EFFECT OF PREHARVEST APPLICATION OF MICRONUTRIENTS (ZINC & BORON) ON PERFORMANCE OF CARROT (*Daucus carota* L.) AND ITS SHELF LIFE UNDER DIFFERENT STORAGE CONDITIONS IN COLD DESERT TRANS-HIMALAYAN LADAKH REGION

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Horticulture (Vegetable Science)

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2025

DECLARATION

I, hereby declared that the presented work in the thesis entitled **"Effect of Preharvest Application of Micronutrients (Zinc & Boron) on Performance of Carrot (*Daucus carota* l.) and Its Shelf Life Under Different Storage Conditions in Cold Desert trans-Himalayan Ladakh Region"** in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of **Dr. Khushboo Kathayat, Assistant Professor, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India** and **Dr. Narendra Singh, Scientist 'G', Division of Vegetable Science, Defence Institute of High Altitude Research (DIHAR)-Defence Research and Development Organization (DRDO), Leh-Ladakh, 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 another 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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SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled **"Effect of Preharvest Application of Micronutrients (Zinc & Boron) on Performance of Carrot (*Daucus carota* l.) and Its Shelf Life Under Different Storage Conditions in Cold Desert trans-Himalayan Ladakh Region"** submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Horticulture (Vegetable Science), School of Agriculture is a research work carried out by **Vivek Kumar Tiwari**, **Registration No. 11900930,** is bonafide record of his 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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AKNOWLEDGEMENT

Finally, the day has come to look around and think about the people who have encouraged and inspired me during this long academic journey. This is the most difficult part of my thesis to write since it is so personal and because words never seem enough to express how grateful I am for everyone's help and encouragement. First of all, I am thankful to almighty GOD for all the blessings. He has bestowed upon me and it's under his grace that we live, learn & flourish. It's the blessings of my well-wishers down the earth which helped me to fulfill the present task.

The first person who comes to my mind is my revered teacher and supervisor, Dr. Narendra Singh, Scientist 'G', DIHAR-DRDO who gave me the strength to dream big and then live it. Without his guidance, supervision, and inspiration this thesis would have been a distant reality. His dedication to research and great scientific temperament served as a source of motivation and benefited my growth as a student and a researcher. I still remember the extreme patience he used to keep in making me understand the tactics of planning and execution of experiments. He used to go the additional mile to ensure that my study was never impeded, despite the fact that there were a number of obstacles that would appear from time to time. It's difficult for me to put my experiences into words. I am thankful to you sir for all the suggestions, encouragement and constant inspiration you gave me, and the confidence you had in me that helped a lot during my entire research period as well as at the time of thesis writing.

I am immensely thankful to my mentor and supervisor Dr. Khushboo Kathayat, Assistant Professor, LPU who was a source of inspiration for me. Her valuable suggestions and personal guidance during my experiments are memories of a life time. I am grateful to her for the immense moral support and affection bestowed by her without which this landmark could never be accomplished. Her constant perusal of my research work and personal advices at difficult times kept my spirits high. Also, I am grateful to her for squeezing time to edit my thesis in due time.

I take this opportunity to express my sincere thanks to Dr. O.P. Chaurasia (Director, DIHAR-DRDO) and The Head, Department of Horticulture, School of Agriculture, LPU, Punjab, for facilitating me with the necessary infrastructure and resource to accomplish my research work during my tenure of Ph.D.

I am expressing my heartfelt gratitude for the entire faculty and staff of the Lovely Professional University, Phagwara, Panjab, who was very helpful and provided me with all the necessary assistance in completing my Ph.D. I extend my thanks and gratitude to the Dr. Shailesh Kumar Singh for their continuous support and valuable suggestions and also for their insights in my thesis work. I also wish to thank to the office staff and Administrative Block staff for their invaluable help.

I am gratefully acknowledging DRDO, HQ, New Delhi for financial assistance in the form of Junior Research Fellowship (JRF) and Senior Research Fellowship (SRF), without that I could not have been pursued this fine work of research.

I would like to thank all scientists of DIHAR family, Dr. Shweta Saksena, Dr. Tsering Stobdan, Dr. Vijay K. Bharti, Dr. Somen Acharya, Dr. Anand Kumar Katiar, Mr. Raj Kumar, Mr. Prabhu Prasad Sarangi, and Dr. Swati for their kind help during my stay at DIHAR and time-to-time discussion on my work.

Our lab was like a second home to me. Thanks to all my lab members for providing a healthy and scientific working atmosphere. Special thanks to my senior Dr. Vivek Chandra Verma, Dr. Kaushal Kumar, Anjali, Seema Bhati, Thupstan Tsewang, Avantika and Diksha from whom I learned all of my research skills. Their support and guidance and care as a senior have supported me to perform in difficult times. I want to convey my special thanks to Shardulya Shukla and Sunil with whom I shared my best and worst moments of my Ph.D journey; they made an unforgettable experience for me. Heartfelt thanks go to all my seniors and juniors from the DIHAR, Dr. Pushpendra, Dr. Nitish, Dr. Bhupendra, Dr. Kalai, Dr. Arup, Vikas, Preeti, Neha, Yogesh Singh, Abul Qasim and Amita for their all help and which is still going on.

