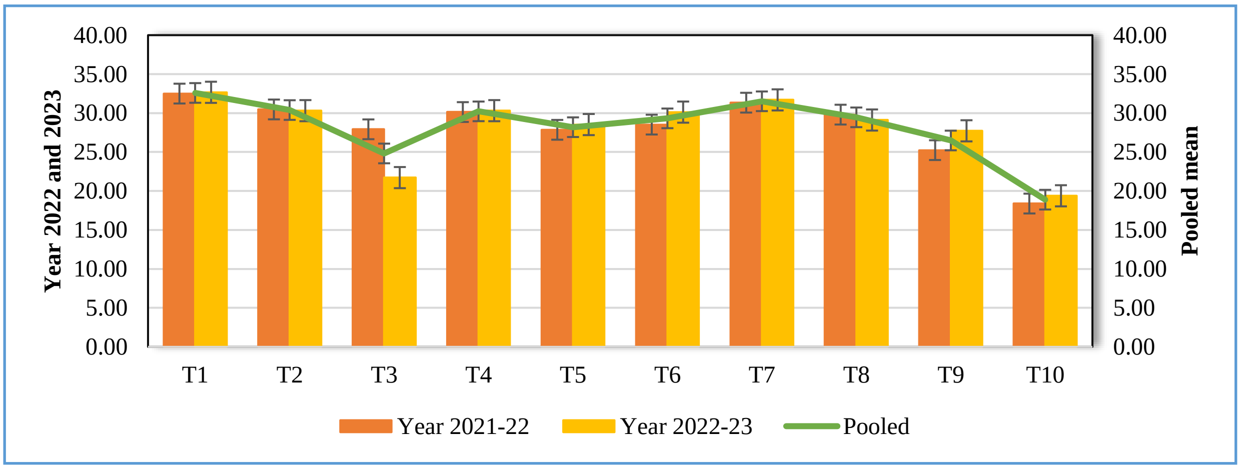


Fig. 4.2 Effects of various treatments on plant height of palak at 40 DAS (cm)

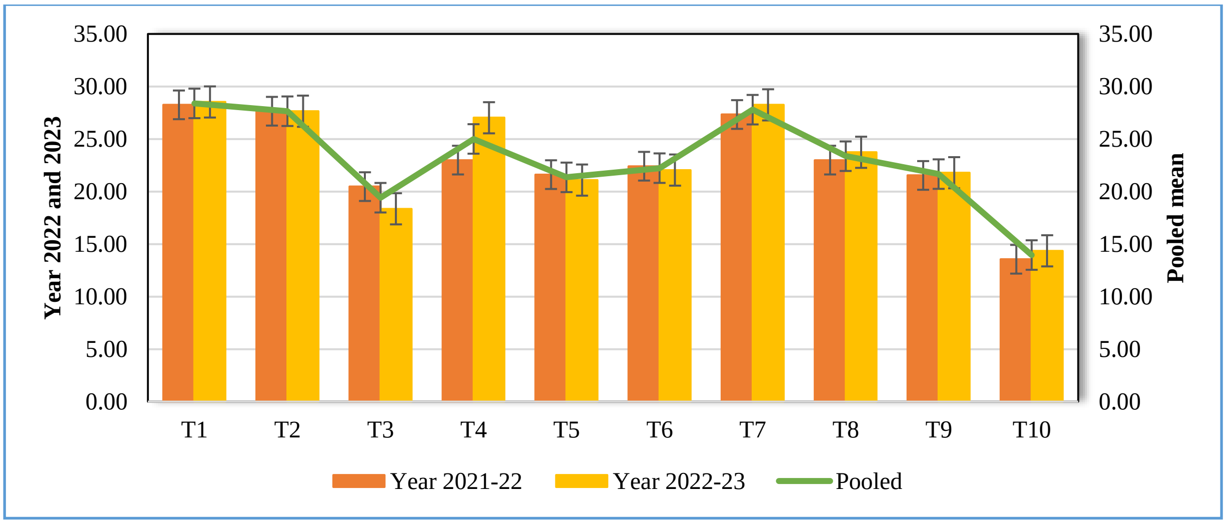


Fig. 4.3 Effect of various treatments on plant height of palak at 55 DAS (cm)

During pooled data analysis over the years, it was observed that, treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) demonstrated a considerable increase in plant height and performs at par to treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) which recorded maximum plant height. This could be because compost improves the characteristics of soil, both physically and biologically, including the availability of nearly all plant nutrients required for plant growth and development. Thus, appropriate nutrients in a proper environment may have aided in the development of new tissues and the growth of new shoots, thereby greatly improving crop characteristics. Comparable outcomes were stated by Rady *et al.,* (2016), Jagadeesha *et. al.,* (2019b) and Jamoh, 2021.

4.2.5 Number of leaves

One of the observable key aspects (phenotypes) that characterizes a plant's development and growth is the number of leaves it possesses (Dobrescu *et al.,* 2017). It is connected to the plant's health and prospective yield, allowing for the estimation of growth rate.

The data given in Table 4.3 and Figure 4.4 show that the number of palak leaves varies significantly for both years of study. The number of leaves at 25 DAS in different treatment combinations in the present studies varied from 4.18 to 8.90 having a mean value of 6.41 during the first year (2022) and the values varied from 4.23 to 9.21 with a mean value of 7.15 during second year. The pooled mean values for number of leaves ranged from 4.20 to 9.06.

In the both years, the maximum number of leaves was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 8.90 and 9.21 at 25 DAS. The number of leaves for control i.e. treatment (T_{10}) was found to be 4.18 and 4.23 that was fewest among all treatment combination, respectively.

Also, in pooled data over the years the maximum number of leaves was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 9.06, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2

(RDF 50% + FYM (10 tonnes/ha) with values of 8.83 and 8.47 at 25 DAS, respectively. The number of leaves for control i.e. treatment (T_{10}) was found to be 4.20 that was fewest among all treatment combination, respectively.

The data for number of palak leaves reported in Table 4.3 and Fig 4.5 confirms considerable variance in number of leaves. The number of leaves at 40 DAS in different treatment combinations in the present studies varied from 5.6 to 12.44 having a mean value of 9.65 during the first year (2022) and the values varied from 6.14 to 13.59 having a mean value of 9.92 during the second year. The pooled mean values for number of leaves ranged from 5.87 to 13.01.

In the both years, the maximum number of leaves was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 12.44 and 13.59 at 40 DAS. The number of leaves for control i.e. treatment (T_{10}) was found to be 5.60 and 6.14 that was fewest among all treatment combination, respectively.

Also, in pooled data over the years the maximum number of leaves was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 13.01 at 40 DAS. Treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) showed similar results with values of 12.69 and 12.02, respectively and statistically at par with treatment T_1. The number of leaves for control i.e. treatment (T_{10}) was found to be 5.87 that was fewest among all treatment combination, respectively.

The statistics referring for number of palak leaves reported in Table 4.3 and Fig. 4.6, confirms there is a substantial variation in palak leaves. The number of leaves at 55 DAS in different treatment combinations in the present studies varied from 5.20 to 8.70 having a mean value of 7.58 during the first year (2022) and the values ranged from 5.63 to 8.60 with a mean value of 7.49 during second year. The pooled mean values for number of leaves ranged from 5.42 to 8.65. In the both years, the maximum number of leaves was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 8.70 and 8.60 at 55 DAS. The number of leaves for control i.e. treatment (T_{10}) was found to be 5.20 and 5.63 that was fewest among all treatment combination, respectively. Also, in pooled data over the years the maximum number of leaves was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 8.65 at 55 DAS. Treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) showed similar results with values of 8.30 and 7.91, respectively and statistically at par with treatment T_1. The number of leaves for control i.e. treatment (T_{10}) was found to be 5.87 that was fewest among all treatment combination, respectively.

The maximum number of leaves was observed in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) during the first year. It is due to higher nutrient availability in inorganic treatments at the time of growth that is the reason for improved root growth and branching, which aids in nutrition absorption. Similar results were revealed by Barik, 2017. During pooled data analysis over the years, it was found that treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) and T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (10 tonnes/ha) performs similar to each other. This may be brought about by the microbial consortium found in organic fertilizers and a favourable environment is created for root respiration, nutrient absorption, and upper part growth when organic manure improves soil formation, air circulation, water retention capacity, and nutrient flow all contribute to a greatly improved character. Similar outcomes were published by Anwar *et al*., (2017) and Jagadeesha *et al.*, (2019b) and Jamoh, 2021.

Table 4.3 Effect of various treatments on number of leaves of palak at 25, 40 and 55 DAS

Treatments	Number of leaves at 25 DAS			Number of leaves at 40 DAS			Number of leaves at 55 DAS		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	8.90	9.21	9.06	12.44	13.59	13.01	8.70	8.60	8.65
T_2	8.50	8.43	8.47	12.24	11.80	12.02	8.30	7.52	7.91
T_3	5.16	5.18	5.17	7.93	7.74	7.84	7.20	7.13	7.17
T_4	5.82	7.43	6.63	9.35	9.61	9.48	8.03	7.73	7.88
T_5	5.24	7.07	6.16	8.87	8.76	8.81	7.62	7.31	7.46
T_6	7.00	7.29	7.14	9.59	9.25	9.42	7.80	7.59	7.69
T_7	8.46	9.19	8.83	11.89	13.50	12.69	8.13	8.48	8.30
T_8	5.61	7.50	6.55	9.37	9.80	9.59	7.49	7.80	7.64
T_9	5.20	5.98	5.59	9.23	8.99	9.11	7.33	7.14	7.24
T_{10}	4.18	4.23	4.20	5.60	6.14	5.87	5.20	5.63	5.42
Mean	**6.41**	**7.15**	**6.78**	**9.65**	**9.92**	**9.78**	**7.58**	**7.49**	**7.54**
CD($p \leq 0.05$)	**0.28**	**0.28**	**0.36**	**0.50**	**0.22**	**0.50**	**0.36**	**0.34**	**0.45**
CV %	**2.56**	**2.34**	**2.42**	**3.03**	**1.31**	**2.30**	**2.79**	**2.70**	**2.24**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)

*T_2= RDF 50% + FYM (10 10 tonnes/ha)

*T_3= FYM (20 tonnes/ha)

*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)

*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)

*T_6= Vermicompost (5 tonnes/ha)

*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost

*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost

*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost

*T_{10}= Control

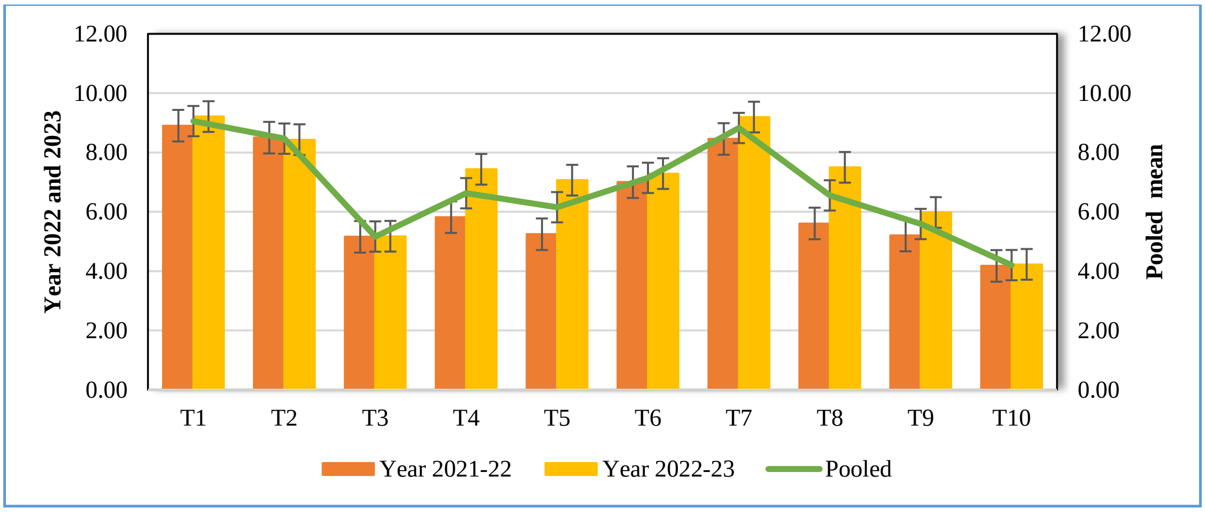


Fig. 4.4 Effect of various treatments on number of leaves of palak at 25 DAS

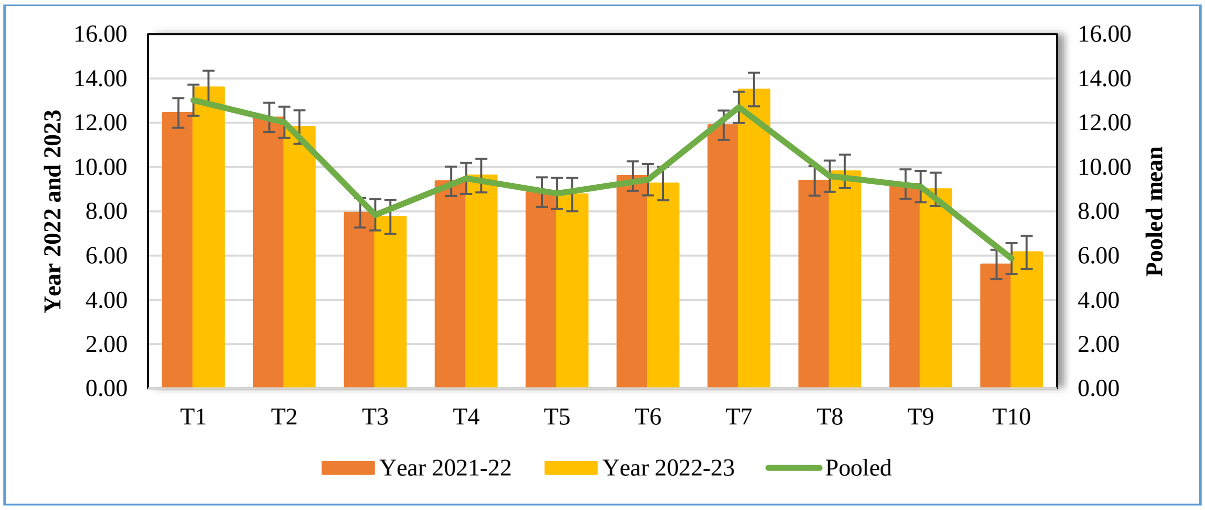


Fig. 4.5 Effect of various treatments on number of leaves of palak at 40 DAS

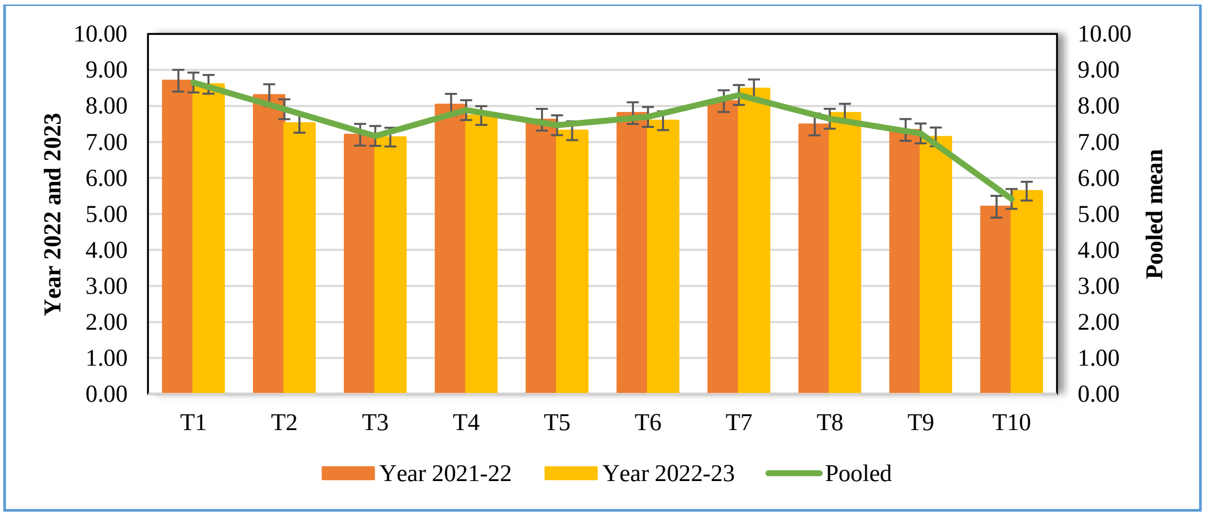


Fig. 4.6 Effect of various treatments on number of leaves of palak at 55 DAS

4.2.6 Length of petiole (cm)

Petioles are crucial plant organs that connect stems to leaf blades. They have an impact on the leaf's capacity to absorb light and on the movement of nutrients, water, and chemical messages (Filartiga *et al.,* 2022).

The data pertains to length of petiole of palak given in Table 4.4 and Fig 4.7, confirms significant variations in length of petiole. The length of petiole at 25 DAS in different treatment combinations in the present studies ranged from 10.53 to 16.04 cm with a mean value of 13.17 cm during the first year (2022) and the values ranged from 9.36 to 15.87 cm having a mean value of 12.99 cm during second year. The pooled mean values for length of petiole ranged from 9.95 to 15.95 cm.

During both years, the length of petiole was recorded maximum in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 16.04 and 15.87 cm at 25 DAS. The length of petiole for control i.e. treatment (T_{10}) was found to be 10.53 and 9.36 cm that was minimum among all other treatment combination, respectively.

Also, in pooled data analysis the maximum length of petiole was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 15.95 cm, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 15.49 and 14.71 cm, at 25 DAS, respectively. The length of petiole for control i.e. treatment (T_{10}) was found to be 9.95 cm that was minimum among all treatment combination, respectively.

The data concerning to length of petiole in palak shown in Table 4.4 and Fig 4.8, confirms noteworthy variation in length of petiole. The length of petiole at 40 DAS in different treatment combinations in the present studies ranged from 14.36 to 22.38 cm having a mean value of 18.43 cm during the first year (2022) and the values ranged from 10.96 to 22.33 cm having a mean value of 18.11 cm during second year. The pooled mean values for length of petiole ranged from 12.66 to 22.36 cm.

In the both years, the maximum length of petiole was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 22.38 and 22.33 cm at 40 DAS. The length of petiole for control i.e. treatment (T_{10}) was found to be 14.36 and 10.96 cm that was minimum among all treatment combination, respectively.

Also, in pooled data analysis the maximum length of petiole was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 22.36 cm, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 21.60 and 20.90 cm, at 40 DAS, respectively. The length of petiole for control i.e. treatment (T_{10}) was found to be 12.66 cm that was minimum among all treatment combination, respectively.

The data concerning to length of petiole in palak, shown in Table 4.4 and Fig 4.9, confirms noteworthy variations in length of petiole. The length of petiole at 55 DAS in different treatment combinations in the present studies ranged from 10.02 to 16.10 cm having a mean value of 13.47 cm during the first year (2022) and the values ranged from 11.02 to 15.7 cm, having a mean value of 13.65 cm during second year. The pooled mean values for length of petiole ranged from 10.52 to 15.98 cm.

During both of years, the maximum length of petiole was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 16.10 and 15.87 cm at 55 DAS. The length of petiole for control i.e. treatment (T_{10}) was found to be 10.02 and 11.02 cm respectively that was minimum amongst all other treatment combination, respectively.

Also, in pooled data analysis the maximum length of petiole was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 15.98 cm, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 15.47 and 14.77 cm at 55 DAS, respectively. The length of petiole for control i.e. treatment (T_{10}) was found to be 10.52 cm that was minimum among all treatment combination.

Table 4.4 Effect of various treatments on length of petiole of palak at 25, 40 and 55 DAS (cm)

Treatments	Length of petiole at 25 DAS (cm)			Length of petiole at 40 DAS (cm)			Length of petiole at 55 DAS (cm)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	16.04	15.87	15.95	22.38	22.33	22.36	16.10	15.87	15.98
T_2	15.39	14.04	14.71	21.85	19.94	20.90	15.39	14.14	14.77
T_3	10.59	11.02	10.80	16.41	16.47	16.44	11.57	12.58	12.08
T_4	13.34	13.37	13.36	18.38	19.89	19.13	14.21	14.04	14.12
T_5	11.89	12.00	11.94	17.20	17.19	17.20	12.35	12.72	12.54
T_6	13.34	12.58	12.96	18.96	18.38	18.67	14.34	13.37	13.86
T_7	15.37	15.62	15.49	20.94	22.27	21.60	15.33	15.62	15.47
T_8	12.93	13.28	13.10	18.34	18.06	18.20	13.10	14.19	13.65
T_9	12.25	12.74	12.49	15.52	15.65	15.59	12.25	12.97	12.61
T_{10}	10.53	9.36	9.95	14.36	10.96	12.66	10.02	11.02	10.52
Mean	**13.17**	**12.99**	**13.08**	**18.43**	**18.11**	**18.27**	**13.47**	**13.65**	**13.56**
CD($p \leq 0.05$)	**0.52**	**0.49**	**0.66**	**0.86**	**0.72**	**1.03**	**0.60**	**0.59**	**0.77**
CV %	**2.34**	**2.21**	**2.28**	**2.72**	**2.34**	**2.54**	**2.60**	**2.54**	**1.90**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (20 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}= Control

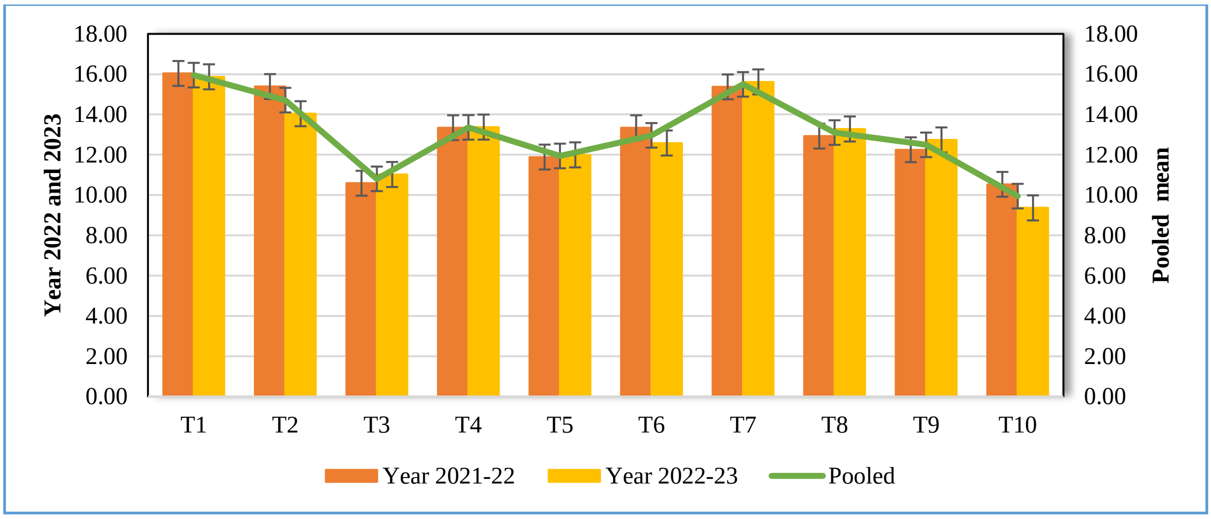


Fig. 4.7 Effect of various treatments on length of petiole of palak at 25 DAS (cm)