I do not want to lose the opportunity to thank Mr. Samar Bahadur Maurya (TO-B), Mr. Tsewang Norbu (TO-B), Mr. Alok Mishra (STA-B), Ms. Anshu Verma (STA-B), and Mr. Shushil Semwal and for their unconditional support at the time of sampling and analysis works.

The administrative staff of DIHAR has been very helpful for various needs. Mrs. Stanzin Dolma, Mrs. Urgain Chorol, Mr. Tsewang Phunstog, Mr. Darshan Lal, Ms. Pooja, Mr. Raj Kumar, Mr. Sandeep and Mrs. Arti from Admin Section all were very helpful.

My sincere thanks to Mr. Tilak Raj Kundan, Mr. Rakesh Kumar Behera, Mr. Krishna Kumar, Mr. Tsewang Tamchos, Mr. Alok Mehta, Mr. Anil Pandit and Mr. Rohit Kumar all of whom have been extremely helpful whenever I approached them.

I want to express my respect and gratitude to my uncle Shri Dinesh Tiwari, my aunty Late Smt. Gayatri Devi, and my father Shri Ashok Tiwari, my mother Smt. Geeta

Devi, my brothers Shri Janmejay Tiwari, and my younger brother Mr. Awadh Kishor Tiwari, and My wife Smt. Juhi Pandey and my lovely daughter Bhavika for their love, affection and constant encouragement. My heartfelt thanks to my special friends Mr. Anil Pandit and Mr. Shardulya Shukla whose presence and support have provided me with the necessary motivation and positivity during my Ph.D. day to move on.

I would like to convey my cordial thanks to all those who have helped me directly or indirectly in fulfilling my aims. I apologize to those whom I might have inadvertently forgotten to mention and acknowledge by name.

I promise all of you that the love and affection you have given me will never go in vain. I will try my best to do the Best.

Vivek

(Vivek Kumar Tiwari)

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LIST OF ABBREVIATION

%	:	Percentage
&	:	And
°C	:	Degree centigrade
°E	:	Degree East
°N	:	Degree North
˚B	:	Brix
µg/L	:	Microgram per litre
µL	:	Micro litres
µM	:	Micro molar
µmol/L	:	Micromole per litreFliter
$AlCl_3$	:	Aluminium chloride
ANOVA	:	Analysis of Variance
ACI	:	Anthocyanin content index
B	:	Boron
Ca	:	Calcium
CCI	:	Chlorophyll content index
cm	:	Centimetres
Cu	:	Copper
DIHAR	:	Defence Institute of High-Altitude Research
DRDO	:	Defence Research and Development Organization
DW	:	Dry weight
eg.	:	Example
et al.	:	Et alibi
FC	:	Folin–ciocalteu reagent
Fe	:	Iron
$FeCl_3$	:	Ferric chloride
$FeSO_4$	:	Ferrous sulfate
FRAP	:	Ferric reducing antioxidant power
FW	:	Fresh weight
FYM	:	Farm yard manure
g	:	Grams

GAE	:	Gallic acid equivalent
H_2O	:	Water
HA	:	High Altitude
HCl	:	Hydrochloric acid
HNO_3	:	Nitric acid
HPLC	:	High Pressure Liquid Chromatography
i.e.	:	That is
IAA	:	Indole acetic acid
K	:	Potassium
kg	:	Kilogram
L or l	:	Litre
LA	:	Low Altitude
LAC	:	Leaf anthocyanin content
LCC	:	Leaf chlorophyll content
LL	:	Leaf length
LW	:	Leaf width
m	:	Meters
M	:	Molar
max	:	Maximum
mg	:	Milli gram
Mg	:	Magnesium
ml	:	Millilitre
Mn	:	Manganese
MSL	:	Mean sea level
MW	:	Molecular weight
N	:	Nitrogen
Na	:	Sodium
Nitrate	:	NO^{3-}
O_2	:	Oxygen
OC	:	Organic carbon
P	:	Phosphorus
$p<0.05$	:	Significance at 5% level
pH	:	Power of hydrogen

PH	:	Plant height
ppm	:	Parts per million
RBD	:	Randomized block design
RD	:	Root diameter
RE	:	Rutin trihydrate equivalents
RL	:	Root length
rpm	:	Rotation per minute
RT	:	Room temperature
S	:	Sulfur
SD	:	Standard deviation
SPSS	:	Statistical Package for the Social Studies
TE	:	Trolox equivalent
Temp	:	Temperature
TFC	:	Total flavonoid content
TAC	:	Total antioxidant capacity
TPC	:	Total polyphenolic content
TSS	:	Total soluble solid
UV	:	Ultra violet
viz.	:	Varifactors Namely
Zn	:	Zinc