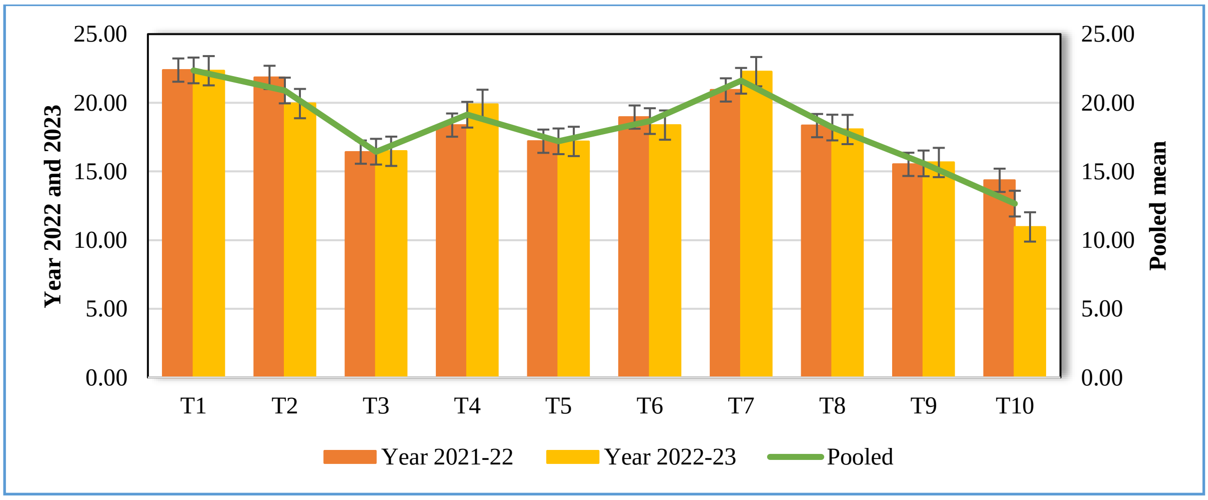


Fig. 4.8 Effect of various treatments on length of petiole of palak at 40 DAS (cm)

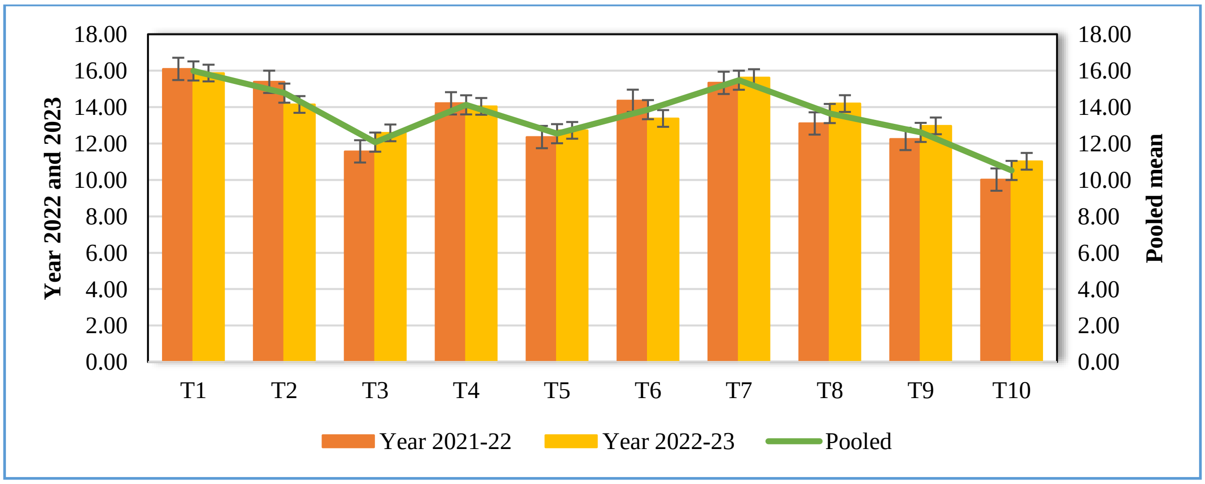


Fig. 4.9 Effect of various treatments on length of petiole of palak at 55 DAS (cm)

The performance of growth parameter in terms of length of petiole also indicated a similar pattern indicated as to plant's height and leaf count. The results were validated with Saikia (2015). The positive effect of enriched compost on these parameters could be related to its participation in giving more plant nutrition and raising the availability of nutrients found in native soil due to higher microbial activity, and similar outcomes were obtained by Meena *et al.*, (2017).

4.2.7 Average leaf area per plant (cm^2)

The vital component of surface area of leaves influences a plant's ability to grow and survive. It has to do with how much light a plant can absorb as well as how much water and nutrients it can take in. Another reliable predictor of a plant's overall biomass is its leaf surface area (Jadon, 2018).

The statistics on the average leaf area per plant of palak is shown in Table 4.5 and Fig. 4.10, confirms notable difference in per plant average leaf area. The average leaf area at 25 DAS in different treatment combinations in the present studies ranged from 29.67 to 51.57 cm^2 with a mean value of 45.33 cm^2 during the first year (2022) and the values ranged from 29.42 to 51.96 cm^2 with a mean value of 45.18 cm^2 during the second year. The pooled mean values for average leaf area ranged from 29.55 to 51.76 cm^2.

In the both years, the maximum average leaf area per plant was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 51.57 and 51.96 cm^2 at 25 DAS. The average leaf area per plant for control i.e. treatment (T_{10}) was found to be 29.67 and 29.42 cm^2 that was minimum amongst all treatment combination present in study.

Also, in pooled data analysis the average leaf area per plant was recorded maximum in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 51.76 cm^2 at 25 DAS. Treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) showed similar results with values of 49.97 and 49.25 cm^2, respectively and statistically at par with treatment T_1. The average leaf area per plant for control i.e. treatment (T_{10}) was found to be 29.55 cm^2 that was minimum among all treatment combination, respectively.

The data concerning to average leaf area per plant of palak shown in Table 4.5 and Fig 4.11, confirms significant variation in average leaf area per plant. The average leaf area at 40 DAS in different treatment combinations in the present studies ranged from 31.16 to 63.03 cm^2 with a mean value of 52.35 cm^2 during the first year (2022) and the values ranged from 34.37 to 63.50 cm^2 with a mean value of 52.49 cm^2 during the second year. The pooled mean values for average leaf area ranged from 32.76 to 63.27 cm^2.

During both years, the maximum average leaf area per plant was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 63.03 and 63.50 cm^2 at 40 DAS. The average leaf area per plant for control i.e. treatment (T_{10}) was found to be 31.16 and 34.37 cm^2 that was minimum among all treatment combination, respectively.

Also, in pooled data analysis over the years the average leaf area per plant was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 63.27 cm^2, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 32.76 and 60.24 cm^2 at 40 DAS, respectively. The average leaf area per plant for control i.e. treatment (T_{10}) was found to be 32.76 cm^2 that was minimum among all treatment combination.

The data related to average leaf area per plant of palak given in Table 4.5 and Fig 4.12, confirms significant variation in average leaf area per plant. The average leaf area at 55 DAS in different treatment combinations in the present study ranged from 53.28 to 101.27 cm^2 with a mean value of 83.39 cm^2 during the first year and the values ranged from 53.80 to 115.79 cm^2 with a mean value of 88.38 cm^2 during the second year. The pooled mean values for average leaf area ranged from 53.54 to 108.53 cm^2.

In the both years, the maximum average leaf area per plant was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 101.27 and 115.79 cm^2 at 55 DAS. The average leaf area per plant for control i.e. treatment (T_{10}) was found to be 53.28 and 53.80 cm^2 that was minimum among all treatment combination, respectively.

Also, in pooled data analysis the average leaf area per plant was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 108.53 cm^2, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 106.52 and 99.38 cm^2 at 55 DAS, respectively. The average leaf area per plant for control i.e. treatment (T_{10}) was found to be 53.54 cm^2 that was minimum among all treatment combination.

The highest leaf area during first year was observed in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) that might be due to highly available nitrogen in soil leading to its immediate effect on palak leaves. This showed vigorous growth and an increase in leaf area of plant. Similar findings were reported by Barik, 2017. During the study of pooled data analysis, organic and inorganic treatments were found to be at par with each other. It may be due to the fact that enriched compost serves as a source of energy for soil microflora, resulting in the transformation of unavailable nutrients contained in soil into accessible forms or provided as fertilisers that are readily utilized by developing plants. Similar results were obtained by Rady *et al.,* (2016).

4.2.8 Diameter of the petiole (cm)

The data pertaining to diameter of the petiole confirms significant variation as shown in Table 4.6 and Fig 4.13. The diameter of the petiole at 25 DAS in different treatment combinations ranged from 0.17 to 0.66 cm with a mean value of 0.44 cm during the first year and the values ranged from 0.26 to 0.66 cm with a mean value of 0.47 cm during the second year. The pooled mean values for average yield per plant ranged from 0.21 to 0.66 cm.

During both the years, the highest diameter of the petiole was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 0.66 cm and 0.66 cm at 25 DAS.

Table 4.5 Effect of various treatments on average leaf area per plant of palak at 25, 40 and 55 DAS (cm^2)

Treatments	Average leaf area per plant at 25DAS (cm^2)			Average leaf area per plant at 40DAS (cm^2)			Average leaf area per plant at 55DAS (cm^2)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	51.57	51.96	51.76	63.03	63.50	63.27	101.27	115.79	108.53
T_2	49.70	48.80	49.25	59.27	61.21	60.24	99.73	99.03	99.38
T_3	38.00	37.60	37.80	41.16	40.67	40.92	70.28	70.31	70.30
T_4	48.01	48.41	48.21	56.26	54.35	55.30	85.90	90.97	88.44
T_5	45.57	45.72	45.64	50.98	51.43	51.21	81.24	80.56	80.90
T_6	47.61	45.88	46.75	54.88	53.53	54.21	83.78	84.16	83.97
T_7	48.73	51.22	49.97	59.17	62.94	61.05	97.32	115.71	106.52
T_8	47.97	48.66	48.31	54.63	52.57	53.60	81.93	91.86	86.89
T_9	46.44	44.11	45.28	52.92	50.37	51.64	79.12	81.57	80.35
T_{10}	29.67	29.42	29.55	31.16	34.37	32.76	53.28	53.80	53.54
Mean	**45.33**	**45.18**	**45.25**	**52.35**	**52.49**	**52.42**	**83.39**	**88.38**	**85.88**
CD($p \leq 0.05$)	**2.19**	**2.35**	**2.94**	**2.27**	**2.85**	**3.13**	**3.75**	**4.09**	**5.08**
CV %	**2.82**	**3.03**	**2.93**	**2.27**	**2.56**	**2.69**	**2.62**	**2.70**	**4.28**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (20 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}= Control

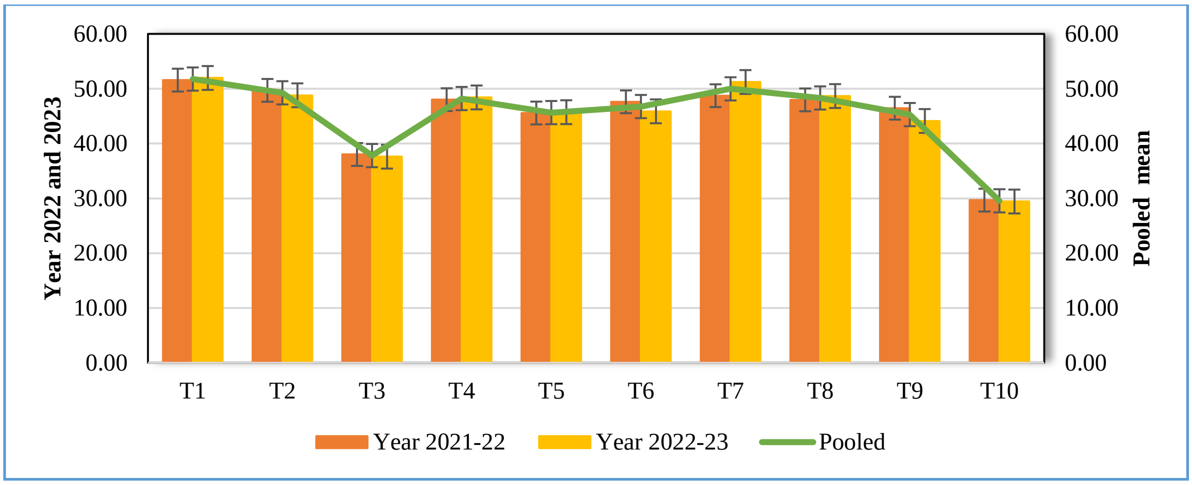


Fig. 4.10 Effect of various treatments on average leaf area per plant of palak at 25 DAS (cm^2)

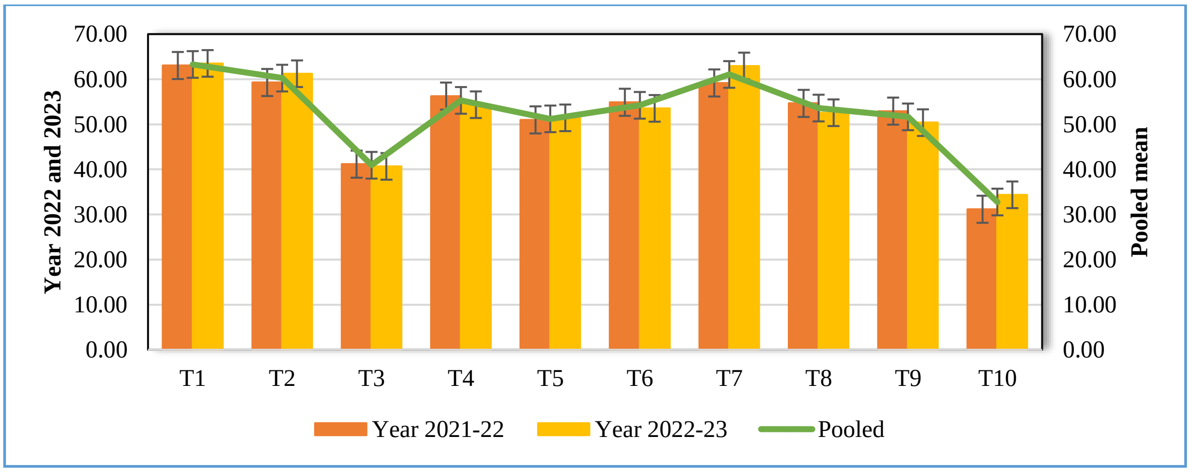


Fig. 4.11 Effect of various treatments on average leaf area per plant of palak at 40 DAS (cm^2)

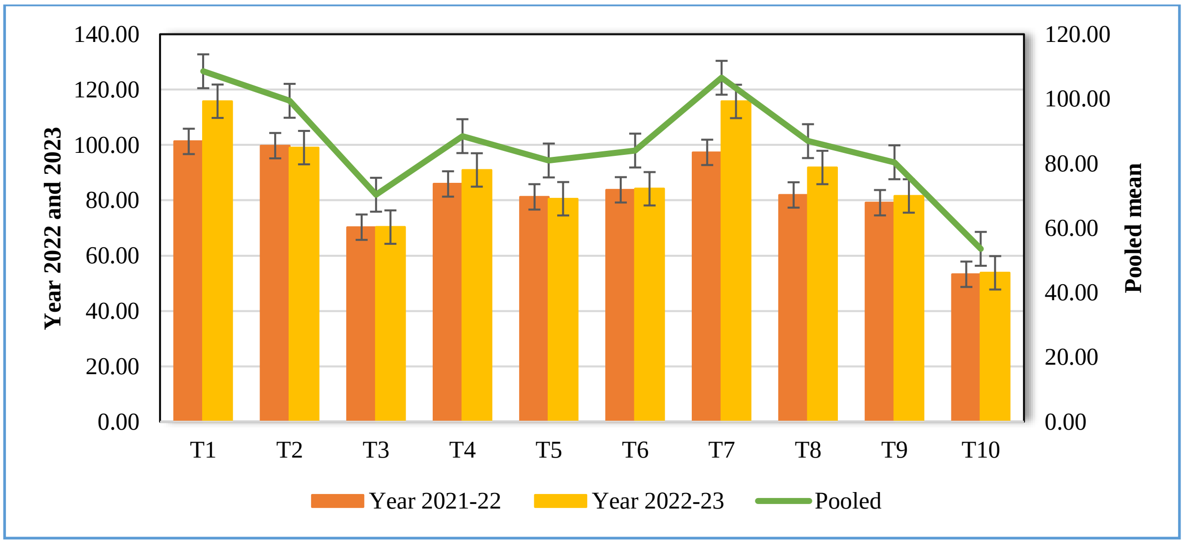


Fig. 4.12 Effect of various treatments on average leaf area per plant of palak at 55 DAS (cm^2)

The diameter of the petiole for control i.e. treatment (T_{10}) was found to be 0.17 and 0.26 cm that was lowest among all treatment combination, during first and second year respectively.

Also, in pooled data analysis the diameter of the petiole was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 0.66 cm, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 0.62 and 0.61 cm at 25 DAS, respectively. The diameter of the petiole for control i.e. treatment (T_{10}) was found to be 0.21 cm that was lowest among all treatment combination.

The data regarding to diameter of the petiole shown in Table 4.6 and Fig 4.14, confirms significant variation in diameter of the petiole at 40 DAS. The diameter of the petiole at 40 DAS in different treatment combinations ranged from 0.26 to 0.86 cm with a mean value of 0.64 cm during the first year and the values varied from 0.46 to 0.86 cm having a mean value of 0.67 cm during second year. The pooled mean values for diameter of the petiole at 40 DAS ranged from 0.36 to 0.86 cm.

During both years, the highest diameter of the petiole was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 0.86 cm and 0.86 cm, respectively at 40 DAS. The lowest diameter of the petiole among all treatment combination was found to be 0.26 and 0.46 cm that was recorded in control i.e. treatment (T_{10}).

Also, in pooled data analysis the diameter of the petiole was recorded maximum at 40 DAS in same treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 0.86 cm, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 0.82 and 0.79 cm, respectively. The diameter of the petiole for control i.e. treatment (T_{10}) was found to be 0.36 cm that was lowest among all treatment combination.

The data pertains to diameter of the petiole shown in Table 4.6 and Fig 4.15, confirms significant variation in given parameter at 55 DAS. Its range in different treatment combinations was obtained between 0.37 to 0.88 cm having a mean value of 0.73 cm during the first year and the values varied from 0.57 to 0.89 cm with a mean value of 0.77 cm during second year. The pooled mean values for diameter of the petiole ranged from 0.47 to 0.89 cm.

During both years, the diameter of the petiole was recorded maximum in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) having value of 0.88 cm and 0.89 cm at 55 DAS. The lowest diameter of the petiole among all treatment combination over the two years was found to be 0.37 and 0.57 cm, respectively for control i.e. treatment (T_{10}).

Also, in pooled data analysis the diameter of the petiole was recorded maximum at 55 DAS in same treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 0.89 cm, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 0.86 and 0.83 cm, respectively. The diameter of the petiole for control i.e. treatment (T_{10}) was found to be 0.47 cm which was lowest among all treatment combination.

The diameter of the petiole recorded maximum in above mentioned treatments might be due to better plant height, maximum count for leaves, petiole length and more leaf area so there is an overall improvement in vegetative growth of the plant in case of inorganic and organic treatments. Similar outcomes were disclosed by Bindiya, 2012 and Pangaribuan *et al.*, (2017).

4.2.9 Average leaf yield per plant (gm)

The data given in Table 4.7 and Fig. 4.16, confirms significant variation for average leaf yield per plant. The average leaf yield per plant in different treatment combinations ranged from 15.31 to 30.23 gm with a mean value of 23.90 gm during the first year and the values ranged from 13.18 to 30.57 gm with a mean value of 23.85 gm during the second year. The pooled mean values for average leaf yield per plant ranged from 14.24 to 30.38 gm.

During both years, the highest average leaf yield per plant was recorded in treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 30.23 gm and 30.53 gm, respectively. The average leaf yield per plant for control i.e. treatment (T_{10}) was found to be 15.31 and 13.18 gm, respectively that was least among all treatment combination, respectively.

Also, in pooled data analysis the average leaf yield per plant was recorded maximum in same treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) having a value of 30.38 gm, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 29.58 and 27.93 gm, respectively. The average leaf yield per plant for control i.e. treatment (T_{10}) was found to be 14.24 gm that was least among all treatment combination, respectively.

4.2.10 Average leaf yield per plot (kg)

The data pertaining to average leaf yield per plot of palak shown in Table 4.7 and Fig 4.17, confirms significant variation in average yield per plot. The average leaf yield per plot in different treatment combinations ranged from 6.43 to 12.88 kg/plot with a mean value of 10.07 kg/plot during the first year and the values ranged from 5.53 to 13.11 kg/plot with a mean value of 10.07 kg/plot during the second year. The pooled mean values for average yield per plot ranged from 5.98 to 12.99 kg/plot.

During both years, the highest average leaf yield per plot was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 12.88 and 13.11 kg, respectively. The average yield per plot for control i.e. treatment (T_{10}) was found to be 6.43 and 5.53 kg/plot that was least among all treatment combination.

Also, in pooled data analysis the average leaf yield per plot was recorded maximum in same treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 12.99 kg per plot, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 12.63 and 11.73 kg/plot, respectively. The average leaf yield per plot for control i.e. treatment (T_{10}) was found to be 5.98 kg/plot that was least among all treatment combination.

4.2.11 Leaf yield (q/ha)

The data pertaining to leaf yield of palak per hectare given in Table 4.7 and Fig 4.18, which showed significant variation between different treatment combinations. The leaf yield q/ha in different treatment combinations ranged from 54.64 to 106.66 q/ha having a mean value of 85.02 q/ha during the first year and the values ranged from 47.04 to 110.73 q/ha having a mean value of 85.30 q/ha during second year. The pooled mean values over the years for leaf yield varied from 50.84 to 108.70 q/ha.

During both the years, the highest leaf yield was recorded in treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 106.66 and 110.73 q/ha, respectively. The leaf yield for control i.e. treatment (T_{10}) was found to be 54.64 and 47.04 q/ha that was least among all other treatment combination.

Also, in pooled data analysis highest leaf yield was recorded in same treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 108.70 q/ha, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 105.71 and 98.69 q/ha, respectively. The leaf yield for control i.e. treatment (T_{10}) was found to be 50.84 q/ha that was least among all other treatment combination.

Table 4.7 showed that the average leaf yield per plant, average leaf yield per plot and leaf yield q/ha was affected significantly due to various nutrient sources. Pooled data over the years showed that, the superior treatment was T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with highest yield followed by treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost), which was at par with treatment T_1.

Table 4.6 Effect of various treatments on diameter of the petiole of palak at 25, 40 and 55 DAS (cm).

Treatments	Diameter of the petiole at 25DAS (cm)			Diameter of the petiole at 40 DAS (cm)			Diameter of the petiole at 55 DAS (cm)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	0.66	0.66	0.66	0.86	0.86	0.86	0.88	0.89	0.89
T_2	0.60	0.62	0.61	0.83	0.75	0.79	0.83	0.85	0.83
T_3	0.26	0.38	0.32	0.43	0.52	0.48	0.66	0.64	0.65
T_4	0.49	0.54	0.52	0.71	0.74	0.73	0.81	0.84	0.83
T_5	0.40	0.38	0.39	0.64	0.64	0.64	0.73	0.75	0.74
T_6	0.44	0.45	0.44	0.69	0.65	0.67	0.80	0.82	0.81
T_7	0.58	0.65	0.62	0.79	0.84	0.82	0.82	0.88	0.86
T_8	0.42	0.39	0.40	0.63	0.61	0.62	0.74	0.74	0.74
T_9	0.37	0.33	0.35	0.58	0.58	0.58	0.60	0.70	0.65
T_{10}	0.17	0.26	0.21	0.26	0.46	0.36	0.37	0.57	0.47
Mean	**0.44**	**0.47**	**0.45**	**0.64**	**0.67**	**0.65**	**0.73**	**0.77**	**0.75**
CD($p \leq 0.05$)	**0.01**	**0.02**	**0.02**	**0.03**	**0.01**	**0.03**	**0.02**	**0.04**	**0.01**
CV %	**2.40**	**3.19**	**0.01**	**3.07**	**1.58**	**0.01**	**1.78**	**3.06**	**0.01**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (20 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}= Control

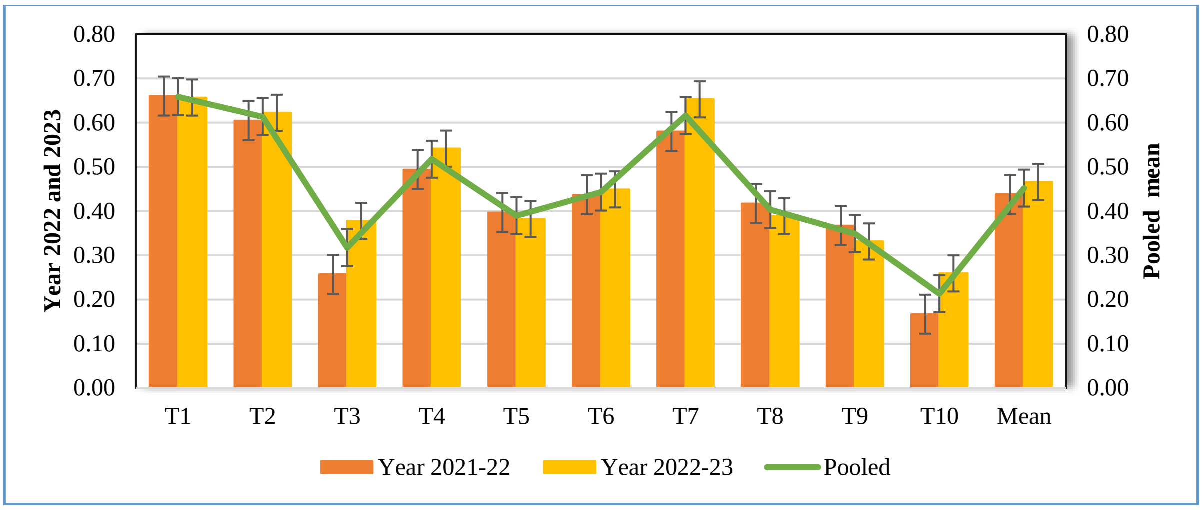


Fig. 4.13 Effect of various treatments on diameter of the petiole of palak at 25 DAS (cm)

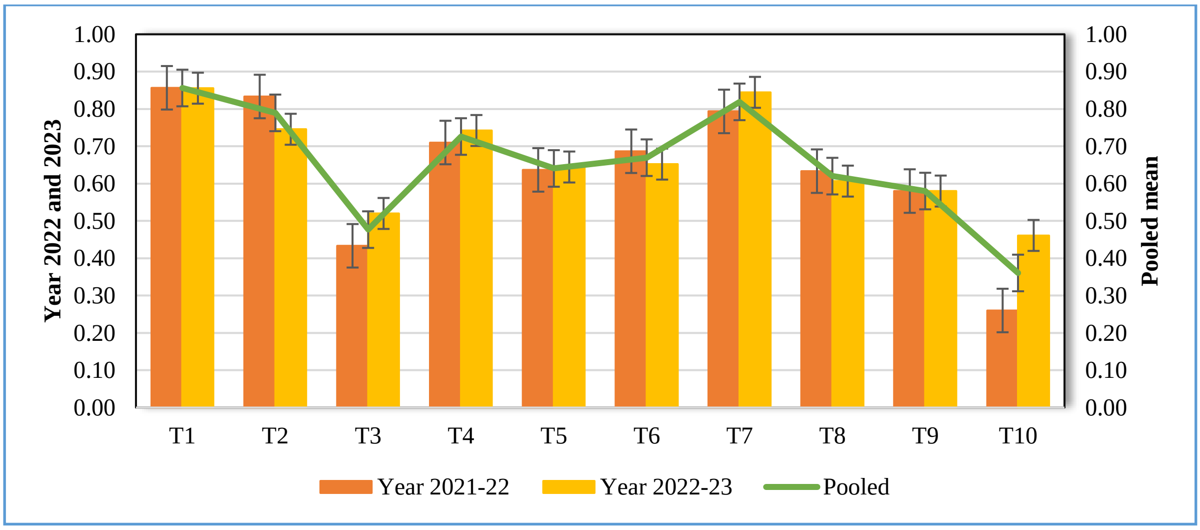


Fig. 4.14 Effect of various treatments on diameter of the petiole of palak at 40 DAS (cm)

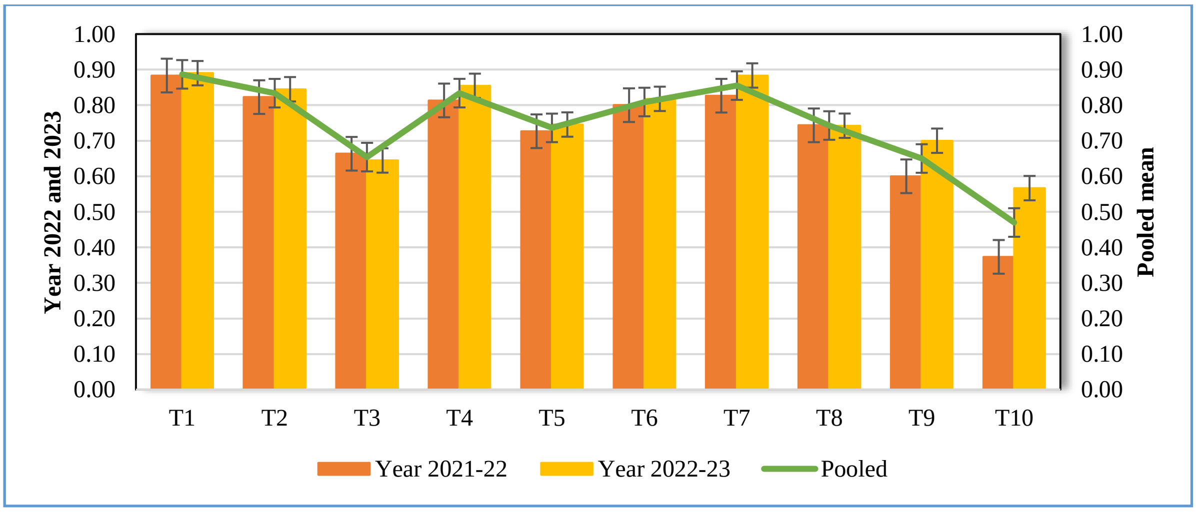


Fig. 4.15 Effect of various treatments on diameter of the petiole of palak at 55 DAS (cm)

The highest leaf yield achieved by treatment might be due to a higher dose of nutrient applied to the soil under, T_1 (RDF). Soil nitrogen a significant component for plant metabolites including fat protein enzyme and chlorophyll, which are necessary for reliable vegetative plant growth. The characteristics of vegetative growth, such as the leaf area, plant height, and count of leaves per plant, showed a linear relationship with yield.

Similar outcomes were recorded by Bharad *et al.* (2010) and Jamoh (2021) in spinach and Gogoi (2016) in knolkhol. The increase in yield of the organic treatment T_7 having enriched compost could be linked to an overall enhancement of the soil physicochemical properties, such as a decrease in pH, improved electrical conductivity, and an increase in all nutrient's availability to the leafy vegetable. These advantageous results promoted improved availability of plant nutrients and their consistent delivery throughout growth for optimal development. Similar results related to overall yield had been seen by Rady *et al.,* (2016), Meena *et al.,* (2015), Pascual *et al.,* (2017), Jagadeesha *et al.,* (2019b) and Jamoh, 2021.

4.3 QUALITY ATTRIBUTES

4.3.1 Moisture content (%)

A perusal of data related to moisture content represented in Table 4.8 and Fig 4.19, indicates the significant impact of treatments on the moisture content of palak leaves. The moisture content in different treatment combinations ranged from 76.56 to 89.99 per cent having a mean value of 85.16 per cent during the first year and the values ranged from 76.69 to 90.13 per cent having a mean value of 85.53 per cent during second year. The pooled mean values for moisture content over the years ranged from 76.63 to 90.06 per cent.

During both years, the maximum moisture content was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 89.99 and 90.13 per cent, respectively. The moisture content for control i.e. treatment (T_{10}) was found to be 76.56 and 76.69 per cent, that was minimum among all treatment combination.

Table 4.7 Effect of various treatments on average leaf yield per plant(gm), per plot(kg) and leaf yield per hectare (q) of palak.

Treatments	Average leaf yield per plant (gm)			Average leaf yield per plot (kg)			Leaf yield q/ha		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	30.23	30.53	30.38	12.88	13.11	12.99	106.66	110.73	108.7
T_2	29.82	26.04	27.93	12.52	10.93	11.73	104.44	92.95	98.69
T_3	18.28	18.58	18.43	7.68	7.80	7.74	65.27	66.32	65.80
T_4	25.21	28.07	26.64	10.59	11.79	11.19	89.99	100.22	95.10
T_5	21.87	22.26	22.06	9.18	9.35	9.27	78.06	79.45	78.76
T_6	24.38	24.16	24.27	10.24	10.15	10.19	87.05	86.26	86.65
T_7	28.59	30.57	29.58	12.18	13.08	12.63	102.31	109.12	105.71
T_8	23.73	22.56	23.14	9.96	9.48	9.72	84.70	80.55	82.62
T_9	21.58	22.51	22.05	9.07	9.46	9.26	77.05	80.38	78.71
T_{10}	15.31	13.18	14.24	6.43	5.53	5.98	54.64	47.04	50.84
Mean	**23.90**	**23.85**	**23.87**	**10.07**	**10.07**	**10.07**	**85.02**	**85.30**	**85.16**
CD($p \leq 0.05$)	**1.03**	**0.88**	**1.24**	**0.42**	**0.48**	**0.58**	**2.87**	**3.54**	**4.17**
CV %	**2.52**	**2.16**	**2.35**	**2.43**	**2.82**	**2.62**	**1.97**	**2.42**	**2.21**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)

*T_2= RDF 50% + FYM (10 tonnes/ha)

*T_3= FYM (20 tonnes/ha)

*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)

*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)

*T_6= Vermicompost (5 tonnes/ha)

*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost

*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost

*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost

*T_{10}= Control

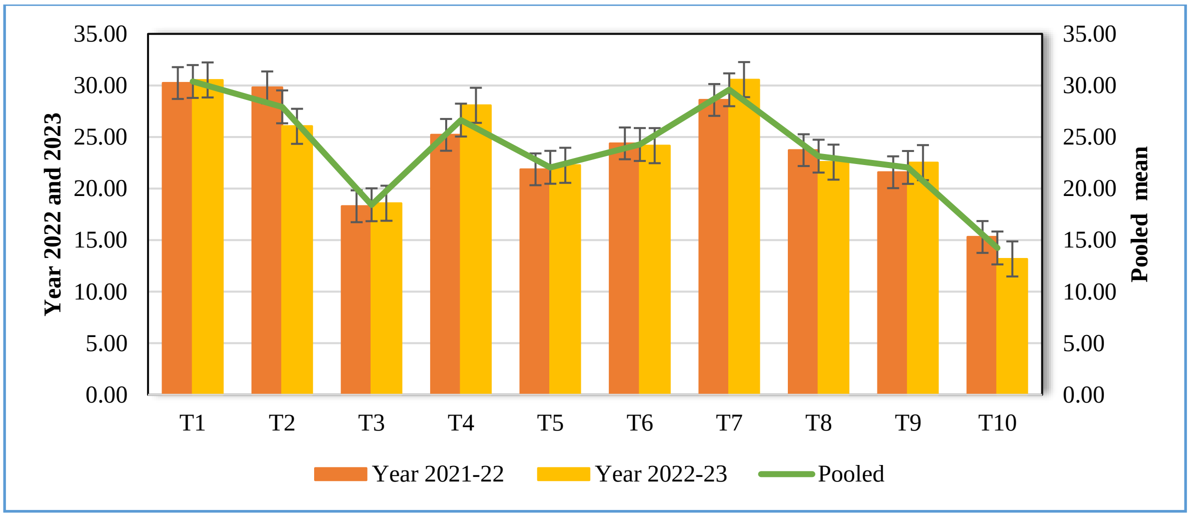


Fig. 4.16 Effect of various treatments on average leaf yield per plant of palak (gm).

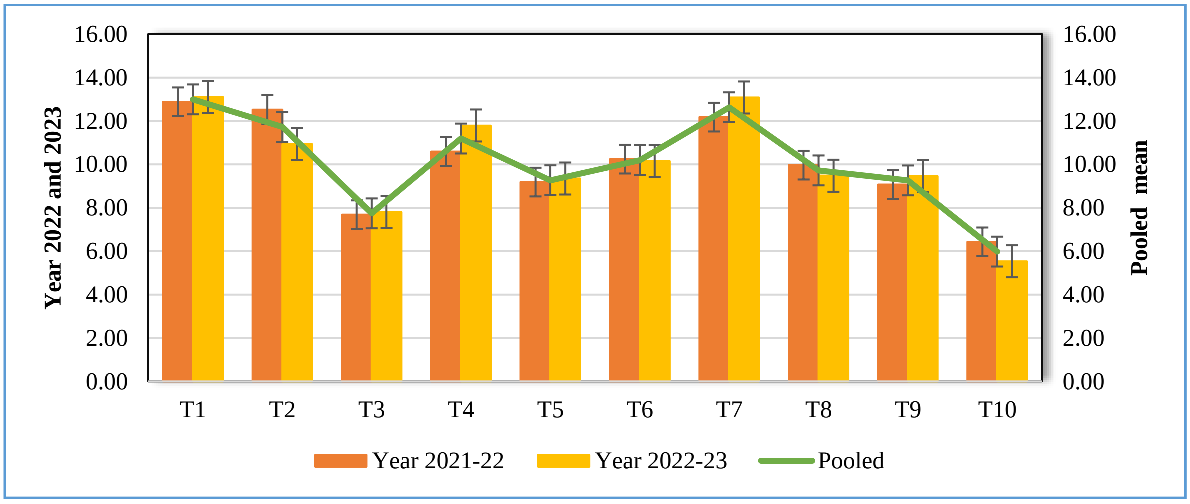


Fig. 4.17 Effect of various treatments on average leaf yield per plot of palak (kg).

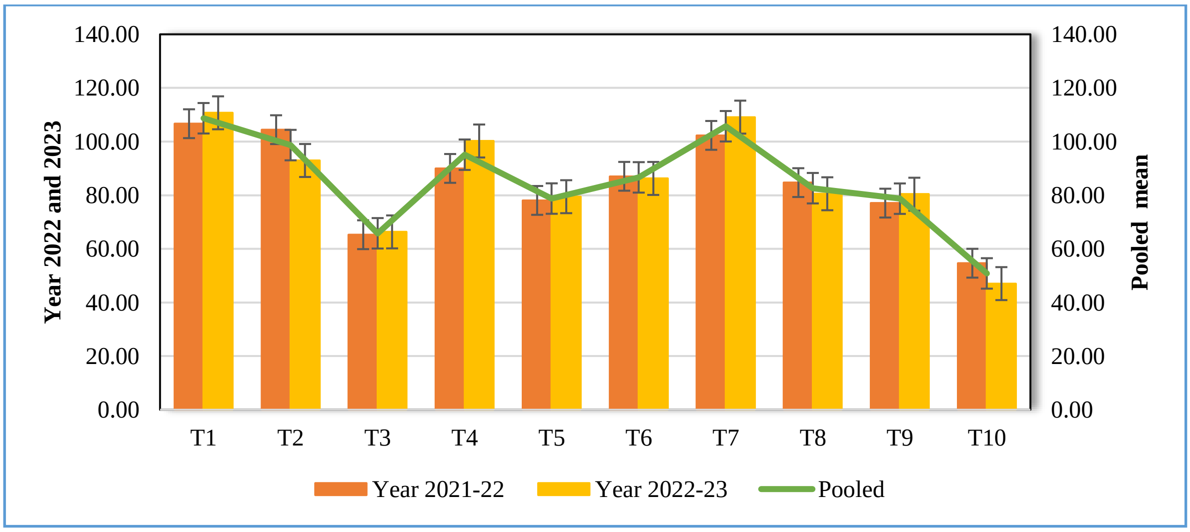


Fig. 4.18 Effect of various treatments on leaf yield per hectare of palak (q/ha)

The pooled data analysis, maximum moisture content was recorded in same treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 90.06 per cent, which was statistically at par with treatment combinations T_7, T_2, T_6 and T_8 with values of 89.64, 89.04, 87.35 and 87.05 per cent, respectively. The moisture content for control i.e. treatment (T_{10}) was found to be 76.63 per cent that was minimum among all treatment combination.

This high moisture may be due to the larger size of leaves in case of the inorganic treatment in comparing to the other organic treatments over control, which resulted in a higher moisture content. Greater moisture absorption into the soil as a result of increased nitrogen fertilizer application leads to an increase in vegetative growth. Similar outcomes were reported by Barik (2017) Jabeen *et al.,* (2018) in palak.

4.3.2 Dry matter content (%)

All the components of plant material, with the exception of water, make up the dry matter. Carbs, lipids, proteins, vitamins, minerals, and antioxidants (such as thiocyanate, anthocyanin, and quercetin) are all included in the dry matter of food (Lefsrud *et al.*, 2008).

The data pertaining to dry matter is shown in the Table 4.8 and Fig 4.20, confirms significant variation. The dry matter content in different treatment combinations ranged from 7.19 to 16.10 per cent having a mean value of 12.89 per cent during the first year and the values ranged from 8.30 to 17.20 per cent having a mean value of 13.51 per cent during second year study. The pooled mean values over the years for dry matter content ranged from 7.75 to 16.65 per cent.

During both the years, the highest dry matter content was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 16.10 and 17.20 per cent, respectively. The dry matter content for control i.e. treatment (T_{10}) was found to be 7.19 and 8.30 per cent, respectively that was lowest among all other treatment combination.

Also, in pooled data analysis, the highest dry matter was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of

16.65 per cent, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed by T_2 **(**RDF 50% + FYM (10 tonnes/ha), with values of 16.09 and 15.10 per cent, respectively. The dry matter content for control i.e. treatment (T_{10}) was found to be 7.75 per cent that was lowest among all treatment combination.

Better nitrogen availability and uptake may have contributed to an increase in plant metabolism and a balanced C/N ratio, as well as an improvement in dry matter. There for mentioned outcome is consistent with the findings of Joshi and Vig (2010) and Jabeen *et al.,* (2018).

4.3.3 Ascorbic acid content (mg/100g)

Apart from its role as a noteworthy redox buffer, ascorbic acid functions as an enzyme cofactor in the manufacture of hormones, photosynthesis, and the renewal of other antioxidants. Ascorbic acid regulates cell development and division and takes role in signal transduction. (Gallie *et. al.,* 2013).

The data pertains to ascorbic acid content shown in Table 4.8 and Fig 4.21, indicate significant variation over years. The content of ascorbic acid in different treatment combinations ranged from 49.33 to 88.46 mg/100g having a mean value of 74.97 mg/100g during the first year and the values ranged from 52.20 to 88.63 mg/100g having a mean value of 77.42 mg/100g during the second year. The pooled mean values for ascorbic acid content over the years ranged from 50.91 to 88.54 mg/100g.

During both years, the maximum ascorbic acid content was recorded in treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with the value of 88.46 and 88.63 mg/100g, respectively. The ascorbic acid for control i.e. treatment (T_{10}) was found to be 49.33 and 52.50 mg/100g, that was minimum among all treatment combination.

Also, in pooled data analysis, the maximum ascorbic acid content was recorded in same treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with a value of 88.54 mg/100g, which was statistically superior over all treatments and was followed by T_8, with values of 82.86 mg/100g. The ascorbic acid content for control i.e. treatment (T_{10}) was found to be 50.91 mg/100g that was minimum among all treatment combination.

It is frequently stated that the amount of applied nitrogen and the vitamin C content are negatively correlated and this may be connected to the possibility that using biofertilizer in addition to organic fertilizer enhanced the absorption of major and micronutrients, which in turn raised the production of vitamins through biosynthesis (Lee and Kader, 2000). This could be because plants receiving organic treatments have smaller leaves and lower vegetative growth, in comparison to plants receiving chemical treatments. As a result, all the leaves receive adequate light and function as a source of carbohydrates. Since carbohydrates constitute the building block of ascorbic acid biosynthesis, an excess of carbohydrates is thus accessible for their conversion to ascorbic acid synthesis (Kumar *et al.,* 2015, Jagadeesha *et al.,* 2019b and Jamoh, 2021).

4.3.4 Total carotenoids content (mg/100g)

A class of more than 750 pigments that are a result of photosynthetic bacteria, algae, and plants in nature are called carotenoids. Many plants get their yellow, orange, and red colours from these vibrantly coloured molecules. The majority of the 40–50 carotenoids included in the human diet come from fruit and vegetables (Ross *et. al.,* 2014).

The data pertaining to total carotenoids content represented in Table 4.9 and Fig 4.22, showed considerable impact on the total carotenoids content in palak. The content of total carotenoids in different treatment combinations ranged from 10.07 to 25.30 mg/100g having a mean value of 19.18 mg/100g during the first year and the values ranged from 10.74 to 28.39 mg/100g having a mean value of 20.84 mg/100g during the second year. The pooled mean values for total carotenoid content ranged from 10.41 to 26.85 mg/100g.

During both years, the total carotenoids content was recorded maximum in treatment T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 25.30 and 28.39 mg/100g, respectively. The total carotenoids content for control i.e. treatment (T_{10}) was found to be 10.07 and 10.74 (mg/100g), that was minimum between all treatment combination, respectively.

Table 4.8 Effect of various treatments on moisture content (%), dry matter content (%), and ascorbic acid content (mg/100g) of palak.

Treatments	Moisture content (%)			Dry matter content (%)			Ascorbic acid content (mg/100g)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	89.99	90.13	90.06	16.10	17.20	16.65	80.15	81.52	80.84
T_2	89.02	89.05	89.04	15.39	14.81	15.10	74.94	76.98	75.96
T_3	80.63	81.00	80.82	9.85	10.57	10.21	67.91	71.08	69.50
T_4	85.27	88.51	86.89	13.34	14.04	13.69	77.05	82.89	79.97
T_5	83.08	82.07	82.58	12.25	12.58	12.42	75.25	78.60	76.93
T_6	87.37	87.32	87.35	13.10	13.37	13.24	75.71	79.40	77.56
T_7	89.66	89.62	89.64	15.08	17.10	16.09	88.46	88.63	88.54
T_8	86.78	87.32	87.05	14.21	14.19	14.20	82.27	83.45	82.86
T_9	83.19	83.53	83.36	12.35	12.97	12.66	78.67	79.20	78.94
T_{10}	76.56	76.69	76.63	7.19	8.30	7.75	49.33	52.50	50.91
Mean	**85.16**	**85.53**	**85.34**	**12.89**	**13.51**	**13.20**	**74.97**	**77.42**	**76.20**
CD($p \leq 0.05$)	**2.93**	**3.03**	**3.86**	**0.67**	**0.71**	**0.89**	**1.66**	**0.84**	**1.70**
CV %	**2.00**	**2.07**	**2.03**	**3.04**	**3.09**	**3.06**	**1.29**	**0.63**	**1.01**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)

*T_2= RDF 50% + FYM (10 tonnes/ha)

*T_3= FYM (20 tonnes/ha)

*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)

*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)

*T_6= Vermicompost (5 tonnes/ha)

*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost

*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost

*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost

*T_{10}= Control

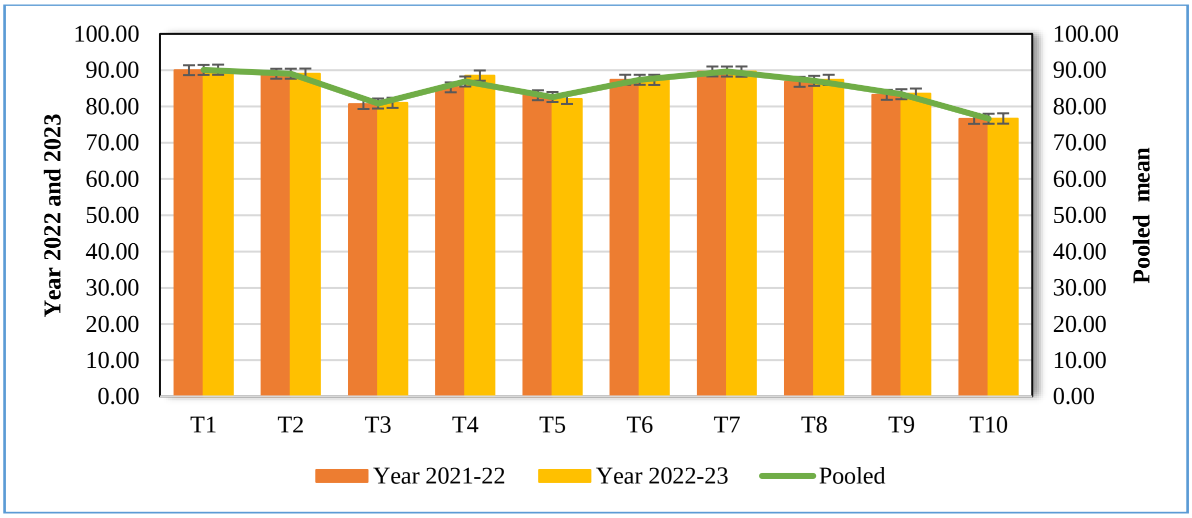


Fig. 4.19 Effect of various treatments on moisture content of palak (%).