ABSTRACT

Natural growth and development of plants in cold arid regions are affected by drought stress limited water availability and soil fertility. Soil in the trans-Himalayan region, Ladakh is sandy, coarse textured, pH 7.79±0.2 and deficient in micronutrients, thereby reducing growth and productivity. The cropping season in trans-Himalayan region of Ladakh is limited during summer season. Carrot is one of the major root vegetable crops growing in this region. This study was aimed at examining the combined effects of boron and zinc supplementation on the physicochemical responses of carrots in high-altitude cold desert environments using different concentrations of these micronutrients. Experiment was carried out in randomized block design (RBD) and treatment means were differentiated using the Tukey's test at a 0.05 level of probability. During the storage trial, three types of storage structures (room condition, underground passive storage, and trench storage) were used to estimate the storage behaviour of carrots. Additionally, different packaging conditions perforated polyethylene bag, cotton bag, leno bag, plastic crate, and wooden crate were studied to assess their impact on the shelf-life quality of carrot roots treated with a preharvest application of boron and zinc.

It was observed that in comparison to control, the foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% significantly improved root diameter, average root weight, yield, sucrose content, total sugar, sweetness index, and total sweetness index in carrots. The maximum chlorophyll content (9.29 CCI) in carrot leaf was observed by foliar application of Boron @ 0.2% + $ZnSO_4$ @ 1.0%, which is statistically at par with foliar application of Boron @ 0.1% + $ZnSO_4$ @ 1.0% (9.27 CCI). However, the highest glucose and fructose content was observed with a foliar application of Boron @ 0.1%. The highest nitrate (351.08 mg/100g) content was recorded in the combined foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5). Among the treatments, maximum values of sulfur (210.73 mg/100g) in carrot root were observed in Boron @ 0.2% + $ZnSO_4$ @ 0.5%. Total carotenoid content was found maximum without the foliar application of boron. However, it was significantly influenced by foliar application of zinc. Maximum values of carotene (4298.78±91.94 µg/100g FW) and total flavonoids (1.75mg RE/g DW) were recorded under the foliar application of $ZnSO_4$ @ 0.5% (T_3), which was at par with application of $ZnSO_4$ @ 1.0% (T_4). However, the maximum value of total phenol concentration (6.59±0.34 mg GAE/g DW) was recorded under

foliar application of $ZnSO_4$ @ 1.0% (T_4), which was at par with $ZnSO_4$ @ 0.5% (T_3). Application of zinc and boron influenced the mineral content of carrots. During plant growth, adding small amounts of zinc and boron to the feeding solutions affected the concentration of other minerals, including Cu, Mn, and Zn, in the roots. Applying different amount of mineral nutrients has the potential to improve the nutritional value and morpho-physical quality of carrots.

After harvest, carrot roots were sorted, graded, and subsequently stored under different storage conditions (room condition, trench, and underground passive storage). In trench, and underground passive storage, data were collected over 150 days from the date of root harvest. In room storage, data were collected over 20 days of storage periods. The root quality of carrot has been evaluated under different storage structure. The results showed that storage conditions had a significant ($p \leq 0.05$) effect on many important quality attributes. During end of storage, weight loss, glucose, and total sugars increased during the storage periods, however, ascorbic acid, titratable acidity and carotene content declined. Total phenolic content and flavonoid content showed a nearly parabolic trend during the storage period. After 30 and 60 days of storage, 6.2% and 6.46% weight loss were observed in underground passive storage, respectively. Whereas minimum weight loss 5% was recorded in the month of January. It increased upto 9.6% in the month of February and sudden weight loss 16.66% was recorded in month of March. It assures that passive underground store has maintained suitable environment for the storage of carrots upto February (120 Days) but during March sudden increase in temperature caused extreme weight loss%.

Overall study observed that the passive underground store is best among all storages. since, carrots in room condition gets rotten within 20 days, whereas in trench there is no facility to open the trench anytime, once open all root must be taken out for use otherwise the moisture is gained and carrots are damaged. whereas in passive store, the carrots were physically and biochemically fit upto February and sudden changes in March were observed.

The ascorbic acid content of carrot roots during storage were found significantly higher in carrot roots stored in the trench storage (4.75 mg/100g), followed by underground passive storage (4.47 mg/100g). The carrot roots stored in underground passive storage maintained the higher average carotene (2980.23 μg/100g FW) and the range between different treatments was 2533.43 to 3319.16 μg/100g FW during the 150 days storage period. The underground passive storage maintained maximum level of total flavonoids content (0.46 mg RE/g DW), sulfate (355.04 mg/100g), Mn (1.34 mg/100g), Zn (6.36 mg/100g) and Fe (9.01 mg/100g) at 150 days storage periods. Among the storage, underground passive storage was maintaining the lowest value of glucose (22.03 g/100g), fructose (9.61 g/100g) and sucrose (11.57 g/100g) content of carrot during the 150 days of storage.

The quality parameters such as weight loss, TSS, ascorbic acid, titratable acidity, carotene, total phenolic compounds, total flavonoids, sugars, anions and minerals were evaluated periodically during storage with different packaging. It was found that packaging affected on physico-chemicals properties of treated carrots in 30 days, 60 days, 90 days, 120 days, and 150 days. It was noticed that the perforated polyethylene bag packed roots maintained the lowest average weight loss (10.25 %), total sugar (39.53 mg/100g), TSS (13.72 °B), and maximum ascorbic acid (5.27 mg/100g), carotene (3507.05 μg/100g FW), TPC (3.98 mg GE/g DW) during 150 days of storage. After 150 days of storage, it was observed that treated roots packed in perforated polyethylene bags had greater nitrate levels than the other packaging materials. The mean nitrate was measured at 270.21 mg/100g, with a range of 227.18–308.23 mg/100g among treatments. It was noticed that perforated polyethylene bag packed treated roots showed higher phosphate than other packaging materials throughout the storage period and recorded mean phosphate (707.2 mg/100g). The perforated polyethylene packed treated roots showed maximum mean sulfate (465.47 mg/100g), range among treatments was 411.60 –507.68 mg/100g, after 150 days of storage periods. However, the treated carrot roots packed in cotton bags maintained the highest average zinc concentration (6.42 mg/100g) at the end of storage. Leno bag-packed-treated roots had the highest average potassium and manganese content across all packaging materials over the storage period, with a mean K and Mn content of 3042.8 mg/100g and 1.34 mg/100g. The maximum average sodium content (286.9 mg/100g) in perforated polyethylene bag packed roots, the range among treatments was 267.27–295.85 mg/100g, from 150 days of storage as compared to leno bag where average sodium (278.7 mg/100g) was found to be the lowest and the range among treatments was 255.44 and 319.30 mg/100g.

The results showed that mineral supply played a crucial role for determining the nutritional value of carrots. By application of micronutrient, carrot crops' nutritional value gets increased while maintaining acceptable physical quality. Since a result,

perforated polyethylene bags in underground passive storage have a potential to enhance post-harvest life of carrots.

Key words: anions, boron, carrot (*Dacus Carota* L.), minerals, phytoconstituents, packaging, sugars, storage, zinc

CHAPTER-1
INTRODUCTION

Carrot (*Daucus carota* L.), a prominent root vegetable, belongs to the family *Apiaceae*. Carrots are a common vegetable produced worldwide and are a major source of dietary carotenoids in Western countries, including the United States (Block, 1994; Torronen *et al*., 1996). They are among the top five most widely consumed vegetables globally, making them economically significant. China leads world in carrot production, followed by Uzbekistan, Russia, the United States, and Ukraine. Global demand for carrots is increasing, driven by growing health awareness and interest in functional foods and value-added carrot-based products, such as juices, purees, and snacks. Carrots are also a key export item, particularly in Europe and Asia. During 2019-20 the area under vegetables was 10.35 Million Hectares with a production of 191.76 MT in India. According to the National Horticulture Board (NHB) statistics (2019–2020), carrot cultivation covers approximately 0.10 million hectares area and production around 1.83 MT. Major carrot-producing states in India include Uttar Pradesh, Assam, Karnataka, Andhra Pradesh, Punjab, and Haryana. Carrot consumption has rapidly grown in recent years due to its reputation as an essential source of vitamins minerals, carbohydrates, and phytonutrients.

Carrot roots contain approximately 88.8% moisture, 0.7% protein, 0.5% fat, 5.6% total sugars, and 2.4% crude fibre. They are also rich in essential minerals, including calcium (34 mg/100 g), iron (0.4 mg/100 g), phosphorus (25 mg/100 g), sodium (40 mg/100 g), potassium (240 mg/100 g), magnesium (9 mg/100 g), copper (0.02 mg/100 g), and zinc (0.2 mg/100 g). In addition, they provide carotenes (5.33 mg/100 g), thiamine (0.04 mg/100 g), riboflavin (0.02 mg/100 g), niacin (0.2 mg/100 g), vitamin C (4 mg/100 g), and have an energy value of 126 kJ/100 g (Sharma *et al*., 2012).

Carrots contain around 10% carbohydrates, with soluble carbohydrates ranging from 6.6 to 7.7 g/100 g and protein content between 0.8 and 1.1 g/100 g. They are also high in vitamins, including vitamin K, vitamin C, vitamin B_6, and folate. Moreover, carrots are rich in different bioactive compounds such as β-carotene, α-carotene, lutein, and polyacetylenes, which contribute to their antioxidant and health-promoting properties (Arscott and Tanumihardjo, 2010). Carrots offer several health benefits due to their rich phytochemical content and high nutritional value. Their higher β-carotene concentration supports eye health and helps prevent night blindness and age-related macular degeneration. The antioxidant compounds found in carrots help combat oxidative stress and may reduce the risk of chronic diseases. Carrots also promote cardiovascular health due to their soluble fibre and potassium content, which help lower blood pressure and manage cholesterol levels. Furthermore, polyacetylenes and carotenoids present in carrots have demonstrated anti-cancer properties, particularly in relation to colon and prostate cancers. The fibre content in carrots supports digestive health and helps maintain a balanced gut microbiota, while the presence of vitamins and antioxidants contributes to a stronger immune system (da Silva Dias, 2014).