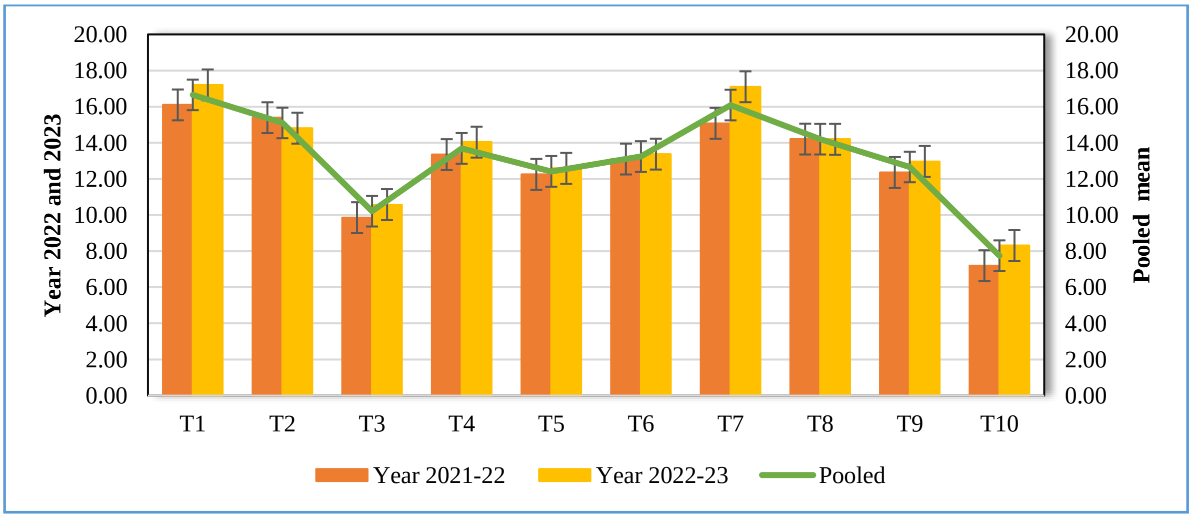


Fig. 4.20 Effect of various treatments on dry matter content of palak (%).

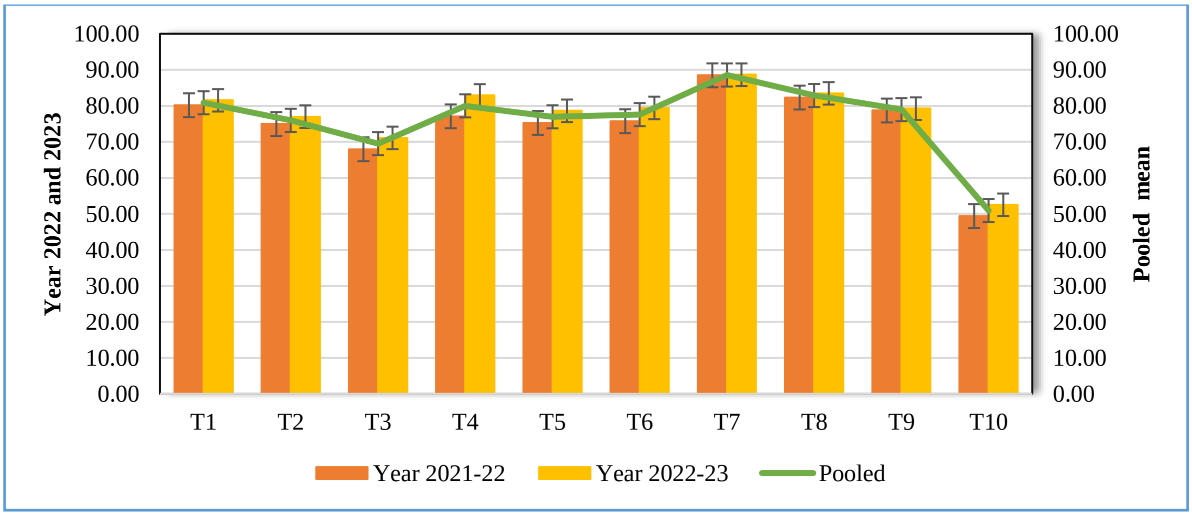


Fig. 4.21 Effect of various treatments on ascorbic acid content of palak (mg/100g).

Also, in pooled data analysis over years, the total carotenoids content was recorded maximum in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 26.85 mg/100g, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 26.25 and 26.05 mg/100g, respectively. The total carotenoids content for control i.e. treatment T_{10} was found to be 10.41 mg/100g that was minimum among all treatment combination. It has also been observed that spinach's carotenoids concentration increased as the amount of nitrogen increased reported by Xu and Mou (2016) and Gutierrez-Rodríguez *et al.,* (2013). Given that microbes facilitate nutrient uptake, it is likely because plants are more able to absorb nutrients from the soil (Gogoi, 2016). According to Vethamoni and Thampi (2018a), applying biofertilizers such as *Azospirillum* solubilizes phosphorus and fixes atmospheric nitrogen, leading to the stimulation of plant hormones that improve nutrient uptake and increase plant biosynthesis.

4.3.5 Total phenols content (mg/100g)

Phenolics are essential to plant development, especially for the formation of lignin and pigments. They also give plants scaffolding support and structural stability. Plant phenolic compounds have several functions such as antioxidants, UV screens, signalling molecules like salicylic acid and flavonoids, structural polymers like lignin, attractants like flavonoids and carotenoids, and defensive response chemicals like tannins and phytoalexins (Wilton, 2023).

The data presented to total phenols content, as seen in the Table 4.9 and Fig 4.23, indicates that different treatments significantly impact phenols content during both years. The total phenols content in different treatment combinations ranged from 14.84 to 22.33 mg/100g having a mean value of 18.98 mg/100g during the first year and the values ranged from 14.75 to 22.70 mg/100g having a mean value of 18.90 mg/100g during the second year. The pooled mean values for total phenols content ranged from 14.79 to 22.52 (mg/100g).

Table 4.9 Effect of various treatments on carotenoids content (mg/100g), phenols content (mg/100g), and antioxidant activity (%) of palak

Treatments	Total carotenoids content (mg/100g)			Total Phenols content (mg/100g)			Antioxidant activity (%)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	25.30	28.39	26.85	17.44	17.75	17.60	2.53	2.60	2.57
T_2	24.85	27.25	26.05	18.15	18.24	18.19	2.79	2.45	2.62
T_3	14.65	16.65	15.65	16.49	16.18	16.34	3.38	3.13	3.26
T_4	18.64	19.31	18.98	19.26	19.18	19.22	3.58	3.40	3.49
T_5	15.64	17.31	16.48	19.94	19.84	19.89	3.44	3.19	3.31
T_6	18.25	18.25	18.25	22.27	21.86	22.07	3.48	3.20	3.34
T_7	24.50	28.00	26.25	22.33	22.70	22.52	4.42	4.49	4.46
T_8	20.42	22.09	21.25	20.68	20.42	20.55	3.71	3.45	3.58
T_9	19.45	20.45	19.95	18.38	18.09	18.24	4.00	3.84	3.92
T_{10}	10.07	10.74	10.41	14.84	14.75	14.79	2.49	2.31	2.40
Mean	**19.18**	**20.84**	**20.01**	**18.98**	**18.90**	**18.94**	**3.38**	**3.21**	**3.29**
CD(p≤0.05)	**0.69**	**0.97**	**1.09**	**1.33**	**0.75**	**1.40**	**1.10**	**0.90**	**1.30**
CV %	**2.11**	**2.71**	**2.46**	**4.10**	**2.32**	**3.33**	**19.05**	**16.49**	**17.90**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (20 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}= Control

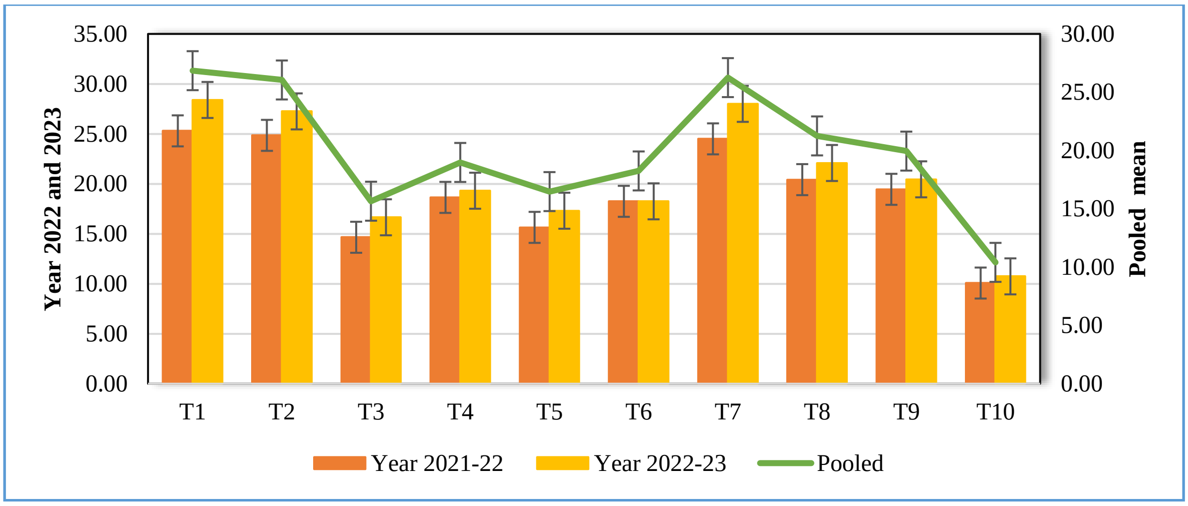


Fig. 4.22 Effect of various treatments on total carotenoids content of palak (mg/100g)

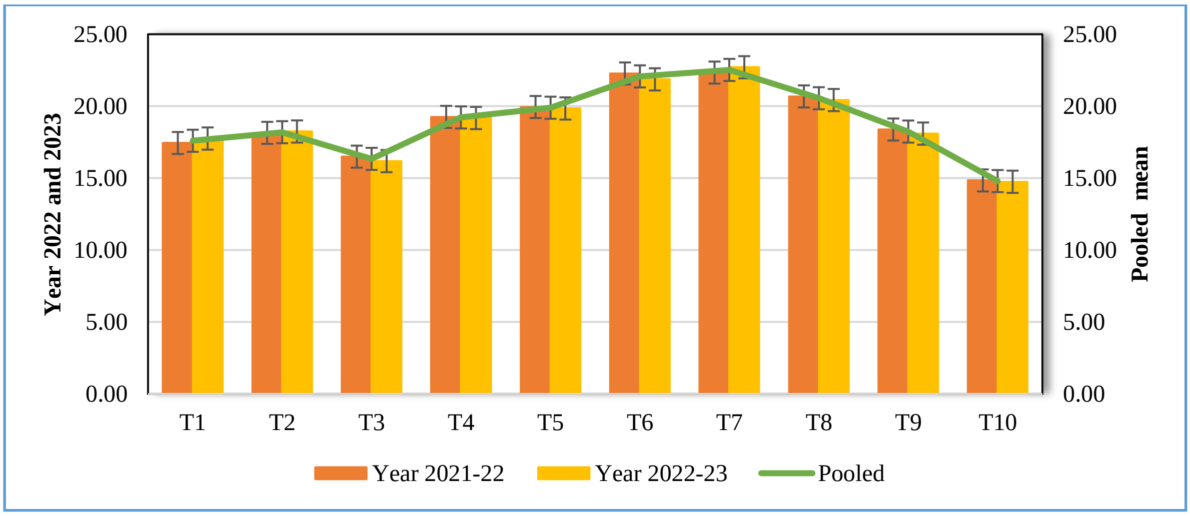


Fig. 4.23 Effect of several treatments on total phenols content of palak (mg/100g)

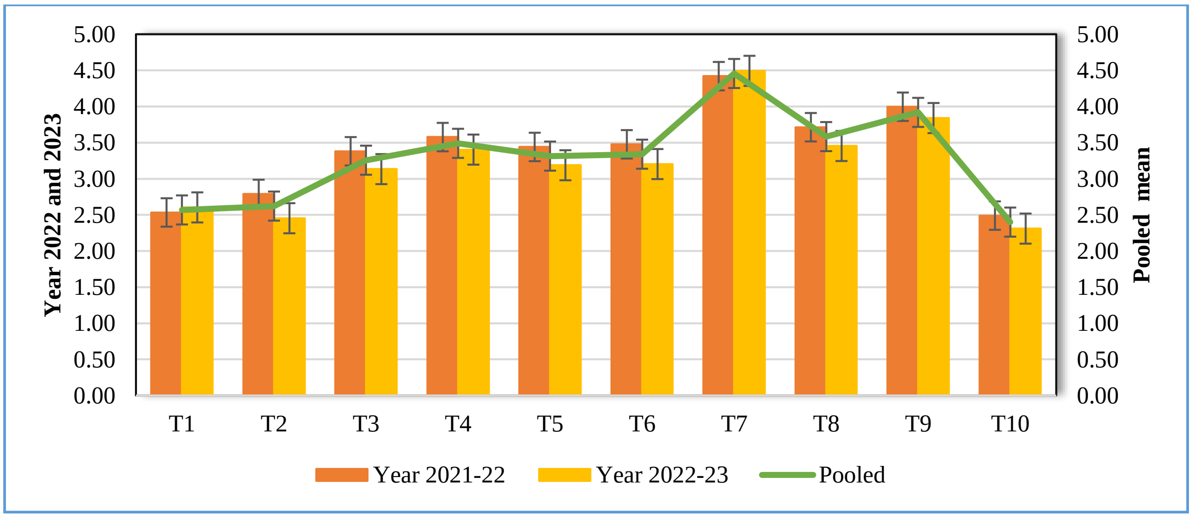


Fig. 4.24 Effect of various treatments on antioxidant activity of palak (%)

During both years, the total phenols content was recorded maximum in treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with the value of 22.33 and 22.70 mg/100g, respectively. The total phenols content for control i.e. treatment (T_{10}) was found to be 14.84 and 14.75 mg/100g, that was minimum among all other treatment combinations.

Also, in pooled data analysis over the years, the total phenols content was recorded maximum in same treatment i.e. T_7 (50% mineral enriched compost + 50% microbial enriched compost) with a value of 22.52 mg/100g which was statistically at par with treatment combination T_6 (vermicompost @5 tonnes/ha) with values of 22.07 mg/100. The total phenols content for control i.e. treatment (T_{10}) was found to be 14.79 mg/100g that was minimum amongst all other treatment combination.

Nitrogen administration in the form of both ammonium and nitrogen caused a considerable drop in leaf-blade phenol content so in organically grown palak have higher amount of total phenols content. This could be because of the presence of nitrogen fixing bacteria and phosphorus solubilising bacteria, which promotes the absorption of macro and micronutrients and increases the manufacture of phenolic chemicals. Similar outcomes were published by Vethamoni and Thampi (2018a) and Jagadeesha *et al.,* (2019b). According to Revathi *et al.* (2014) and Jamoh (2021), using biofertilizers in addition to organic fertilizers improves the production of phenolic chemicals. Thus, data suggests that, as noted by Scheible *et al.,* (2004), reduced soil nitrogen content stimulates the manufacture of total phenol content.

4.3.6 Antioxidant activity (%)

The data presented to antioxidant activity (%), shown in Table 4.9 and Fig 4.24, indicate significant variation for antioxidant activity. The antioxidant activity in different treatment combinations varied from 2.49 to 2.53 per cent having a mean value of 3.38 per cent during the first year and the values varied from 2.31 to 2.60 per cent having a mean value of 3.21 per cent during second year. The pooled mean values for antioxidant activity ranged from 2.40 to 2.57 per cent.

During both years, the antioxidant activity was recorded highest in treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with the value of 4.42 and 4.49 per cent, respectively. The antioxidant activity for control i.e. treatment (T_{10}) was found to be 2.49 and 2.31 per cent, that was least among all treatment combination.

Also, in pooled data analysis over the years, the highest antioxidant activity was recorded in same treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with a value of 4.46 per cent, which was statistically at par with treatment combination T_9, T_8 and T_4 with values of 3.92, 3.58 and 3.49 per cent, respectively. The antioxidant activity for control i.e. treatment (T_{10}) was found to be 2.40 per cent that was least among all other treatment combinations.

It could be because of the soil's high concentration of vitamins, growth hormones, and macro- and micronutrients, which promotes better root development and branching, which aids in nutrient absorption. By providing chemicals that control plant growth (PGR), which aid in nutrient uptake, organic inputs have a direct impact on antioxidant activity of plant. Similar outcomes were observed by Jabeen *et al*. (2018), Sharma and Agarwal (2014), Jagadeesha *et al.,* (2019b) and Jamoh, 2021 in their research findings with spinach beet crop. There has been evidence of a favourable link between phenols and antioxidants in leaves and petioles, with phenols being the main source of antioxidant capacity as observed by Ros *et al.,* (2020).

4.3.7 Minerals content (mg/100g)

The data shown in Table 4.10 and Fig 4.25, indicate significant variation for Fe mineral content. The Fe mineral content in different treatment combinations ranged from 3.21 to 16.10 mg/100g having a mean value of 11.86 mg/100g during the first year and the values ranged from 4.21 to 17.23 mg/100g having a mean value of 12.03 mg/100g during the second year. The pooled mean values for Fe mineral content ranged from 3.71 to 16.67 mg/100g.

During both years, the Fe mineral content was recorded highest in treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with the value of

16.10 and 17.23 mg/100g, respectively. The Fe mineral content for control i.e. treatment (T_{10}) was found to be 3.21 and 4.21 (mg/100g), that was lowest among all other treatment combinations.

Also, in pooled data analysis, the Fe mineral content was recorded highest in same treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with a value of 16.67 mg/100g, which was statistically superior all over treatments and followed by T_4, T_6 and T_8 with values of 15.08, 14.58 and 14.48 mg/100g, respectively. The Fe mineral content for control i.e. treatment (T_{10}) was found to be 3.71 mg/100g that was lowest among all treatment combination.

Perusal of data shown in Table 4.10 and Fig 4.26, showed significant variation for Cu mineral content over the years. The Cu mineral content in different treatment combinations ranged from 1.16 to 4.52 mg/100g having a mean value of 3.20 mg/100g during the first year and the values ranged from 1.91 to 4.67 mg/100g having a mean value of 3.54 mg/100g during the second year. The pooled mean values for Cu mineral content ranged from 1.54 to 4.60 mg/100g.

During both years, the Cu mineral content was recorded highest in treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with the value of 4.52 and 4.67 mg/100g, respectively. The Cu mineral content for control i.e. treatment (T_{10}) was found to be 1.16 and 1.91 mg/100g, that was lowest among all other treatment combination.

Also, in pooled data analysis, the Cu mineral content was recorded highest in same treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with a value of 4.60 mg/100g, which was statistically superior over all other treatment combinations and was followed by T_8 and T_4 with values of 4.24, and 4.05 mg/100g, respectively. The Cu mineral content for control i.e. treatment (T_{10}) was found to be 1.54 mg/100g that was lowest among all treatment combinations.

The data shown in Table 4.10 and Fig 4.27, indicate significant variation for Zn mineral content. The Zn mineral content in different treatment combinations ranged from 4.16 to 8.46 mg/100g having a mean value of 7.42 mg/100g during the first year and the values ranged from 5.21 to 8.66 mg/100g having a mean value of 3.54 mg/100g during the second year. The pooled mean values for Zn mineral estimation ranged from 4.69 to 8.56 mg/100g, respectively.

During both years, the Zn mineral content was recorded highest in treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with the value of 8.46 and 8.66 mg/100g, respectively. The Zn mineral content for control i.e. treatment (T_{10}) was found to be 4.16 and 5.21 (mg/100g), that was lowest amongst all other treatment combination.

Also, in pooled data analysis, the highest Zn mineral content was recorded in same treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) with a value of 8.56 mg/100g, which was statistically superior over all other treatments and was followed by T_8 and T_4 with values of 8.04 and 8.03 and mg/100g, respectively. The Zn mineral content for control i.e. treatment (T_{10}) was found to be 4.69 (mg/100g) that was lowest among all other treatment combination.

The effect of micronutrient uptake could be linked to the organic carbon present in the applied organic manure, which provides energy to soil microorganisms and, upon mineralization, releases organic acids that increase micronutrient availability. This is discovered to be consistent with Vethamoni and Thampi (2018a), Roy *et al.,* (2014) and Jamoh (2021) in relation to Indian spinach. They claimed that adding organic matter to soil improves micronutrient absorption. It has been observed that compounds like lactate and citrate react with the minerals in the soil to increase their availability to plant roots. Likewise, a rise in the minerals found in vegetables because of using enriched compost rather than conventional (Gogoi *et al.,* 2016).

4.3.8 Chlorophyll index

The data exhibited in Table 4.11 and Fig 4.28, confirms significant variation for chlorophyll index. The chlorophyll index of leaves in different treatment combinations ranged from 29.75 to 59.16 having a mean value of 47.13 during the first year and the values ranged from 31.12 to 60.17 having a mean value of 48.27 during the second year. The pooled mean values for chlorophyll index of leaves ranged from 30.43 to 59.66, respectively.