Carrot is cool-season crop that thrive in temperate climate, where they are typically cultivated during the spring. In subtropical regions, they are usually sown in autumn or winter. Temperature plays a crucial role in root development and colour formation. Well-drained loamy soils are ideal for producing long, smooth roots, which are preferred for fresh markets. Sandy loam soils are best suited for early cropping, while heavier soils tend to produce coarser roots (Chadha, 2001). The optimal soil pH for carrot cultivation is around 6.5.

As a biennial crop, temperate carrots complete their life cycle over two seasons. In the first season, the plant focuses on vegetative growth, storing nutrients in the taproot for reproductive development in the second season. Successful cultivation of carrots in both temperate and tropical climates depends largely on variety selection. Temperate varieties require lower temperatures (5°C–8°C) to break dormancy and induce flowering, whereas tropical varieties are more heat-tolerant.

In the Leh district, vegetable production occupies 5.5% of the total 10,319 hectares of agricultural land, with carrots accounting for only 2.0% of the total vegetable production. Carrots are one of the most important crops produced in Ladakh, following potatoes, peas, onions, cabbage, and cauliflower, with an annual production of approximately 242 metric tons (Stobdan *et al*., 2018; Tiwari *et al*., 2025).

This level of production is significant for the region's food security, especially considering the harsh cold-arid conditions that challenge agricultural practices. The nutritional value of carrots and their adaptability to the local environment make them a key crop for sustaining livelihoods and enhancing dietary diversity in Ladakh (Anonymous, 2022).

Importance of foliar application of micronutrients

Micronutrients, particularly zinc (Zn) and boron (B), play an essential role in enhancing plant growth, yield, and quality, making them critical in agricultural practices. Zinc is involved in several biochemical processes, including enzyme activity, chlorophyll formation, and carbohydrate synthesis, all of which directly affect plant growth (Bhat *et al*., 2018). In soils that are coarse, sandy, or calcareous—conditions often found in arid and high-altitude regions—zinc deficiency is prevalent.

This deficiency can be effectively managed through the foliar application of $ZnSO_4$, which increases zinc availability to plants (Singh *et al*., 2022). In addition to its importance in plant development, zinc also plays a vital role in human nutrition, serving as a cofactor in numerous enzymes and regulating essential intracellular signalling pathways (Maret *et al*., 2013).

Similarly, boron is crucial for plant growth, influencing cell wall structure, fruit and seed development, and hormone regulation particularly in root vegetables like carrots (Vera-Maldonado *et al*., 2024; Herrera-Rodríguez *et al*., 2010). Deficiencies in either zinc or boron can lead to reduced yield and quality, making their supplementation through foliar application essential, especially in challenging environments.

In recent years, biofortification, particularly agronomic biofortification has emerged as an effective approach to address micronutrient deficiencies in human diets. By applying micronutrient-enriched fertilizers to crops, essential nutrients such as zinc and boron are not only absorbed by the plants but also accumulate in their edible parts, thereby improving both yield and nutritional quality (Hefferon, 2023). This strategy is especially important in combating malnutrition, which disproportionately affects populations in developing regions, including school-aged children and pregnant women (Keats *et al*., 2019).

In the present study, the application of foliar sprays was investigated as a method to address nutrient deficiencies commonly found in the coarse, sandy soils of cold arid regions like Ladakh, where traditional soil-based fertilization is often less effective. Foliar application allows essential micronutrients like zinc and boron to be made directly available to plants, bypassing soil limitations and enhancing both yield and quality attributes of crops such as carrots.

Post-harvest management and storage of carrots in high altitude regions

Ladakh, a trans-Himalayan region in northern India, is characterized by its rugged mountainous terrain, high-altitude deserts, and extreme climatic conditions. Situated between the Karakoram Range to the north and Himalayas to the south, it lies at elevations ranging from 2,500 to over 7,500 meters. The region's climate is harsh, with scorching summers and frigid winters, where temperatures can plunge below –30°C. This necessitates the cultivation of hardy, less perishable crops such as potatoes, carrots, and cabbage, which can mature quickly and withstand the cold.

Being a hardy root vegetable, carrots are well-suited for extended storage under proper conditions. However, their storage potential is significantly influenced by both pre and post-harvest factors, such as cultivation practices, maturity stage at harvest, and storage environment (Schreiner & Huyskens-Keil, 2006). Post-harvest management, including packaging, plays a critical role in maintaining carrot quality, extending shelf life, and preserving bioactive compounds (Giannakourou & Tsironi, 2021).