Table 4.10. Effect of various treatments on minerals content of palak (mg/100g)

Treatments	Fe Mineral (mg/100g)			Cu Mineral (mg/100g)			Zn Mineral (mg/100g)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	10.22	10.23	10.22	3.02	3.14	3.08	7.80	7.92	7.86
T_2	9.88	9.29	9.59	2.93	3.04	2.99	7.30	7.34	7.32
T_3	8.45	8.12	8.29	2.16	2.45	2.31	7.21	7.12	7.17
T_4	15.05	15.10	15.08	3.93	4.16	4.05	7.95	8.10	8.03
T_5	13.34	13.24	13.29	3.25	3.87	3.56	7.86	8.01	7.94
T_6	14.34	14.81	14.58	3.18	3.73	3.46	7.87	7.94	7.91
T_7	16.10	17.23	16.67	4.52	4.67	4.60	8.46	8.66	8.56
T_8	14.41	14.56	14.48	4.17	4.30	4.24	8.03	8.04	8.04
T_9	13.61	13.56	13.58	3.70	4.14	3.92	7.57	7.67	7.62
T_{10}	3.21	4.21	3.71	1.16	1.91	1.54	4.16	5.21	4.69
Mean	**11.86**	**12.03**	**11.95**	**3.20**	**3.54**	**3.37**	**7.42**	**7.60**	**7.51**
CD($p \leq 0.05$)	**0.64**	**0.52**	**0.76**	**0.26**	**0.13**	**0.26**	**0.35**	**0.33**	**0.44**
CV %	**3.17**	**2.56**	**2.87**	**4.83**	**2.18**	**3.63**	**2.79**	**2.53**	**2.66**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (10 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}=Control

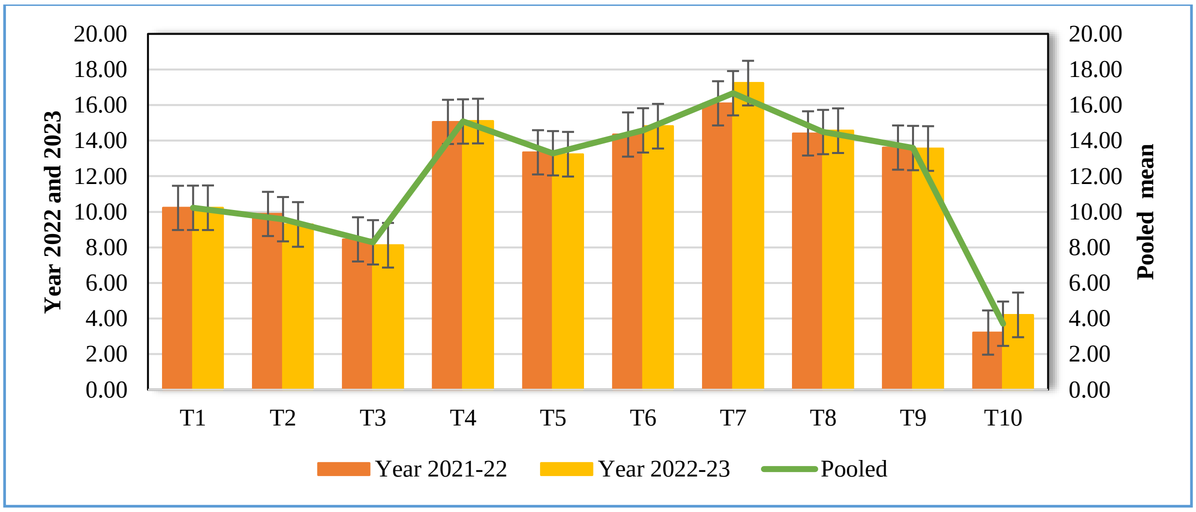


Fig. 4.25 Effect of various treatments on Fe mineral content of palak (mg/100g)

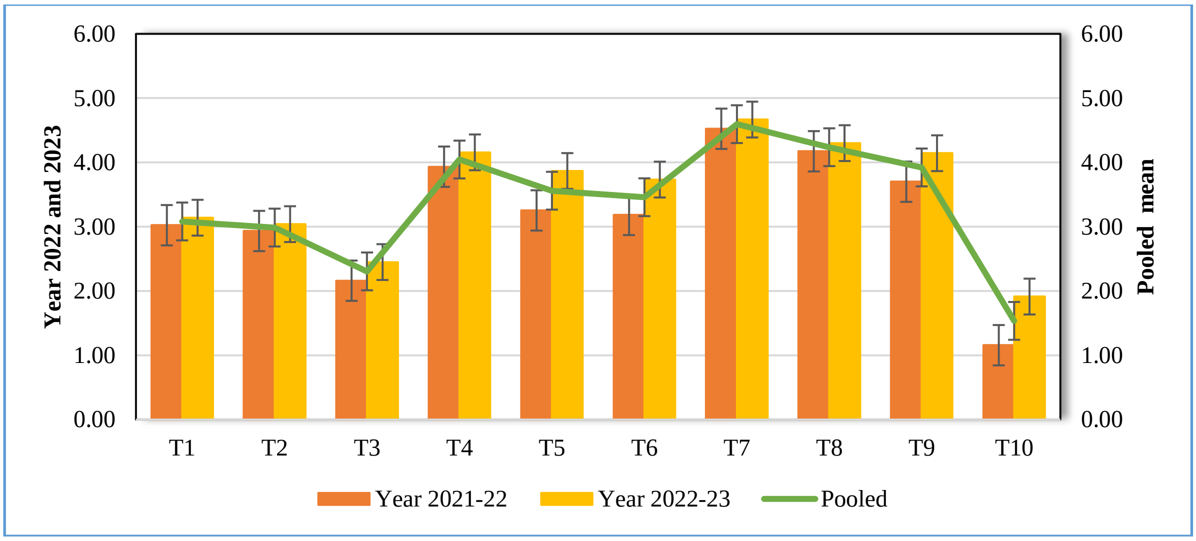


Fig. 4.26 Effect of various treatments on Cu mineral content of palak (mg/100g)

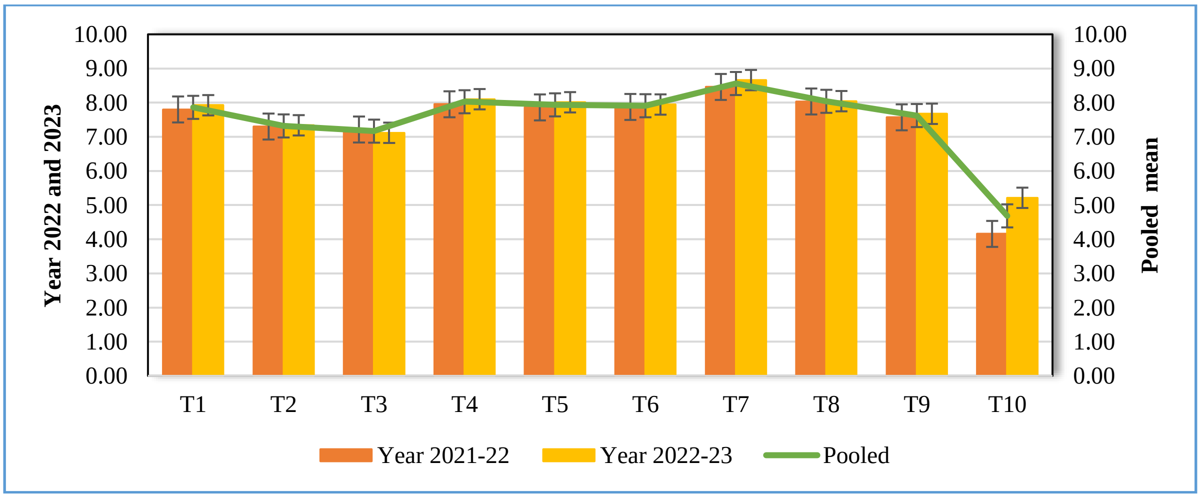


Fig. 4.27 Effect of various treatments on Zn mineral content of palak (mg/100g)

During both years, the chlorophyll index was recorded maximum in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) having a value of 59.16 and 60.17, respectively. The chlorophyll index for control i.e. treatment (T_{10}) was found to be 29.75 and 31.12, that was minimum among all other treatment combination.

Also, in pooled analysis over the years, the maximum chlorophyll index was recorded in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 59.66, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and T_2 **(**RDF 50% + FYM (10 tonnes/ha) with values of 58.75 and 58.19, respectively.

Maximum chlorophyll index of leaves was recorded in T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha), this could be because of the administration of nitrogen-rich urea. The primary component needed to create chlorophyll molecules is nitrogen. These outcomes are same according to the outcomes of Gairola (2009), Bharad *et al.* (2013), and Jagadeesha *et al*., (2019b) during their study in palak. Increased amounts of chlorophyll in T_7 (50% mineral enriched compost + 50% microbial enriched compost) may be due to the result of macro and micronutrients from biofertilizers and enriched compost, especially nitrogen, which is a key component of chlorophyll found by Singh *et al.*, (2014) and Jamoh (2021).

4.3.9 Crude fibre content (%)

The data exhibited in Table 4.11 and Fig 4.29, confirms significant variation for crude fibre content of palak leaves during both the years. The crude fibre content in different treatment combinations ranged from 7.63 to 10.83 per cent, having a mean value of 8.55 per cent during the first year and the values ranged from 6.91 to 11.77 per cent having a mean value of 8.58 per cent during second year. The pooled mean values for crude fibre content ranged from 7.27 to 11.30, respectively.

During both years, the crude fibre content was recorded maximum in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 10.83 and 11.77 per cent, respectively. The crude fibre content for treatment (T_7) was found to be 7.63 and 6.91 per cent, which was minimum among all treatment combination, respectively.

Also, in pooled data analysis, the crude fibre content was recorded maximum in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 11.30 per cent, which was statistically at par with treatment combination T_7 (50% mineral enriched compost + 50% microbial enriched compost) and followed T_2 and T_{10} with values of 9.5 and 8.71, respectively.

In present experiment, the highest crude fibre content was noted in the treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha). The plants that receive the least amount of organic manure have compacted soil (greater bulk density) due to fertilizers, which reduces their responsiveness to overall growth but increases the amount of fibre in the soil. However, because of the impact of organic acids released by the microorganisms, treatment T_7, which received the largest amount of organic manure and consortia, tended to yield sensitive palak leaves with the least amount of fibre reported by Jabeen *et al.*, (2018), Jagadeesha *et al.*, (2019b) and Jamoh, 2021.

4.3.10 Leaf nitrate content (mg kg^{-1})

The data exhibited in Table 4.11 and Fig 4.30, indicate significant variation for leaf nitrate content. The content of leaf nitrate in different treatment combinations ranged from 322.30 to 697.07 mg kg^{-1} having mean value of 438.89 mg kg^{-1} during first year (2022) and the values ranged from 312.99 to 659.06 mg kg^{-1} having mean value of 421.88 mg kg^{-1} during the second year. The pooled mean values for leaf nitrate content ranged from 317.65 to 678.07 mg kg^{-1}.

During both years, the leaf nitrate content was recorded highest in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the value of 697.07 and 659.06 mg kg^{-1}, respectively. The leaf nitrate content for control i.e. treatment (T_{10}) was found to be 322.30 and 312.99 mg kg^{-1}, that was minimum amongst all other treatment combination.

During pooled data analysis, the leaf nitrate content was recorded highest in same treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 678.07 mg kg^{-1}, which was statistically superior all over treatment combinations and was followed by T_2 with values of 601.26 mg kg^{-1}, respectively.

Additionally, it has been reported earlier that increasing the frequency at which potassium is applied stimulates the metabolism and usage of nitrate, aids in its absorbing and moving in the upward direction of the plant, and eventually lowers the buildup of nitrates in vegetable crops. According to Qureshi *et al.,* (2014) N, P, K, and S play important roles in the synthesis of proteins, which lowers nitrate levels in plants. This could be the result of adding organic material, which raises the soil's organic carbon content and affects characteristics and functions of soil directly and indirectly (Gairola *et al.,* 2009). They also found that vegetables grown using organic fertilizers have lower nitrate contents than vegetables grown conventionally or with mineral fertilizers.

4.4 OBSERVATIONS RECORDED FOR SHELF-LIFE STUDIES

4.4.1 Physiological loss in weight (%)

Perusal of data in Table 4.12 and Fig 4.31, showed significant variation for physiological weight loss (PLW). During both years of study, the highest physiological loss in weight was found to be in treatment combination T_7 control (no packing) with the value of 20.56 and 20.81 per cent, and it was recorded lowest in treatment T_4 (PP-40 micron at 0 % vent) with value of 3.95 and 3.95 per cent, respectively.

During pooled data analysis, the highest PLW was recorded in treatment T_7 control (no packing) with the value of 20.68 per cent, and followed by treatment T_3 (LDPE 40 micron with 2 % vent.) with value of 6.16 per cent whereas, the lowest PLW was recorded in treatment T_4 (PP- 40 micron at 0 % vent) with the value of 3.95 per cent.

Table 4.11 Effect of various treatments on chlorophyll index, crude fibre content (%) and leaf nitrate content (mg kg^{-1}) of palak

Treatments	Chlorophyll index			Crude Fibre content (%)			Leaf Nitrate Content (mg kg^{-1})		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	59.16	60.17	59.66	10.83	11.77	11.30	697.07	659.06	678.07
T_2	58.03	58.36	58.19	9.14	9.86	9.50	614.25	588.27	601.26
T_3	34.50	35.16	34.83	7.94	8.18	8.06	463.92	422.45	443.19
T_4	48.37	50.70	49.53	8.17	7.87	8.02	526.40	504.87	515.64
T_5	41.15	42.15	41.65	8.30	8.08	8.19	339.57	337.70	338.64
T_6	46.00	47.33	46.66	8.60	8.23	8.42	359.61	328.44	344.03
T_7	58.25	59.25	58.75	7.63	6.91	7.27	339.33	344.93	342.13
T_8	50.51	51.18	50.84	8.20	7.82	8.01	375.23	368.57	371.90
T_9	45.58	47.25	46.417	8.21	8.15	8.18	351.21	351.54	351.38
T_{10}	29.75	31.12	30.43	8.47	8.94	8.71	322.30	312.99	317.65
Mean	**47.13**	**48.27**	**47.70**	**8.55**	**8.58**	**8.57**	**438.89**	**421.88**	**430.39**
CD($p \leq 0.05$)	**1.48**	**2.52**	**2.67**	**1.36**	**1.02**	**1.56**	**0.23**	**0.17**	**0.27**
CV %	**1.83**	**3.04**	**2.53**	**9.32**	**6.95**	**8.21**	**3.40**	**2.57**	**3.01**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (20 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost (5 tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}=Control

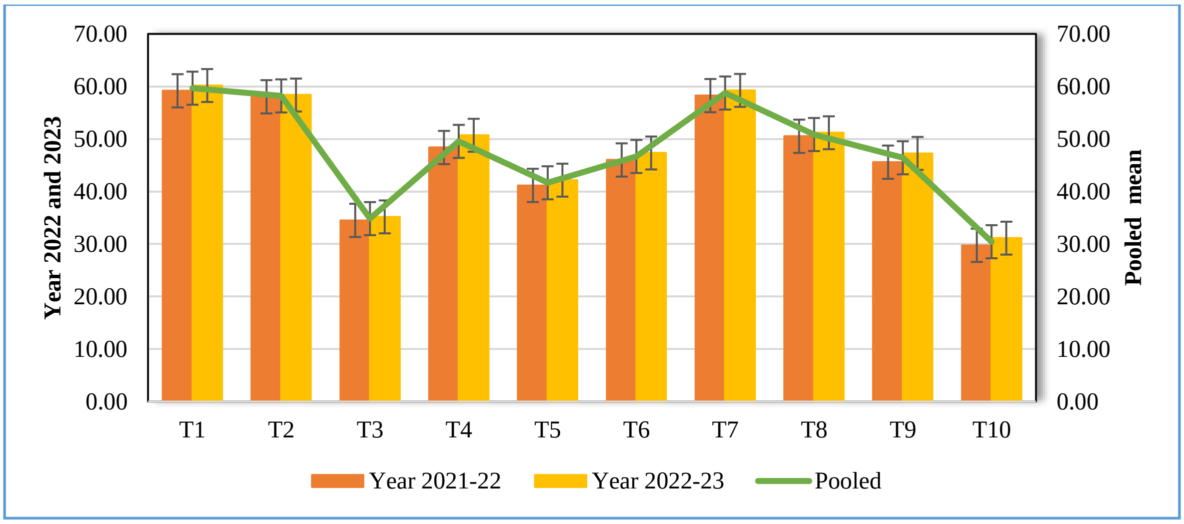


Fig. 4.28 Effect of various treatments on chlorophyll index of palak

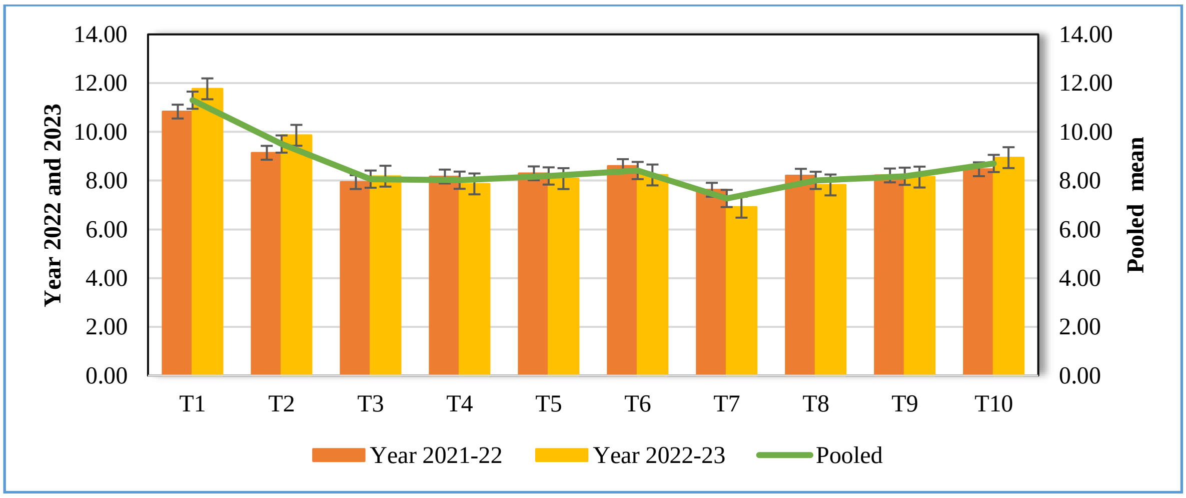


Fig. 4.29 Effect various treatments on crude fibre content of palak (%)

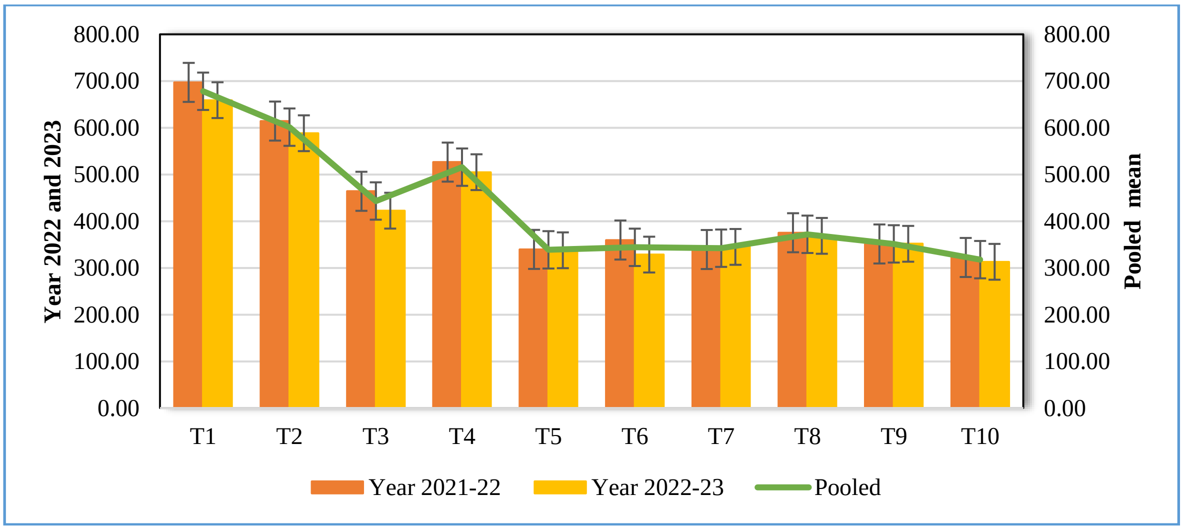


Fig. 4.30 Effect of various treatments on leaf nitrate content of palak (mg kg^{-1})

It was evident that the packing procedures had a big impact on the PWL during the storage time. The samples' Physiological Weight Loss significantly increased with an increase in vent%, even with the packaging films, samples with higher ventilation percentages had a much higher physiological weight loss than samples without any ventilation were observed by Patel, 2011. Ambrose *et al.,* (2017) noted an increase in PWL% and shrinkage in the control sample during packaging trials with moringa leaves.

4.4.2 Shelf life (days)

The data regarding shelf life of palak is shown in the Table 4.12 and Fig 4.32, confirms significant variation for shelf life. The study of both years revealed that, the longest shelf life was recorded to be in treatment combination T_5 (PP- 40 micron at 1 % vent.) with the value of 6.50 and 6.48 days, and it was recorded shortest in treatment T_7 control (no packing) with value of 1.56 and 1.55 days.

In pooled data analysis, the longest shelf life was recorded in treatment T_5 (PP- 40 micron at 1 % vent.) with the value of 6.49 days, and followed by treatment T_2 (LDPE 40 micron with 1 % vent.) with value of 5.00 days and shortest shelf life recorded in treatment T_7 control (no packing) with the value of 1.56 days. Similar results reported by Reddy, (2014).

4.4.3 Days to 50% colour change

The data pertains, days to 50 per cent colour change, in Table 4.13 and Fig 4.33, confirms significant variation over years. During both year of study, the maximum number of days was recorded to be in treatment combination T_4 (PP- 40 micron at 0 % vent) with the value of 4.50 and 4.70 days, and it was recorded minimum number of days in treatment T_7 control (no packing) with value of 1.00 and 1.25 days.

During pooled data analysis, the number of days was recorded maximum in treatment T_4 (PP- 40 micron at 0 % vent) with the value of 4.60 days, and followed by treatment T_1 (LDPE-40 micron at 0 % vent) with value of 3.90 days and for minimum number of days recorded in treatment T_7 control (no packing) with the value of 1.13 days.

Table 4.12 Effect of various packaging on physiological loss in weight (PLW%) and shelf life of palak

Treatments	PLW %			Shelf life (Days)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	4.23	4.24	4.23	3.20	3.51	3.36
T_2	5.45	5.44	5.44	5.00	5.01	5.00
T_3	6.34	6.32	6.33	2.50	2.51	2.50
T_4	3.95	3.95	3.95	4.50	4.52	4.51
T_5	4.85	4.93	4.89	6.50	6.48	6.49
T_6	6.12	6.21	6.16	3.07	3.08	3.08
T_7	20.56	20.81	20.68	1.56	1.55	1.56
Mean	**7.36**	**7.41**	**7.38**	**3.76**	**3.81**	**3.79**
CD($p \leq 0.05$)	**0.66**	**0.23**	**0.60**	**0.25**	**0.23**	**0.33**
CV %	**5.12**	**1.83**	**3.58**	**3.91**	**3.58**	**3.91**

Note *T_1= LDPE 40 micron with 0 % vent.
*T_2= LDPE 40 micron with 1 % vent.
*T_3= LDPE 40 micron with 2 % vent.
*T_4= PP 40 micron with 0 % vent.
*T_5= PP 40 micron with 1 % vent
*T_6= PP 40 micron with 2 % vent.
*T_7= Control (No packaging)

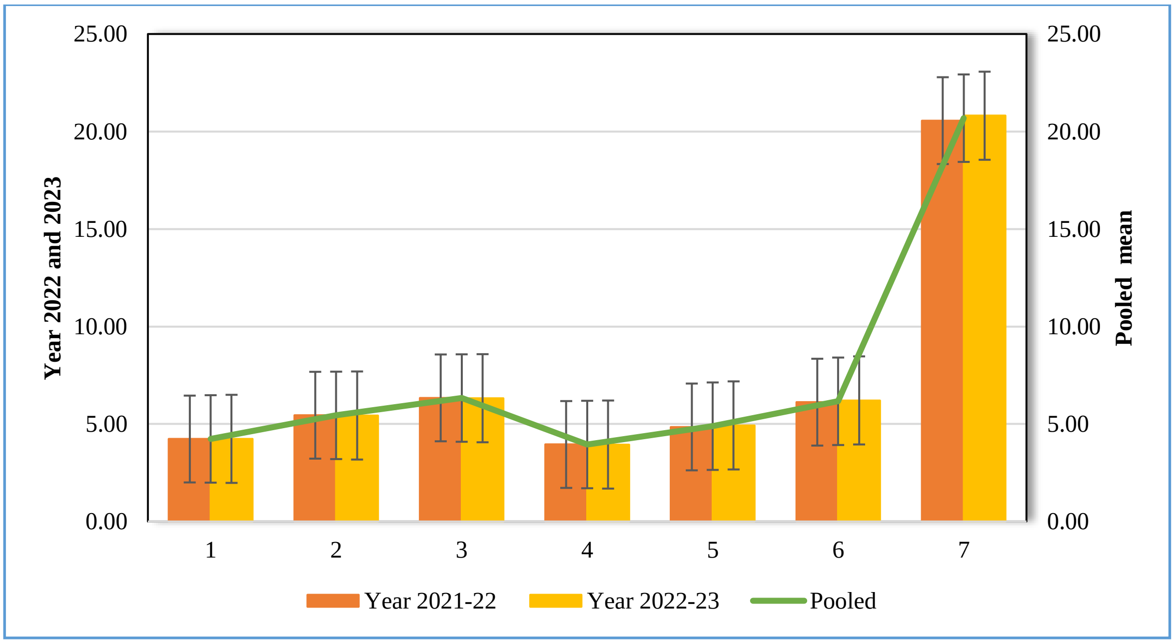


Fig. 4.31 Effect of various packaging on physiological loss in weight of palak (%)

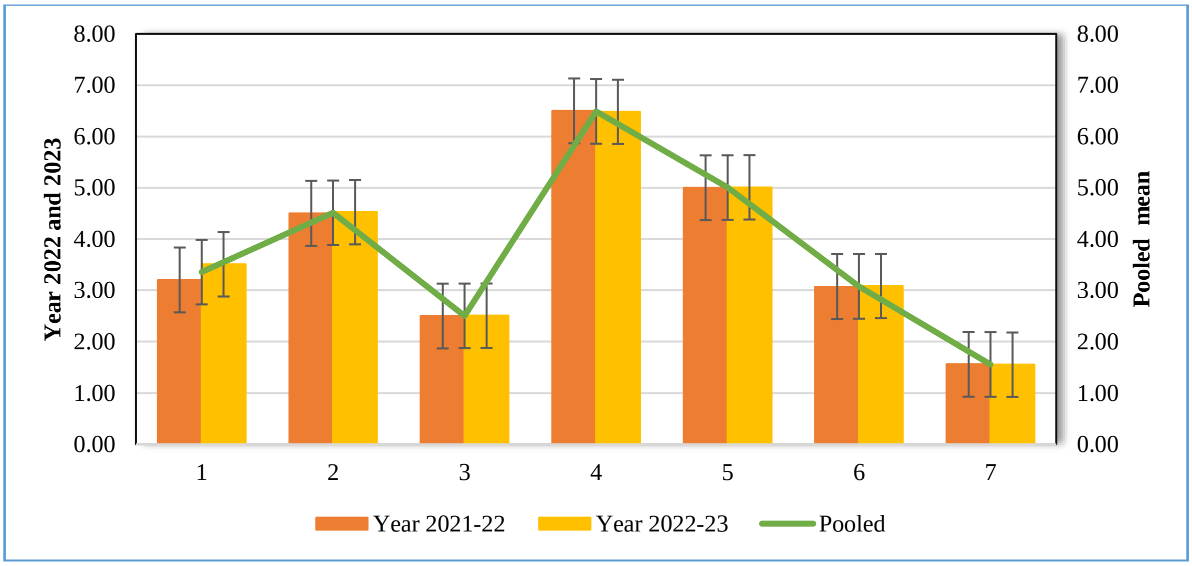


Fig. 4.32 Effect of various packaging on shelf life of palak (Days)

Table 4.13 Effect of various packaging on days to 50% colour change and 50 % rotting of palak

Treatments	Days to 50% colour change			Days to 50% Rotting		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	3.85	3.95	3.90	3.12	3.15	3.13
T_2	2.49	2.60	3.20	4.00	3.99	3.99
T_3	1.50	1.70	1.60	2.12	2.13	2.12
T_4	4.50	4.70	4.60	4.25	4.25	4.25
T_5	3.06	3.35	3.20	6.00	6.02	6.01
T_6	2.67	2.80	2.74	2.80	2.84	2.82
T_7	1.00	1.25	1.13	1.10	1.08	1.09
Mean	**2.72**	**2.91**	**2.82**	**3.34**	**3.35**	**3.35**
CD($p \leq 0.05$)	**0.13**	**0.10**	**0.14**	**0.19**	**0.16**	**0.23**
CV %	**2.87**	**2.06**	**2.24**	**3.36**	**2.77**	**3.13**

Note *T_1= LDPE 40 micron with 0 % vent.
*T_2= LDPE 40 micron with 1 % vent.
*T_3= LDPE 40 micron with 2 % vent.
*T_4= PP 40 micron with 0 % vent.
*T_5= PP 40 micron with 1 % vent
*T_6= PP 40 micron with 2 % vent.
*T_7= Control (No packaging)

Produce kept in film packets without ventilation frequently keeps a nice appearance. This could be the result of a changed environment with more CO_2 and less O_2. However, even if the product appears appealing, bad tastes and odors can develop in sealed packets. (Ambrose *et al.*, 2017; Prasad *et al.,* 2018).

4.4.4 Days to 50% rotting

The data regarding, days to 50 per cent rotting represented in Table 4.13 and Fig 4.34, showed considerable impact on days to 50 per cent rotting. During both year of study, the maximum number of days was recorded to be in treatment combination T_5 (PP- 40 micron at 1 % vent.) with the value of 6.00 and 6.02 days, and it was recorded minimum number of days in treatment T_7 control (no packing) with value of 1.10 and 1.08 days.

During pooled data analysis, the number of days was recorded maximum in same treatment T_5 (PP- 40 micron at 1 % vent.) with the value of 6.01 days, and followed by treatment T_4 (PP-40 micron at 0 % vent) with value of 4.25 days and for minimum number of days recorded in treatment T_7 control (no packing) with the value of 1.09 days.

Due to proper ventilation in T_5 (PP- 40 micron at 1 % vent.) and T_2 (LDPE-40 micron at 1 % vent) during storage it takes more days to rotting according to Ambrose *et al.* (2017). Moreover, increased moisture in the microenvironment in 0 per cent ventilation treatments favour decaying earlier. Similar outcomes were discovered by Prasad *et al.,* (2018) in spinach beet.

4.5 ECONOMICS OF THE TREATMENTS

Through table 4.14 and 4.15 treatment wise cultivation cost and return analysis (B-C ratio) has been shown for two consecutive years of the study. During economic analysis, the treatment combination T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) obtained highest net returns of ₹ 164,648 and ₹ 159,806 per hectare with corresponding B-C ratio of 2.72 and 2.73 for first and second year, respectively.

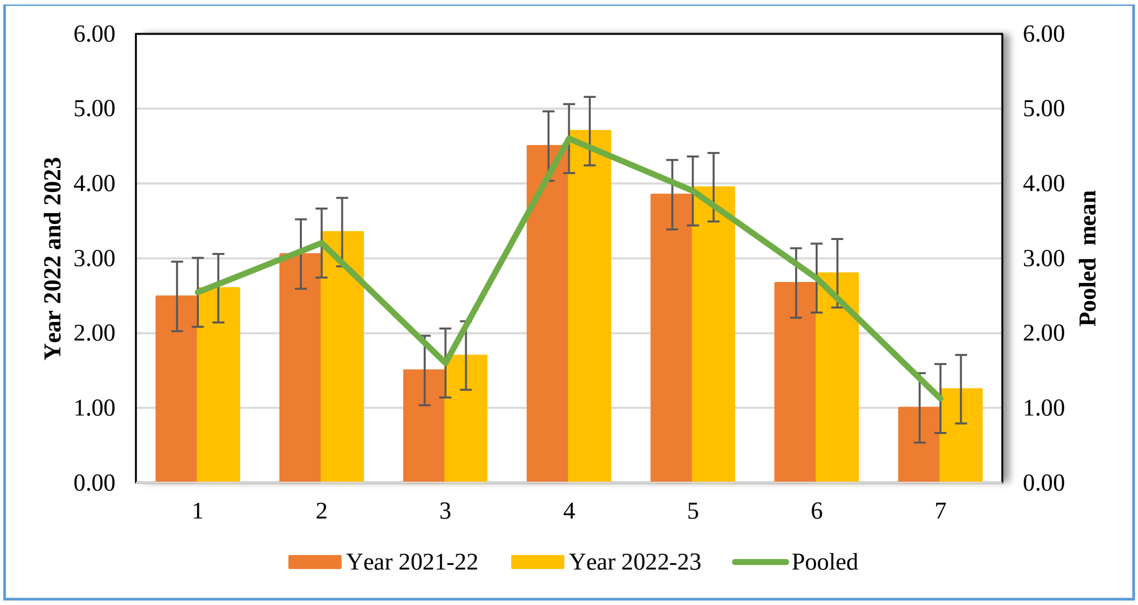


Fig. 4.33 Effect of various packaging on days to 50 % colour change of palak

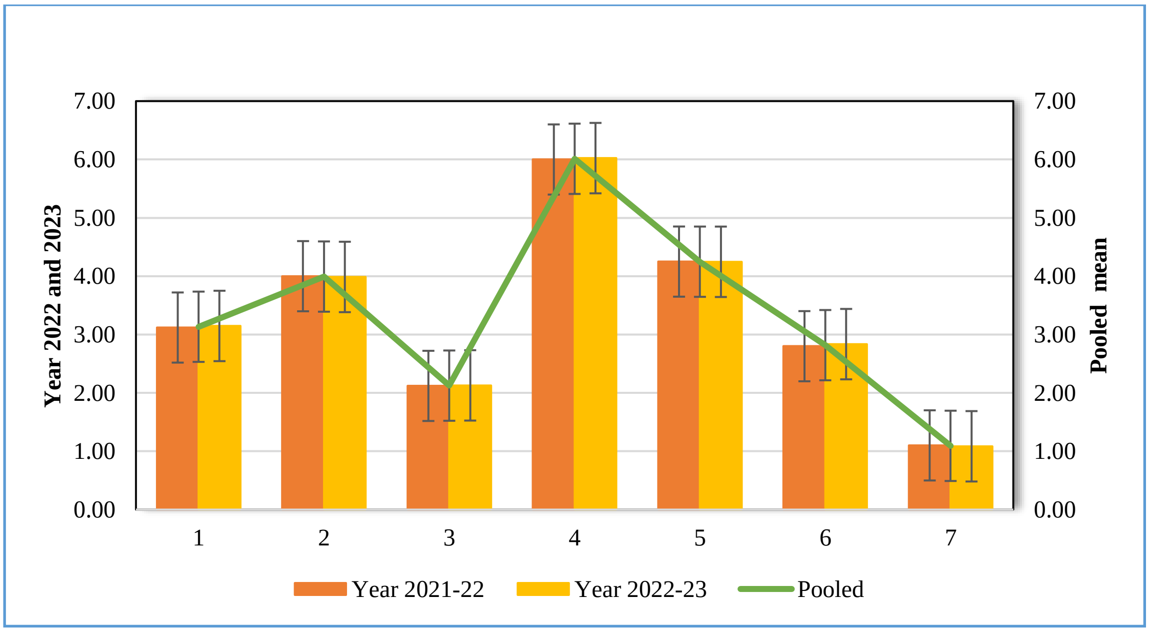


Fig. 4.34 Effect of various packaging on days 50 % rotting of palak

This was followed by treatment combination T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) which earned ₹123,604 with B-C ratio of 1.81 during first year and in second year it was followed by treatment combination T_4 (mineral enriched compost 5 tonnes/ha) which earned ₹ 120,212 having B-C ratio of 2.00. With no application of chemical fertilizers in treatment T_7 it has reduced cultivation cost and gave more net return per hectare.

4.6 EFFECT OF DIFFERENT ENRICHED COMPOST ON PHYSICO-CHEMICAL PROPERTIES OF SOIL

Effect of various treatments on soil physicochemical properties were studied during present investigation i.e. presented in tables 4.16 to 4.17.

4.6.1 Soil pH

The pH of the soil is a crucial factor in determining the sustainability of the ecosystem and the health of the soil. The importance of soil pH for both environmental sustainability and soil health is examined in this study. Microbial activity, soil structure, and nutrient availability are all impacted by soil pH. 6.0–7.0 is the ideal pH range for soil structure, microbial activity, and nutrient availability. These qualities may be compromised by too high or low soil pH, which would lead to poor soil health and reduced environmental sustainability (Jagadeesha *et al.*, 2019a, Jamoh 2021 and Dewangan *et al.*, 2023).

The data given in Table 4.16 and Fig 4.35, demonstrated that the addition of enriched compost considerably lowered the pH of the soil in comparison to the other treatments including RDF and control during both the years. The pH of the soil in different treatment combinations ranged from 7.63 to 8.43 having a mean value of 8.05 during the first year and the values ranged from 7.68 to 8.46 having a mean value of 8.07 during the second year. The pooled mean values for soil pH ranged from 7.66 to 8.46, respectively.

Table 4.14 Effect of various treatments on economics in palak crop (first year)

Treatment	Total cost (₹)	Sale Price (₹/q)	Yield 2022 (q/ha)	Gross income (₹)	Net income (₹)	B:C Ratio
T_1	68384	1800	106.66	191,988.00	123,604.00	1.81
T_2	66784	1800	104.44	187,992.00	121,208.00	1.81
T_3	65184	1500	65.27	97,905.00	32,721.00	0.50
T_4	62184	1800	89.99	161,982.00	99,798.00	1.60
T_5	58684	1800	78.06	140,508.00	81,824.00	1.39
T_6	143184	1800	87.05	156,690.00	13,506.00	0.09
T_7	60434	2200	102.31	225,082.00	164,648.00	2.72
T_8	61309	1900	84.7	160,930.00	101,371.00	1.70
T_9	59559	1800	77.05	138,690.00	77,381.00	1.26
T_{10}	53824	1500	54.64	81,960.00	28,136.00	0.52

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (20 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}=Control

Table 4.15 Effect of various treatments on economics in palak crop (second year)

Treatment	Total cost (₹)	Sale Price (₹/q)	Yield 2023 (q/ha)	Gross income (₹)	Net income (₹)	B:C Ratio
T_1	68384	1800	110.73	199,314.00	130,930.00	1.91
T_2	66784	1800	92.95	167,310.00	100,526.00	1.51
T_3	65184	1500	66.32	99,480.00	34,296.00	0.53
T_4	60184	1800	100.22	180,396.00	120,212.00	2.00
T_5	56684	1800	79.45	143,010.00	86,326.00	1.52
T_6	143184	1800	86.26	155,268.00	12,084.00	0.08
T_7	58434	2000	109.12	218,240.00	159,806.00	2.73
T_8	59559	1900	80.55	153,045.00	93,486.00	1.57
T_9	57559	1800	80.38	144,684.00	87,125.00	1.51
T_{10}	53184	1500	47.04	70,560.00	17,376.00	0.33

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)

*T_2= RDF 50% + FYM (10 tonnes/ha)

*T_3= FYM (20 tonnes/ha)

*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)

*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost tonnes/ha)

*T_6= Vermicompost (5 tonnes/ha)

*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost

*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost

*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost

*T_{10}=Control

During both years, the highest pH values were recorded in treatment T_{10} (Control) with the value of 8.47 and 8.51 and was followed by T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) and T_2 with the values of 8.43, 8.46 and 8.41, 8.40, respectively. The soil pH for treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) was found to be 7.63 and 7.68, that was the lowest among all treatment combination.

Also, in pooled data analysis, the highest soil pH was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 8.46 which was followed by T_{10} (Control) with values of 8.46, respectively.

Activity of bacteria that aid in the breakdown of organic matter, converting previously unavailable mineral nutrients into forms that are suitable for crop growth and development, enhancing the soil's organic carbon content and maintaining a balance pH (Tekasangla *et al.,* 2015, Jagadeesha *et al.,* 2019a and Jamoh 2021).

4.6.2 EC (dSm^{-1})

The EC, or electrical conductivity of a solution is a measurement of its capacity to conduct electricity. The EC of the solution rises when ions, or salts, are present. The low EC indicates in the absence of salts that the solution does not conduct electricity well. Sandstone mineral soils and media are not significantly harmed directly by the soil's EC. On plants growing in soil or other mediums, however, EC directly affects them. The way that EC affects plants is directly influenced by water management (Mylavarapu *et al.,* 2020).

Data given in the Table 4.16 and Fig 4.36, demonstrated that the use of various treatment combinations significantly improve the soil electrical conductivity, over the years and pooled data. The electrical conductivity of the soil in different treatment combinations varied from 0.37 to 0.58 dSm^{-1} having mean value of 0.45 dSm^{-1} during the first year and the values varied from 0.38 to 0.63 dSm^{-1} having mean value of 0.51 dSm^{-1} during the second year. The pooled mean values for soil electrical conductivity varied from 0.37 to 0.61 dSm^{-1}.

During both years, the EC value was recorded highest in treatment combination T_1 i.e. RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with the values of 0.58 dSm^{-1} and 0.63 dSm^{-1} which was statistically at par with treatments T_2, T_3 and T_{10}, respectively. The soil EC for treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) was found to be 0.37 and 0.38 dSm^{-1}, that was lowest among all treatment combination.

Also, in pooled data analysis, the highest soil EC was recorded in treatment T_1 RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 0.61 dSm^{-1} which was statistically at par with T_2 and T_3. The soil EC for treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) was found to be 0.37 dSm^{-1}, that was lowest among all treatment combination in pooled analysis.

The data given in Table 4.16 and Fig 4.37 reveals significant decrease in EC of soil treated with organic matter (Enriched compost) and it might be due to addition of humic compounds by the organic matter. This may be the consequence of chelating, which detoxifies the harmful ions, particularly Na^+ and Cl^- leading to improvement in the soil aggregation and the generation of organic acids during the breakdown of organic materials (Zahid and Niazi, 2006). The current findings of the outcomes are comparable to Surekha *et al.*, (2016), Meena *et al.*, (2017) and Jamoh, 2021.

4.6.3 Organic carbon (%)

The amount and composition of organic matter in soils determines their physical, chemical, and biological qualities. Humic compounds are the most refractory component of organic matter to degradation. Humic compounds contain humic acids and fulvic acids. One of the most essential metrics for determining "humus quality" is the humic acid to fulvic acid ratio content (Jaskulska *et al.,* 2023).

It is clear from values given in Table 4.16 and Fig 4.37, that the use of enriched compost increased notably organic carbon in soil following the palak crop's harvest in each year and on a combined basis. The organic carbon in different treatment combinations ranged from 0.42 to 0.61 per cent, having mean value of 0.52 per cent during the first year and the values ranged from 0.42 to 0.72 per cent having mean value of 0.54 per cent, during second year. The pooled mean values for organic carbon of soil varied from 0.42 to 0.66 per cent, respectively.

During both years, the value of organic carbon 0.61 and 0.72 per cent in soil was observed highest under treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) which was followed by treatment T_5 (Microbial enriched compost 5 t ha^{-1}) with the value of 0.60 and 0.61 per cent, respectively.

Also, in pooled data analysis, the highest organic carbon was recorded in treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) with a value of 0.66 per cent which was followed by T_5 (Microbial enriched compost 5 tonnes/ ha) with a value of 0.61 per cent. The organic carbon for T_2 treatment was found to be 0.42 per cent, which was lowest among all treatment combination.

It could be because organic manure has comparatively larger carbon content than other organic and inorganic treatments. The minimal distribution to the soil, which promotes greater storage, may be the cause of the rise in organic carbon. Comparable outcomes were published by Rai *et al.,* (2012) and Jamoh, 2021. They noticed a noteworthy enrichment in the proportion of organic carbon in the mineral + microbial enriched compost.

4.6.4 Available nitrogen (kg/ha)

An essential component for soil health and plant growth is nitrogen. Both organic (amino acids, amino sugars, and nucleic acid bases) and inorganic (NO_2–, NO_3^-) forms of nitrogen are present in soil. The fixation of nitrogen by microorganisms, losses through crop removal and leaching, volatilization, and the emission of N_2O and N_2 determine the amount of nitrogen in the soil. First, ammonification is used to convert $NH4^+$. Next, nitrite is transformed to nitrate by the nitrification process (Shafreen *et. al.,* 2021; Kumar *et al.,* 2018).

The pooled analysis of the data depicted in Table 4.17 and Fig 4.38, showed that the use of enriched compost significantly increases available nitrogen in the soil following the palak crop's harvest in each year. The available nitrogen in different treatment combinations ranged from 95.47 to 146.24 kg/ha, having mean value of

129.69 kg/ha, during first year and the values ranged from 106.75 to 148.77 kg/ha having a mean value of 133.71 kg/ha during second year. The pooled mean values for available nitrogen ranged from 101.11 to 147.50 kg/ha.

The maximum amount of accessible nitrogen 146.24 and 148.77 kg/ha in soil was obtained under treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) which was superior over T_1 (RDF 100% (85:30:0 N: P: K kg/ha + FYM 10 tonnes/ha) treatment as well as control (T_{10}) during second year. The lowest value of soil available nitrogen 95.47 and 106.71 kg/ha, was recorded under control (T_{10}) for both years.

During pooled data analysis, the maximum accessible nitrogen was recorded in treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) with a value of 147.50 kg/ha which was statistically at par with treatment T_1 having a value of 143.12 kg/ha, respectively. The available nitrogen for control i.e. treatment (T_{10}) was found to be 101.11 kg/ha, that was minimum among all treatment combination.

As a result of the mineralization of both native and applied nutrients via organics, the total and accessible nutrient status of the soil increased and the affiliation fixing atmospheric N into the rhizosphere during the cropping season by combining *Rhizobium* with *Azotobacter* and *Azospirillum* may be the cause of the increase of accessible N significantly after the addition of mineral + microbial enriched compost into soil. Our findings are in line with the outcomes of various other studies (Qureshi *et. al*., 2014; Rai *et. al.*, 2012 and Jamoh, 2021.

4.6.5 Available phosphorus (kg/ha)

A crucial macronutrient for plant overall advancement is phosphorus (P) the availability of phosphorus in soil, its vital function in plant physiology, and its interactions with other nutrients in soil and plants. There may be a limit to the amount of phosphorus that is available in the soil, and deficits may hinder plant growth and productivity. The microbial population can be significantly be impacted by the presence or absence of soil microorganisms, which are crucial to the phosphorus cycle. The volume of organic substances in the soil has a significant impact on the availability of phosphorus (Rassaei *et. al.,* 2023).

Data in Table 4.17 and Fig 4.39 show that the soil available phosphorus content after harvesting of the palak increased significantly over the years of the study. The available phosphorus in different treatment combinations ranged from 47.73 to 62.50 kg/ha, having mean value of 54.45 kg/ha, during first year (2022) and the values ranged from 49.12 to 68.96 kg/ha, having mean value of 57.80 kg/ha during second year. The pooled mean values for available phosphorus ranged from 48.43 to 65.73 kg/ha.

Value for maximum available phosphorus 62.50 and 68.96 kg/ha were recorded under treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) which was statistically at par with treatment T_6 (vermicompost 5 t ha^{-1}) and T_5 (microbial enriched compost 5 t ha^{-1}) treatments with the value of 60.27, 65.54 and 55.57, 59.00 kg/ha, respectively during both the years. The lowest value of available phosphorus 47.73 and 49.12kg/ha were recorded under control (T_{10}) over the years.