In Ladakh, traditional methods of vegetable storage have been practiced for centuries, utilizing simple, low-tech approaches that reflect the region's unique climate and cultural practices. Open storage is common, where vegetables like carrots are kept in well-ventilated areas. However, this method is vulnerable to weather fluctuations, pests, and diseases, which can lead to spoilage. Another approach involves burying root vegetables in the ground, allowing for better temperature and moisture regulation; yet, this labour-intensive method may expose produce to soil-borne pests. Some farmers use natural insulation by storing vegetables in structures made from local materials like stone or mud, which offer some protection from extreme temperatures but often lack humidity control, thereby affecting the quality of the stored produce (Kishore & Samant, 2021).

Additionally, the extreme climatic conditions, geographic isolation, and limited agricultural season in Ladakh make advanced storage facilities essential for the region. The short growing season restricts the availability of fresh produce to just a few months, making effective storage crucial to ensure food supply during the long winters. The region's remoteness and poor connectivity, particularly during winter when roads are blocked by snow, limit external food imports, further emphasizing the need for local self-sufficiency. Moreover, the cold, dry environment can quickly spoil fresh produce without proper humidity and temperature-controlled storage. With its strategic military importance, Ladakh also hosts numerous army deployments that rely on a steady supply of fresh, nutritious food, making modern storage technology critical to meet the dietary needs of soldiers stationed in high-altitude areas.

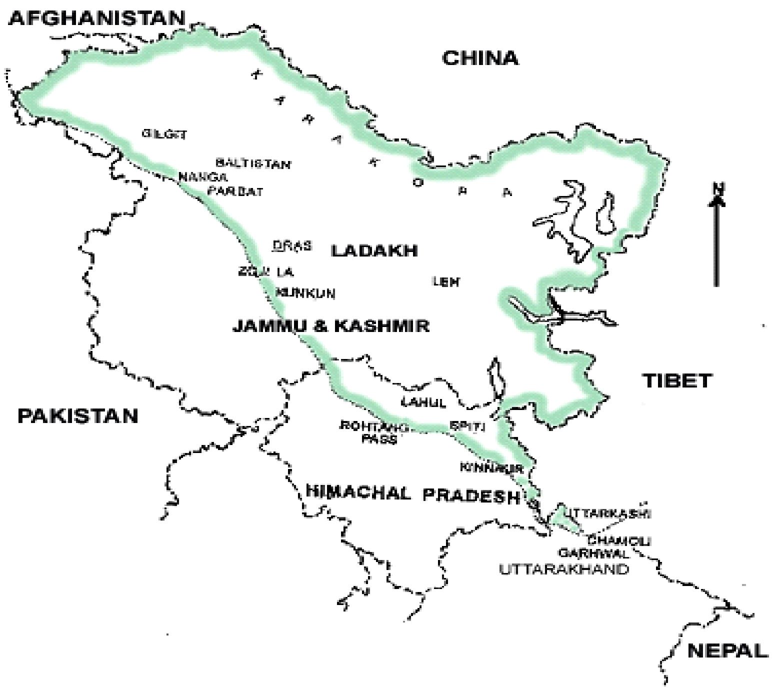


Figure 1.1. Map of Cold Desert (Kumar *et al.*, 2024)

Knowledge gap in agriculture in the Ladakh cold desert Trans-Himalayan region:

Agriculture in the cold desert region of Ladakh, located in the trans-Himalayan agroclimatic zone, is hampered by several environmental and infrastructure constraints uncommon to high-altitude cold dry areas. These include significant temperature swings, low air pressure, limited precipitation, poor soil fertility, and a very short cropping season of only four to five months. Despite these limits, agriculture continues to provide a key source of income for the local community.

However, scientific understanding of crop management approaches, nutrient optimization, and post-harvest handling procedures appropriate for this region remains limited. Most of the agricultural technology and suggestions available today are based on research undertaken in temperate or tropical environments, and do not take into consideration Ladakh's specific environmental pressures and resource restrictions. There is a distinct shortage of region-specific research on the use of micronutrients such as zinc and boron to boost crop production and quality in cold, dry climates. Furthermore, typical post-harvest storage methods are frequently insufficient, resulting in significant losses during the prolonged winter months when produce is unavailable. The limited examination of climate-adapted storage methods, such as passive underground storage structures, and the scarcity of research on scientific cultivation of carrot show a huge knowledge gap. Addressing these concerns via targeted research is critical for establishing sustainable agricultural practices, increasing production of crops, lowering post-harvest losses, and enhancing regional food security.