Also, in pooled data analysis, the available phosphorus was recorded maximum in treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) with a value of 65.73 kg/ha which was followed by T_6 with a value of 62.91 kg/ha. The available phosphorus for control i.e. treatment (T_{10}) was found to be 48.43 kg/ha, that was minimum among all other treatment combinations.

The higher available P in treatment may be due to the creation of different organic acids by microorganisms that solubilize phosphate and the expulsion of organic acids during the breakdown of organic materials and rock phosphate. This organic acid acts as a chelating agent and produces steady combinations with iron and aluminium, which are common in acid soil. The creation of more stable organic chelates with organic legends, which are less susceptible to precipitation, adsorption, and fixation in soil, increased nutrient availability, and other comparable outcomes, is supported by Meena *et al.,* (2019) and Jamoh, 2021.

4.6.6 Available potassium (kg/ha)

Potassium (K) is needed for plant growth and metabolic functions. Inadequate K application causes soil mining, resulting in crop insufficiency symptoms and reduced yield and quality. Recent research indicates that farmers in intensively planted areas employ optimal to suboptimal P, imbalanced nitrogen, and non-application of K (Ramzan *et. al.,* 2023).

Analyzing the data from Table 4.17 and Fig 4.40, it is clearly visible significant variations of available potassium content analysed after harvest from soil during both the years. The available potassium in different treatment combinations ranged from 221.67 to 224.67 kg/ha having a mean value of 223.27 kg/ha during the first year and the values ranged from 223.04 to 227.23 kg/ha having a mean value of 224.58 kg/ha during the second year. The pooled mean values for available potassium ranged from 222.35 to 225.95 kg/ha.

The value for maximum available potassium i.e. 224.67 and 223.27 kg/ha in soil was recorded under treatment T_7 (50% Mineral enriched compost + 50% Microbial enriched compost) during both the years in soil analysis that was done after harvest. The lowest value of available potassium i.e. 221.67 and 223.04 kg/ha in soil were recorded under control (T_{10}).

Also, in pooled data analysis, the maximum available potassium was recorded under treatment T_7 (50% Mineral enriched compost + 50% Microbial Enriched Compost) with a value of 225.95 kg/ha which was followed by T_1 (RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha) with a value of 225.18 kg/ha, respectively. The available potassium for control i.e. treatment (T_{10}) was found to be 222.35 kg/ha, that was minimum among all treatment combination.

The enhanced nutrient availability may also be related to the intrinsic capability of enriched compost, which accelerates the mineralization of organically bound macronutrients found in native soil. Additionally, it might have been caused by higher K retention from organic sources, which prevented leaching loss. Comparable results are published by Meena *et. al.,* (2022), Qureshi *et. al*., (2014) and Jamoh, 2021.

Table 4.16 Effect of various treatments on pH, Electrical conductivity (EC dSm^{-1}) and organic carbon content (%) in soil under palak crop experiment

Treatments	pH			EC (dSm^{-1})			Organic carbon content (%)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	8.43	8.46	8.46	0.58	0.63	0.61	0.47	0.48	0.48
T_2	8.41	8.40	8.42	0.55	0.61	0.58	0.42	0.42	0.42
T_3	8.20	8.23	8.22	0.57	0.60	0.58	0.53	0.53	0.53
T_4	7.90	7.93	7.92	0.36	0.39	0.38	0.57	0.59	0.58
T_5	7.87	7.82	7.85	0.42	0.40	0.41	0.60	0.61	0.61
T_6	7.67	7.72	7.70	0.38	0.58	0.48	0.47	0.50	0.48
T_7	7.63	7.68	7.66	0.37	0.38	0.37	0.61	0.72	0.66
T_8	8.00	8.00	8.00	0.40	0.41	0.41	0.51	0.53	0.52
T_9	7.97	7.89	7.93	0.39	0.58	0.48	0.55	0.57	0.56
T_{10}	8.47	8.51	8.46	0.49	0.52	0.51	0.44	0.46	0.45
Mean	**8.05**	**8.07**	**8.06**	**0.45**	**0.51**	**0.48**	**0.52**	**0.54**	**0.53**
CD($p \leq 0.05$)	**0.26**	**0.16**	**0.28**	**0.12**	**0.07**	**0.12**	**0.01**	**0.02**	**0.05**
CV %	**1.88**	**1.17**	**1.15**	**15.69**	**8.77**	**11.40**	**2.14**	**2.94**	**0.18**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (20 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}=Control

Table 4.17 Effect of various treatments on available N, P, and K in soil under palak crop experiment (kg/ha)

Treatments	Available Nitrogen (kg/ha)			Available Phosphorus (kg/ha)			Available Potassium (kg/ha)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	143.84	142.40	143.12	51.17	54.50	52.83	224.33	226.02	225.18
T_2	138.94	140.63	139.79	50.33	52.81	51.57	222.67	223.16	222.92
T_3	100.97	113.10	107.03	55.03	58.21	56.62	224.67	225.83	225.25
T_4	135.52	138.02	136.77	54.87	58.94	56.90	223.00	223.94	223.47
T_5	137.25	138.31	137.78	55.57	59.00	57.28	224.33	224.54	224.44
T_6	134.21	143.77	138.99	60.27	65.54	62.91	222.33	223.57	222.95
T_7	146.24	148.77	147.50	62.50	68.96	65.73	224.67	227.23	225.95
T_8	132.97	133.05	133.01	53.83	55.68	54.76	222.67	223.75	223.21
T_9	131.49	132.31	131.90	53.23	55.23	54.23	222.33	224.72	223.53
T_{10}	95.47	106.75	101.11	47.73	49.12	48.43	221.67	223.04	222.35
Mean	**129.69**	**133.71**	**131.70**	**54.45**	**57.80**	**56.13**	**223.27**	**224.58**	**223.92**
CD($p \leq 0.05$)	**3.61**	**4.46**	**5.25**	**2.23**	**2.60**	**3.13**	**4.06**	**2.26**	**4.25**
CV %	**1.62**	**1.94**	**1.79**	**2.38**	**2.63**	**2.52**	**1.06**	**0.58**	**0.85**

Note *T_1= RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)
*T_2= RDF 50% + FYM (10 tonnes/ha)
*T_3= FYM (20 tonnes/ha)
*T_4= Mineral (Rock Phosphate) enriched compost (5 tonnes/ha)
*T_5= Microbial (N-fixing, PSB, KSB, & Trichoderma, pseudomonas) Enriched Compost tonnes/ha)
*T_6= Vermicompost (5 tonnes/ha)
*T_7= 50% Mineral enriched compost + 50% Microbial Enriched Compost
*T_8= 75% Mineral enriched compost + 25% Microbial enriched compost
*T_9= 25% Mineral enriched compost + 75% Microbial enriched compost
*T_{10}=Control

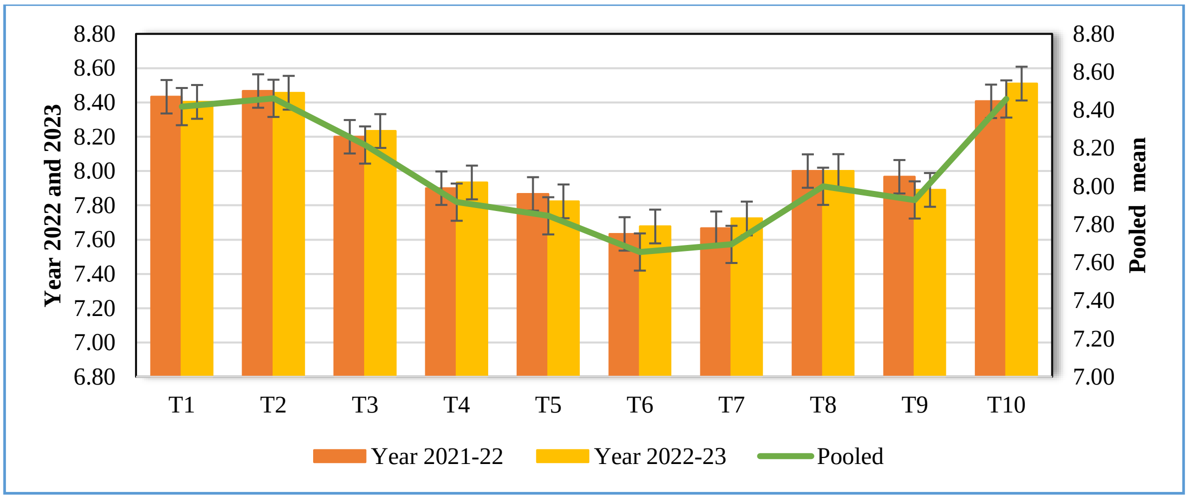


Fig. 4.35 Effect of various treatments on pH of soil under palak crop

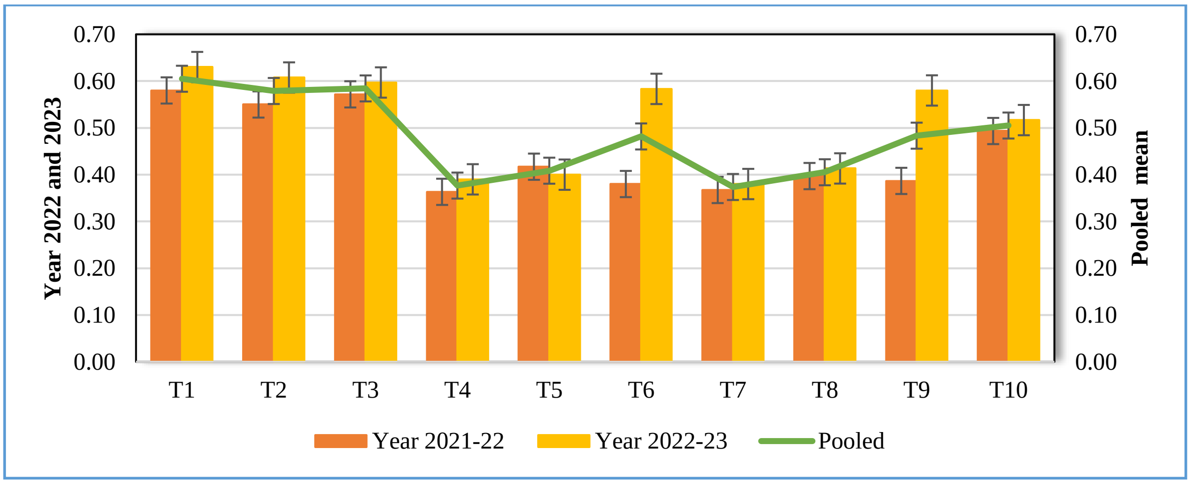


Fig. 4.36 Effect of various treatments on electrical conductivity of soil under palak crop (dSm^{-1}).

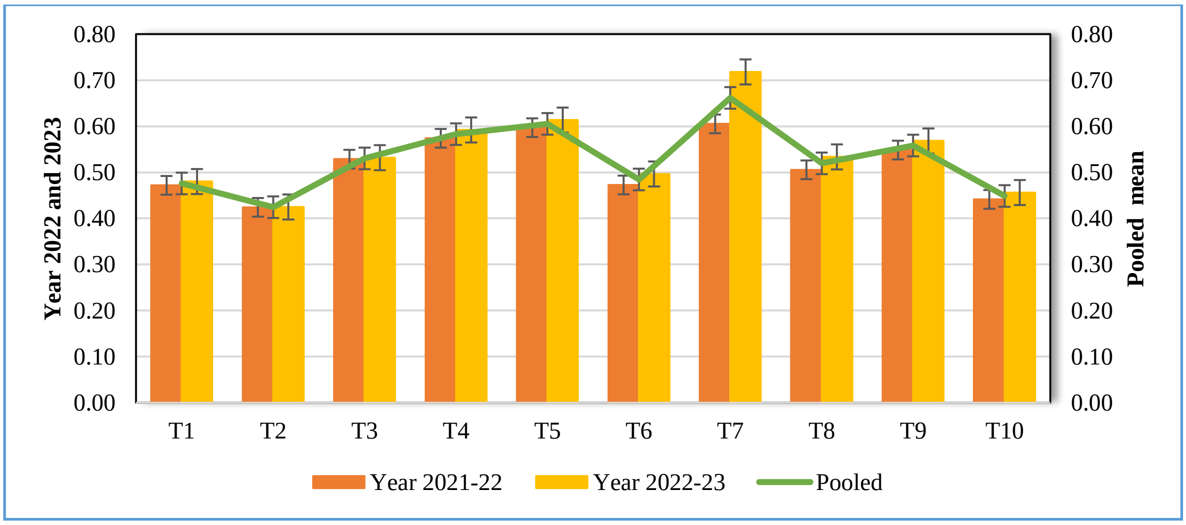


Fig. 4.37 Effect of various treatments on organic carbon content of soil under palak crop (%)

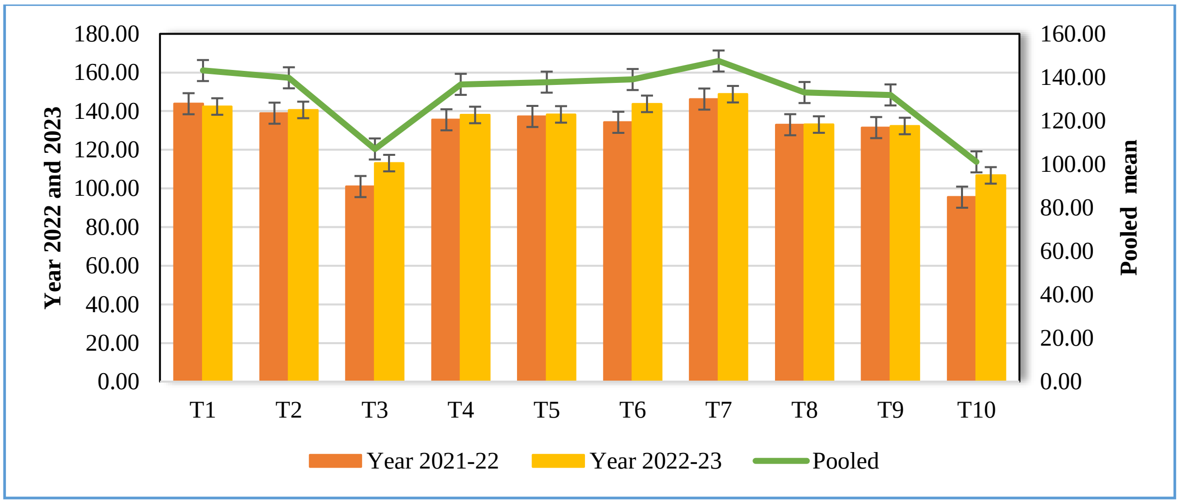


Fig. 4.38 Effect of various treatments on available nitrogen in soil under palak crop (kg/ha)

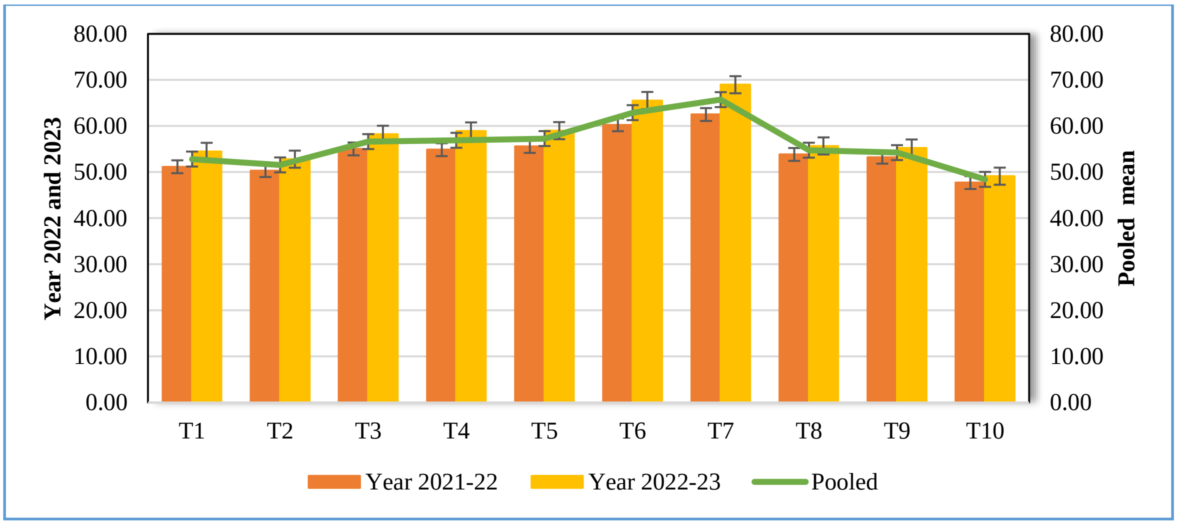


Fig. 4.39 Effect of various treatments on available phosphorus in soil under palak crop (kg/ha)

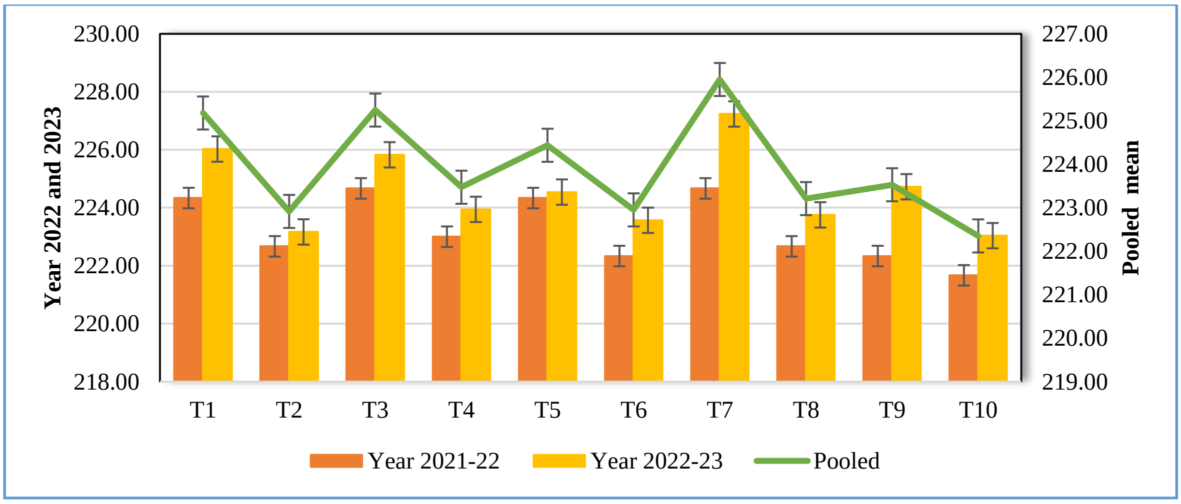


Fig. 4.40 Effect of various treatments on available potassium in soil under palak crop (kg/ha)

CHAPTER-5 SUMMARY AND CONCLUSION

The present study titled "**Study on the preparation and influence of enriched compost on the growth, yield and quality of palak (*Beta vulgaris* L.)"** was performed at Vegetable Farm, Department of Horticulture, Lovely Professional University, Phagwara, Punjab, during the two consecutive cropping seasons of 2022 and 2023. Considering this, first the preparation of different enriched composts was done to extend the nutritional status of enriched compost and then its effect on growth, yield, and quality along with shelf life of palak was studied.

- The study was conducted using randomized block design, replicated three times containing following ten treatment combinations: T_1- fertilizers recommended dosage (RDF) + Farm yard manure (FYM) (85:30:0 N: P: K kg/ha+ 20 tonnes/ha); T_2- fertilizers recommended dosage (RDF) + Farm yard manure (FYM) (50% + 10 tonnes/ha); T_3- Farm yard manure (FYM) (20 tonnes/ha); T_4- mineral enriched compost (rock phosphate) (MEC_1) (5 tonnes/ha); T_5- microbial enriched compost (MEC_2) (5 tonnes/ha); T_6- vermicompost(VC) (5 tonnes/ha); T_7- MEC_1 @ 2.5 tonnes/ha + MEC_2 @ 2.5 tonnes/ha (50%+50%); T_8- MEC_1 @ 3.75 tonnes/ha + MEC_2 @ 1.25 tonnes/ha (75%+25%); T_9- MEC_1 @ 1.25 tonnes/ha + MEC_2 @ 3.75 tonnes/ha (25%+75%); T_{10}- absolute control (no application) for two consecutive years. The palak seeds were sown directly in the main field on 24th February, 2022 and 25th February, 2023 as a off season spring crop with a spacing of 25 cm × 10 cm. The chemical fertilizers (NPK) were given according to the standard protocol, which contained urea (46% nitrogen) and single super phosphate (16% phosphorus). As a baseline dosage, the full doses of P, as well as half the amount of N, were administered prior to seed sowing. After 30 days of sowing, the left over half dose of N was used as a top dressing. During the soil preparation step, all enriched compost and manures were physically added to the different plots based on their treatment allocation in the field. The observations on plant height, number of leaves, length of petiole, diameter of petiole, leaf area, average yield per plant, average yield (plant^{-1}, plot^{-1} and hectare^{-1}), quality parameters of palak including moisture content, dry matter, ascorbic acid content, total carotenoid content, phenols, crude fiber content, chlorophyll index, minerals and leaf nitrate content were recorded. Upon the conclusion of the experiment the soil samples were obtained from each treatment plot, and its pH, electrical conductivity (dSm^{-1}), organic carbon (%), and accessible N, P, and K(kg/ha) were analyzed. Additionally, the economics of the various treatments were calculated.

THE EXPERIMENTAL FINDINGS HAVE BEEN SUMMARIZED BELOW

CHARACTERIZATION OF ENRICHED COMPOST

- The pH of enriched composts for first- and second-year ranges between 7.40 – 7.90 and 7.39 to 7.89, respectively that was slightly neutral in the nature which is most suitable for plant growth.
- The electrical conductivity of enriched composts i.e. E_1 (mineral compost), E_2 (microbial compost) and E_3 (mineral + microbial compost) for first and second year were 3.4, 3.1, 2.1 dSm^{-1} and 3.41, 3.05, 2.12 dSm^{-1}, respectively.
- The available nitrogen (N) in enriched composts i.e. E_1 (mineral compost), E_2 (microbial compost) and E_3 (mineral + microbial compost) for first and second year was found to be 1.25, 1.12, 1.73 per cent and 1.26,1.13, 1.74 per cent, accordingly.
- The phosphorus (P) content in enriched composts i.e. E_1 (mineral compost), E_2 (microbial compost) and E_3 (mineral + microbial compost) for first and second year were recorded as 1.35, 0.50, 1.75 per cent and 1.34, 0.55, 2.18, respectively.
- The potassium (K) content in enriched composts i.e. E_1 (mineral compost), E_2 (microbial compost) and E_3 (mineral + microbial compost) for first and second year were recorded as 0.86, 0.76, 1.14 per cent and 0.85, 0.77, 1.16, accordingly.
- The secondary and micronutrient concentration was also higher in enriched compost.

EFFECT OF DIFFERENT ENRICHED COMPOST ON GROWTH YIELD AND QUALITY ATTRIBUTES

- Growth attributes showed a substantial influence from various treatments. The plant height (22.63, 32.58 and 28.39 cm) number of leaves (9.06, 13.01 and 8.65), length of petiole (15.95, 22.36 and 15.98 cm), average leaf area per plant

(51.76, 63.27 and 108.53 cm^2), diameter of middle of the petiole (0.66, 0.86 and 0.89 cm) was recorded highest at 25, 40 and 55 DAS in treatment T_1 [RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)]. However, organic treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) showed similar results for all above parameters.