Future scope of carrot cultivation in the Ladakh cold desert agroclimatic zone:

Carrot cultivation has a high future potential in the Ladakh cold desert agroclimatic zone due to the crop's resilience to frigid temperatures, nutritional value, and rising demand for nutritious, locally grown veggies. The region's cold desert environment, with cool nights and intense sunlight throughout the short summer season, promotes carrot root development, colour enhancement, and sugar buildup, all of which contribute to improved flavor and quality. Additionally, carrots have a relatively short growth cycle, making them suitable for Ladakh's limited cropping window. With a growing emphasis on nutritional security and climate-resilient agriculture, carrots can be a valuable biofortified crop for addressing micronutrient deficiencies in the local population. There is also the possibility to increase off-season and organic carrot output using scientific cultivation techniques. Furthermore, scientific treatments such as foliar micronutrient management (e.g., boron and zinc) and enhanced storage solutions have the potential to increase production, quality, and shelf life, more economically viable for local farmers. Promotion of value addition through processing (e.g., juice, dried products) may expand market potential. Carrot cultivation has the potential to significantly improve livelihoods, nutrition, and sustainability in the Trans-Himalayan area with appropriate research assistance, training, and infrastructure development.

Therefore, examining the effects of storage conditions on vegetables is crucial for achieving food security, maintaining product quality, and promoting sustainability in Ladakh. To advance carrot cultivation, improve storage methods, and extend shelf life in such demanding environments, the following objectives were formulated:

1. To investigate the effects of foliar application of micronutrients (zinc and boron) on the yield and quality attributes of carrots.
2. Comparative evaluation of traditional and modified storage structures for physio-chemical changes of carrot with storage time in cold desert Trans-Himalayan Ladakh region.
3. To evaluate the effect of different packaging materials on the shelf-life of carrots under storage conditions.

CHAPTER-2
REVIEW AND LITERATURE

The experimental findings of various researchers on evaluation of "Effect of preharvest application of micronutrient on performance of carrot and Its shelf life under different storage conditions in cold desert trans-Himalayan Ladakh region" was reviewed as under:

2.1 Importance of carrot

Carrot is a nutrient-rich root vegetable stored with important vitamins, minerals, and bioactive compounds that are known for their beneficial effects on health and nutrition. Antioxidant, anti-inflammatory, plasma lipid-modifying, and anti-tumor properties are fundamental for qualifying the risks associated with cancer and cardiovascular disorders. A combination of factors influences the quantity and composition of these phytochemicals in carrots. For instance, orange carrots have high levels of carotene, yellow carrots contain notable concentrations of lutein, red carrots are rich in lycopene, purple carrots have high anthocyanin levels in the root, and black carrots are abundant in phenolic compounds. Across several cultivars, carotenoid levels ranged from 3.2 to 170 mg/kg, whereas vitamin C content varied widely from 21 to 775 mg/kg (Ahmad *et al*., 2019). Carrot seed extracts offer various important properties, including cardiovascular and hepatoprotective effects, as well as antibacterial, antifungal, calming, and pain-relieving qualities. Carrots are a major root crop rich in biochemical components like carotenoids and soluble fibre, as well as a diversity of supplementary functional compounds that are known to improve health. Carrots are attractive and popular because they are a good source of natural antioxidants with anticancer properties. In India, their predictable use in servings of mixed greens and curries can be effectively integrated into a diverse range of health-enhancing products, including juice, condensed milk, dry powder, canned goods, jam, pickles, and gajerella. Additionally, carrot pomace, which contains nearly 50% beta-carotene, is used to produce a variety of beneficial products and innovative items such as cakes, bread, and biscuits (Varshney & Mishra, 2022). Carrot root storage contains a wealth of biologically active compounds, many of which are critical for human health. Que *et al*., (2019) reported that carrots are used in the food industry to produce juice, dietary fibre, and other products. However, few studies have investigated the pharmacological properties of the active substances for medicinal applications. Carrots provide many antioxidants, such as anthocyanins, carotenoids, and polyacetylene, which play essential roles in disease prevention. With increasing awareness of health benefits, the active components of carrots hold substantial research value and medicinal applications. Future research could include investigating the medicinal uses of carrots. Carrot, botanically known as *Daucus carota*, is a usually famous vegetable grown and consumed around the world. It exists in white, orange, red, and purple cultivars. Carrots are exceptional sources of dietary antioxidants when included in one's diet due to their wealth of phytochemicals like carotenoids, anthocyanins, and phenolic compounds. The most abundant cancer prevention agents intensified in carrots include α-and β-carotene, vitamin E, and anthocyanin. Interestingly, the color of the carrot is determined by the levels of antioxidant pigments in various cultivars. Due to their antioxidant capacity and nutritional content, carrots are believed to offer several health benefits, including the potential to prevent certain cancers and cardiovascular diseases (Jaiswal *et al*., 2020).