- Regarding yield attributes, treatment T_1 [RDF 100% (85:30:0 N: P: K kg/ha) + FYM (20 tonnes/ha)] exhibited the maximum yield per plant (30.38 gm), yield per plot (12.99 kg) and yield q ha^{-1} (108.70 q). However, among organic treatments only treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) was at par to T_1.
- Whereas all the growth and yield attributes were significantly least in T_{10} (control).
- Quality attributes such as ascorbic acid (88.54 mg/100g), phenols (22.52 mg/100g), antioxidant activity (4.46 per cent) minerals i.e. Fe, Cu, Zn (16.67, 4.60 and 8.56 mg/100g) were recorded highest in treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost).
- In case of different packaging material to enhance shelf life, it was observed that treatment T_5 (PP 40 micron with 1 per cent vent.) was best packaging material with respect of physiological loss in weight (PLW), shelf life (days), colour change (days) and rotting (days) during the storage period of the 6^{th} day.
- Physiological loss in weight (PLW), shelf life (days), colour change (days) showed significantly least values for treatment T_7 (No packing).

SOIL ANALYSIS

- The soil chemical analysis, treatment T_7 (50% mineral enriched compost + 50% microbial enriched compost) exhibited the best value for soil pH (7.66) among the all treatments.
- EC of the soil ranged from 0.37 (T_7) to 0.61 dS/m (T_1) for various treatment combinations which was also within suitable range for the production of vegetable crops.
- After the harvest of palak crop, the mean soil analysis revealed maximum availability of N: P: K (147.50:65.73:225.95 kg/ha) under treatment T_7 (50%

mineral enriched compost + 50% microbial enriched compost), respectively over the recommended practice (143:52:225.18 kg/ha).

CONCLUSION

The investigation of present study on the preparation and influence of enriched compost on the growth, yield and quality of palak (*Beta vulgaris* L.) showed substantial variations for growth, yield and yield attributing traits also for the quality and soil fertility status after harvesting the palak crop. Among all the treatment combinations, T_7 which comprised of 50% mineral enriched compost @ 2.5 tonnes/ha + 50% microbial enriched compost @ 2.5 tonnes/ha was considered the most effective for growth, leaf yield, post-harvest quality of leaves in addition to the fertility state of the soil after harvest as compared to RDF and the other treatments.

Over the two years, the annual net return of study was found to be substantially highest (₹ 1,64,648 and ₹ 1,59,806 ha^{-1}) having B: C ratio of 2.72 and 2.73, respectively in the treatment combination T_7 comprising 50% mineral enriched compost + 50% microbial enriched compost.

Therefore, it can be concluded that treatment combination T_7 (50% mineral enriched compost @ 2.5 tonnes/ha + 50% microbial enriched @ 2.5 tonnes/ha) led to a saving of 100 % fertilizers (NPK), increased yield, improved growth, and net returns and improved soil nutrient status. The experimental findings have proved the utility of enriched compost as an important source of nutrients in cultivation of leafy vegetables. Also, the quantity for using this enriched compost will be very less as compared to ordinary farm yard manure and its easy handlings. The treatment combination T_7 (50% mineral enriched compost @ 2.5 tonnes/ha + 50% microbial enriched compost @ 2.5 tonnes/ha application can be recommended as a cost-effective combination for reaping maximum yields coupled with best quality leafy vegetable crop based on sustainable.

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Appendix-Ia

METEROLOGICAL DATA DURING THE PERIOD OF EXPERIMENT (2022)

DATE	Max Temp (^{0}C)	Min Temp (^{0}C)	RH (%)	RH (%)	Windspeed (km/hr)	Rain (mm)
2/23/2022	22	11	68	51	4	0
2/24/2022	20	11	67	50	Calm Condition	0
2/25/2022	20	12	66	52	2	0
2/26/2022	15	8	60	48	6	16
2/27/2022	18	10	62	48	2	0
2/28/2022	16	9	64	48	4	0
3/1/2022	18	10	60	48	2	0
3/2/2022	16	9	62	50	0	0
3/3/2022	17	10	60	49	4	0
3/4/2022	20	9	58	48	4	0
3/5/2022	21	10	56	46	0	0
3/6/2022	22	10	52	44	0	0
3/7/2022	20	11	54	45	4	0
3/8/2022	22	13	56	44	0	0
3/9/2022	24	18	54	42	0	0
3/10/2022	20	18	55	44	0	0
3/11/2022	20	20	56	42	4	0
3/12/2022	18	18	54	42	2	0
3/13/2022	22	20	54	44	0	0
3/14/2022	26	20	58	48	4	0
3/15/2022	28	20	50	40	4	0
3/16/2022	32	19	58	42	0	0

3/17/2022	30	22	56	40	2	0
3/18/2022	32	20	56	42	4	0
3/19/2022	32	20	54	40	0	0
3/20/2022	30	19	55	42	8	0
3/21/2022	32	23	52	40	0	0
3/22/2022	33	23	54	42	0	0
3/23/2022	34	22	52	44	0	0
3/24/2022	32	23	50	44	4	0
3/25/2022	30	21	50	42	4	0
3/26/2022	31	20	52	40	12	0
3/27/2022	32	21	50	38	0	0
3/28/2022	30	20	48	45	4	0
3/29/2022	31	19	52	48	2	0
3/30/2022	32	20	54	42	6	0
3/31/2022	32	25	50	44	4	0
4/1/2022	32	22	52	40	0	0
4/2/2022	33	23	53	42	6	0
4/3/2022	34	22	52	43	4	0
4/4/2022	30	24	48	44	12	0
4/5/2022	34	24	47	40	2	0
4/6/2022	32	24	45	38	0	0
4/7/2022	34	26	44	36	0	0
4/8/2022	35	26	42	34	0	0
4/9/2022	40	27	45	32	4	0
4/10/2022	40	27	42	30	16	0
4/11/2022	42	26	44	32	0	0
4/12/2022	44	28	48	37	4	0
4/13/2022	42	29	45	36	0	0
4/14/2022	40	26	44	34	2	0.5
4/15/2022	41	27	44	32	2	0

Appendix-Ib

METEROLOGICAL DATA DURING THE PERIOD OF EXPERIMENT (2023)

DATE	Max Temp (^{0}C)	Min Temp (^{0}C)	RH (%)	RH (%)	Windspeed (km/hr)	Rain (mm)
2/23/2023	27.7	13.7	90	58	11	0
2/24/2023	27.7	13.7	91	61	8	0
2/25/2023	27.6	14	87	62	8	0
2/26/2023	28.7	14.4	86	59	10	0
2/27/2023	29	13	81	52	8	0
2/28/2023	25	15	76	50	10	0
3/1/2023	28	14	50	48	9	0.02
3/2/2023	29	15	65	43	4	0
3/3/2023	24	13	58	47	14	0
3/4/2023	28.4	13.5	48	36	9	0
3/5/2023	28.3	13	38	31	10	0
3/6/2023	28.9	11.6	30	32	10	0
3/7/2023	31.3	12.8	29	31	10	0
3/8/2023	28.7	14	50	40	8	0
3/9/2023	30	15.1	50	42	9	0
3/10/2023	29.4	16	48	46	5	0
3/11/2023	29.3	15.6	80	39	9	0
3/12/2023	28.4	15.7	79	39	8	0
3/13/2023	30	17.1	75	37	10	0
3/14/2023	30.6	19.5	73	34	12	0
3/15/2023	31	15.2	72	35	11	0
3/16/2023	32.4	17.3	48	35	12	0

3/17/2023	22.8	17.1	80.8	59	2.2	0
3/18/2023	19.6	15.2	93	77	19	15
3/19/2023	25.7	14.1	92	59	1.9	0
3/20/2023	21.8	15.3	93	67	1.7	1.4
3/21/2023	25	11.9	93	51	0.8	0
3/22/2023	26.7	13.8	93	59	0.7	0
3/23/2023	27	12.6	94	56	1.7	0
3/24/2023	22.7	14.1	94	65	3.1	12
3/25/2023	23.8	15.6	94	61	2.5	25
3/26/2023	26.2	12.6	93	58	12	0
3/27/2023	28	15	90	40	8	0
3/28/2023	27	16	92	52	10	0
3/29/2023	33	17	88	39	4	0
3/30/2023	32	18	90	40	8	0
3/31/2023	22	18	93	68	16	2.2
4/1/2023	25.2	13.4	75	57	13	0.02
4/2/2023	25.7	13.3	60	51	9	0
4/3/2023	20.49	16.4	83	66	2.1	2.2
4/4/2023	27.2	16.39	64	44	2.1	0.2
4/5/2023	29.6	12.88	62	27	1.5	0
4/6/2023	28.7	15.38	62	33	1.9	0
4/7/2023	30.7	13	61	23	2	0
4/8/2023	31.9	11.84	64	20	1.9	0
4/9/2023	32.19	12.76	65	18	1.8	0
4/10/2023	33.56	12.8	60	22	1.9	0
4/11/2023	34.41	15.5	66	22	2.4	0
4/12/2023	34.4	20.6	85	31	12	0
4/13/2023	36.62	17.03	85	26	2.4	0
4/14/2023	37.79	16.91	85	30	1.7	0
4/15/2023	39.31	17.3	84	19	1.4	0

Appendix-II

Analysis of variance (ANOVA) for growth and yield traits in palak as affected by different treatments during 2022

Source of variation	DF	Mean sum of square (MSS)			
		Plant height at 25 DAS (cm)	Plant height at 40 DAS (cm)	Plant height at 55 DAS (cm)	Number of leaves at 25 DAS
Replication	2	0.019	0.601	0.345	0.017
Treatment	9	11.405	48.317	55.739	8.504
Error	18	0.095	0.619	0.354	0.027

Source of variation	DF	Mean sum of square (MSS)			
		Number of leaves at 40 DAS	Number of leaves at 55 DAS	Length of petiole at 25 DAS (cm)	Length of petiole at 40 DAS (cm)
Replication	2	0.135	0.033	0.019	0.278
Treatment	9	13.25	2.737	11.405	21.506
Error	18	0.086	0.045	0.095	0.253

Source of variation	DF	Mean sum of square (MSS)			
		Length of petiole at 55 DAS (cm)	Leaf area per plant at 25 DAS (cm^2)	Leaf area per plant at 40 DAS (cm^2)	Leaf area per plant at 55 DAS (cm^2)
Replication	2	0.02	0.276	0.213	3.761
Treatment	9	11.252	129.682	270.638	630.234
Error	18	0.123	1.635	1.763	4.799

Source of variation	DF	Mean sum of square (MSS)			
		Diameter of petiole at 25 DAS (cm)	Diameter of petiole at 40 DAS (cm)	Diameter of petiole at 55 DAS (cm)	Average leaf yield (gm)
Replication	2	0.001	0.001	0.001	0.138
Treatment	9	0.071	0.101	0.068	71.337
Error	18	0.001	0.001	0.001	0.364

Source of variation	DF	Mean sum of square (MSS)	
		Average leaf yield (kg)	Leaf yield q/ha
Replication	2	0.055	2.949
Treatment	9	13.14	866.14
Error	18	0.06	2.813

Appendix-III

Analysis of variance (ANOVA) for quality traits in palak as affected by different treatments during 2022

Source of variation	DF	Mean sum of square (MSS)			
		Moisture content (%)	Dry matter content (%)	Ascorbic acid content (mg/100g)	Total carotenoid content (mg/100g)
Replication	2	20.338	0.011	1.85	0.459
Treatment	9	56.178	21.916	329.397	72.2
Error	18	2.918	0.154	0.942	0.164

Source of variation	DF	Mean sum of square (MSS)			
		Phenol content (mg/100g)	Antioxidant activity%	Fe mineral content (mg/100g)	Cu mineral content (mg/100g)
Replication	2	0.673	14.017	0.197	0.035
Treatment	9	17.578	10.445	417.204	26.544
Error	18	0.606	7.467	2.55	0.429

Source of variation	DF	Mean sum of square (MSS)			
		Zn mineral content (mg/100g)	Chlorophyll index	Crude fibre content (%)	Leaf nitrate content (mg kg^{-1})
Replication	2	0.195	2.99	6.469	28,923.70
Treatment	9	39.069	300.403	2.414	52,362.65
Error	18	0.765	0.751	0.635	2,339.18

Appendix-IV

Analysis of variance (ANOVA) for growth and yield traits in palak as affected by different treatments during 2023

Source of variation	DF	Mean sum of square (MSS)			
		Plant height at 25 DAS (cm)	Plant height at 40 DAS (cm)	Plant height at 55 DAS (cm)	Number of leaves at 25 DAS
Replication	2	0.224	0.1	0.1	0.005
Treatment	9	41.888	55.156	55.156	8.028
Error	18	0.202	0.362	0.362	0.028

Source of variation	DF	Mean sum of square (MSS)			
		Number of leaves at 40 DAS	Number of leaves at 55 DAS (cm)	Length of petiole at 25 DAS (cm)	Length of petiole at 40 DAS (cm)
Replication	2	0.052	0.135	0.376	0.454
Treatment	9	17.224	2.03	11.586	34.123
Error	18	0.017	0.041	0.083	0.181

Source of variation	DF	Mean sum of square (MSS)			
		Length of petiole at 55 DAS	Leaf area per plant at 25 DAS (cm^2)	Leaf area per plant at 40 DAS (cm^2)	Leaf area per plant at 55 DAS (cm^2)
Replication	2	0.067	4.499	0.075	14.14
Treatment	9	6.318	141.848	261.596	1092.749
Error	18	0.121	1.884	2.242	5.711

Source of variation	DF	Mean sum of square (MSS)			
		Diameter of petiole at 25 DAS (cm)	Diameter of petiole at 40 DAS (cm)	Diameter of petiole at 55 DAS (cm)	Average leaf yield (gm)
Replication	2	0.005	0.001	0.001	0.823
Treatment	9	0.061	0.052	0.035	86.706
Error	18	0.001	0.001	0.001	0.266

Source of variation	DF	Mean sum of square (MSS)	
		Average leaf yield (kg)	Leaf yield q/ha
Replication	2	0.042	2.898
Treatment	9	16.316	1133.462
Error	18	0.081	4.27

Appendix-V

Analysis of variance (ANOVA) for quality traits in palak as affected by different treatments during 2023

Source of variation	DF	Mean sum of square (MSS)			
		Moisture content (%)	Dry matter content %	Ascorbic acid content (mg/100g)	Total carotenoid content (mg/100g)
Replication	2	0.356	0.034	0.462	0.136
Treatment	9	60.055	21.948	292.973	97.403
Error	18	3.139	0.175	0.242	0.321

Source of variation	DF	Mean sum of square (MSS)			
		Phenol content (mg/100g)	Antioxidant activity%	Fe mineral content (mg/100g)	Cu mineral content (mg/100g)
Replication	2	0.329	10.395	0.141	0.024
Treatment	9	17.859	11.692	424.948	20.986
Error	18	0.193	5.047	1.706	0.1

Source of variation	DF	Mean sum of square (MSS)			
		Zn mineral content (mg/100g)	Chlorophyll index	Crude fibre content (%)	Leaf nitrate content (mg $kg^{-1)}$
Replication	2	0.034	4.806	2.368	11,568.08
Treatment	9	23.874	294.564	5.502	44,070.11
Error	18	0.661	2.162	0.356	640.456

Appendix-VI

Analysis of variance (ANOVA) for growth & yield traits in palak as affected by various treatments pooled

Source of variation	DF	Mean sum of square (MSS)			
		Plant height at 25 DAS (cm)	Plant height at 40 DAS (cm)	Plant height at 55 DAS (cm)	Number of leaves at 25 DAS
Replication	4	438.107	0.041	2.53	8.303
Treatment (T)	9	0.121	0.351	0.20	0.011
Year (Y)	9	46.228	95.276	118.14	15.647
Interaction (T × Y)	36	7.066	8.198	3.60	0.885
Error	59	0.149	0.491	0.27	0.027

Source of variation	DF	Mean sum of square (MSS)			
		Number of leaves at 40 DAS	Number of leaves at 55 DAS	Length of petiole at 25 DAS (cm)	Length of petiole at 40 DAS (cm)
Replication	4	1.065	0.112	0.472	1.531
Treatment (T)	9	0.093	0.084	0.197	0.366
Year (Y)	9	29.782	4.565	22.308	52.523
Interaction (T × Y)	36	0.692	0.203	0.684	3.107
Error	59	0.051	0.043	0.089	0.217

Source of variation	DF	Mean sum of square (MSS)			
		Length of petiole at 55 DAS (cm)	Leaf area per plant at 25 DAS (cm^2)	Leaf area per plant at 40 DAS (cm^2)	Leaf area per plant at 55 DAS (cm^2)
Replication	4	0.535	0.319	0.402	373.551
Treatment (T)	9	0.043	2.387	0.144	8.951
Year (Y)	9	16.538	268.821	524.741	1651.026
Interaction (T × Y)	36	1.032	2.708	7.493	71.957
Error	59	0.122	1.76	2.002	5.255

Source of variation	DF	Mean sum of square (MSS)			
		Diameter of petiole at 25 DAS (cm)	Diameter of petiole at 40 DAS (cm)	Diameter of petiole at 55 DAS (cm)	Average leaf yield (gm)
Replication	4	0.012	0.007	0.028	0.034
Treatment (T)	9	0.001	0.001	0.001	0.48
Year (Y)	9	0.128	0.144	0.097	152.458
Interaction (T × Y)	36	0.004	0.009	0.006	5.584
Error	59	0.001	0.007	0.028	0.315

Source of variation	DF	Mean sum of square (MSS)	
		Average leaf yield (kg)	Leaf yield q/ha
Replication	4	0.001	1.273
Treatment (T)	9	0.049	2.924
Year (Y)	9	28.442	1934.881
Interaction (T × Y)	36	1.014	64.721
Error	59	0.07	3.541

Appendix-VII

Analysis of variance (ANOVA) for quality traits in palak as affected by different treatments pooled

Source of variation	DF	Mean sum of square (MSS)			
		Moisture content (%)	Dry matter content (%)	Ascorbic acid content (mg/100g)	Total carotenoid content (mg/100g)
Replication	4	2.126	5.946	1.156	0.298
Treatment (T)	9	10.347	0.023	617.925	167.722
Year (Y)	9	114.444	43.115	4.445	1.88
Interaction (T × Y)	36	1.789	0.749	0.592	0.243
Error	59	3.028	0.164	1.156	0.298

Source of variation	DF	Mean sum of square (MSS)			
		Phenol content (mg/100g)	Antioxidant activity%	Fe mineral content (mg/100g)	Cu mineral content (mg/100g)
Replication	4	0.501	6.103	0.085	0.015
Treatment (T)	9	35.333	2.426	93.125	5.196
Year (Y)	9	0.104	0.034	0.448	0.085
Interaction (T × Y)	36	0.4	0.348	0.118	0.015
Error	59	0.501	6.103	0.085	0.015

Source of variation	DF	Mean sum of square (MSS)			
		Zn mineral content (mg/100g)	Chlorophyll index	Crude fibre content (%)	Leaf nitrate content (mg $kg^{-1)}$
Replication	4	0.057	19.437	4.418	4.418
Treatment (T)	9	6.84	3.898	7.485	7.485
Year (Y)	9	0.153	594.48	0.432	0.432
Interaction (T × Y)	36	0.04	0.487	0.495	0.495
Error	59	0.057	1.456	4.418	4.418

Appendix-VIII

Analysis of variance (ANOVA) for soil Physicochemical properties as affected by different treatments during 2022

Source of variation	DF	Mean sum of square (MSS)		
		pH	EC (dSm^{-1})	Organic carbon (%)
Replication	2	0.008	0.024	0.0002
Treatment	9	0.285	0.023	0.0020
Error	18	0.023	0.005	0.0001

Source of variation	DF	Mean sum of square (MSS)		
		Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Replication	2	17.31	7.949	6.533
Treatment	9	893.857	14.864	3.763
Error	18	4.44	3.339	5.607

Appendix-IX

Analysis of variance (ANOVA) for soil physicochemical properties as affected by different treatments during 2023

Source of variation	DF	Mean sum of square (MSS)		
		pH	EC (dSm^{-1})	Organic carbon (%)
Replication	2	0.001	0.001	0.0004
Treatment	9	0.291	0.031	0.0038
Error	18	0.009	0.002	0.0003

Source of variation	DF	Mean sum of square (MSS)		
		Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Replication	2	0.044	4.029	1.738
Treatment	9	548.457	18.305	5.722
Error	18	6.79	1.982	1.749

Appendix-X

Analysis of variance (ANOVA) for soil physicochemical properties as affected by different treatments pooled

Source of variation	DF	Mean sum of square (MSS)		
		pH	EC (dSm^{-1})	Organic carbon (%)
Replication	4	0.004	0.012	0.0001
Treatment (T)	9	0.572	0.046	0.006
Year (Y)	9	0.004	0.009	0.00001
Interaction (T × Y)	36	0.016	0.003	0.000001
Error	59	0.004	0.012	0.0001

Source of variation	DF	Mean sum of square (MSS)		
		Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Replication	4	8.677	5.989	4.136
Treatment (T)	9	1,405.08	32.935	8.63
Year (Y)	9	37.234	0.234	0.855
Interaction (T × Y)	36	5.615	2.66	3.678
Error	59	8.677	5.989	4.136

Appendix-XI

Operating cost of Palak 2022													
Sr. No.	Item	Unit (Tractor hrs., labour)	Rate (₹/unit)	Treatment									
				T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
A.	**Labour**												
1.	Harrowing	3hrs.	500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
2.	Rotavator	3 hrs.	1500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
3.	Layout preparation	10	428	4280	4280	4280	4280	4280	4280	4280	4280	4280	4280
4.	Seed sowing	4	500	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
5.	Irrigation	8	428	3424	3424	3424	3424	3424	3424	3424	3424	3424	3424
6.	Weeding	20	428	8560	8560	8560	8560	8560	8560	8560	8560	8560	8560
7.	Harvesting	15	428	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420
	Total			**30684**	**30684**	**30684**	**30684**	**30684**	**30684**	**30684**	**30684**	**30684**	**30684**
B	**Input**												
1.	Cost of Seed	25	300	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
2.	Fertilizer			3200	1600	0	0	0	0	0	0	0	0
3.	Compost/FYM			10000	10000	10000	9000	5500	90000	7250	8125	6375	0
4.	Plant Protection	4 Spray	500	2000	2000	2000	0	0	0	0	0	0	0
	Total			22700	21100	19500	16500	13000	97500	14750	15625	13875	7500
C	**Fixed cost**	Rental value of land for 6 months	15,000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
	Grand total			**68384**	**66784**	**65184**	**62184**	**58684**	**143184**	**60434**	**61309**	**59559**	**53184**

Appendix-XII

Operating cost of Palak 2023													
Sr. No.	**Item**	**Unit (Tractor hrs., labour)**	**Rate (₹/unit)**	**Treatment**									
				T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**	**T_{10}**
A.	**Labour**												
1.	Harrowing	3hrs.	500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
2.	Rotavator	3 hrs.	1500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
3.	Layout preparation	10	428	4280	4280	4280	4280	4280	4280	4280	4280	4280	4280
4.	Seed sowing	4	500	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
5.	Irrigation	8	428	3424	3424	3424	3424	3424	3424	3424	3424	3424	3424
6.	Weeding	20	428	8560	8560	8560	8560	8560	8560	8560	8560	8560	8560
7.	Harvesting	15	428	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420
	Total			**30684**	**30684**	**30684**	**30684**	**30684**	**30684**	**30684**	**30684**	**30684**	**30684**
B	**Input**												
1.	Cost of Seed	25	300	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
2.	Fertilizer			3200	1600	0	0	0	0	0	0	0	0
3.	Compost/FYM			10000	10000	10000	7000	3500	90000	5250	6125	4375	0
4.	Plant Protection	4 Spray	500	2000	2000	2000	0	0	0	0	0	0	0
	Total			22700	21100	19500	14500	11000	97500	12750	13875	11875	7500
C	**Fixed cost**	Rental value of land for 6 months	15,000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
	Grand total			**68384**	**66784**	**65184**	**60184**	**56684**	**143184**	**58434**	**59559**	**57559**	**53184**