2.2 Role of micronutrients on growth, yield, and quality of plants

Plants need appropriate quantity of essential micronutrient nutrients to grow successfully. Scientists have studied the importance of various mineral elements for plants from multiple perspectives over the decades. Finally, they selected 17 elements as essential for plant growth: C, O, H, N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B, Mo, Cl, and Ni was considered as essential nutrients, lack of any of these nutrients in the growing medium disturbs the plant's life cycle. Each nutrient serves a unique purpose in the plant development cycle and cannot be replaced by another. Providing sustainable, appropriate, and nutritious food to a growing population is a major issue for agriculture and plant research. The micronutrient composition of food crops deserves attention. Micronutrient deficiencies in cultivated soils and plants are a global concern that have a negative influence on crop output, plant nutritional quality, and human health. Plants need essential micronutrients, including boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn), to survive. Similarly, animals and people require micronutrients to maintain their health and well-being.

According to Assunção *et al*., (2022), micronutrient shortages are becoming increasingly prevalent globally, affecting both crops and humans. Minute deficiencies are more likely to affect agricultural productivity across broader regions than those with evident signs. Plant-based diets lack adequate vitamin levels and bioavailability, resulting in widespread micronutrient deficiencies in humans. Essential nutrients play crucial roles in plant metabolism and influence various physiological processes. Unlike macro and micronutrients, they are needed in smaller amounts for growth and primarily serve as components of prosthetic groups in metalloproteins and catalysts in enzyme processes. Micronutrients, particularly transition metals such as Fe, Mn, Cu, and Mo, aid in redox reactions via electron transfer. Essential nutrients can also form enzyme-substrate complexes (e.g., Fe and Zn) and enhance enzyme activity by altering the molecular structure of enzymes or substrates, as observed with Zn (Römheld and Marschner, 1991). Minerals are crucial for plants because they influence numerous metabolic functions. Although these nutrients are commonly present in soil, plants absorb only small quantities of them. Essential micronutrients such as B, Cu, Fe, Mn, and Zn required for plant growth and development. Minerals helped with important plant metabolism activities such as nutrition management, reproductive growth, chlorophyll synthesis, carbohydrate generation, and fruit and seed formation. Adequate amount of these trace elements increases physiological, biochemical, and metabolic processes that are essential for healthy plant development, whereas deficiencies can result in aberrant growth. The prevalence of micronutrient deficiencies has lately grown, owing to the needs of new crop types and enhanced soil erosion (Tripathi *et al*., 2015). Fe, Mn, Cu, Mo, Zn, B, Cl, and Ni are essential for plants in very small concentrations to support growth and reproduction. Despite their low concentrations in plant tissues and organs, micronutrients are as vital as macronutrients for plant nutrition. At these lower levels, micronutrients play critical roles: they are essential for growth and development, functioning as components of cell walls (B), membranes (B, Zn), enzymes (Fe, Mn, Cu, Ni), enzyme activators (Mn, Zn), and in photosynthesis (Fe, Cu, Mn, Cl). Plant nutritionists and agronomists are progressively interested in micronutrients due to their importance in crop production. Insufficient micronutrient levels can limit growth and may go unnoticed. They not only directly affect crop development but also reduce the efficiency of macronutrient fertilizers (Kirkby & Romheld, 2004). Micronutrients had an important impact on carrot height, leaf number, shoot weight, root weight, and root yield. The largest diameter (6.42 cm) was recorded in the control plot using NPK as basal. The lower dose of micronutrients (Zn, B, Cu, Mn) resulted in the highest plant height (60.30 cm), number of leaves (13.8), shoot weight (84.67 g/plant), root weight (147.3 g/plant), and root production (29.76 t/ha), a 37.26% increase over the control. Higher dosages of these micronutrients reduced yield (Naher & Alam, 2013).

2.3 Effect of zinc on plant growth and nutrition

According to Kumar and Kumar, (2020), Indian soils are unable to fulfil all nutritional requirements. As a result, nutrients are obtained from sources outside the body. The use of micronutrients such as boron, iron copper, and zinc has a significant impact on several potato parameters. It has been proven that the application of NPK, together with an acceptable level of micronutrients such as boron, copper, zinc, and manganese, is required to generate a good tuber yield in potato. In this regard, a new study proposes foliar zinc spray at 30 ppm since it contributes to higher potato output and quality. Foliar Zn treatment at high concentrations is harmful, and as photosynthesis decreases, plant performance declines. Foliar boron fertilization provides a constant supply of plant nutrients for a longer time of crop growth or as needed by the plants, perhaps facilitating a consistent transmission of photosynthesis and resulting in better crop production than soil application.

According to Mousavi *et al.*, (2013), zinc (Zn) is an essential trace element or micronutrient which are crucial for the metabolic processes that govern plant growth and development. As Zn^{2+}, zinc is absorbed and utilized by plants, contributing to vital physiological functions across all living systems. These functions include maintaining the structural and functional integrity of biological membranes, facilitating protein production and gene expression, supporting enzyme structure, energy metabolism, and the Krebs cycle. Zinc also positively influences crop growth and yield. Zinc deficiency is especially problematic in calcareous soils with high phosphorus (P) levels and elevated pH. Zinc interacts chemically and biologically with various elements, such as phosphorus, iron, and nitrogen within plants, and actively participates in biochemical reactions. Interactions between copper and phosphorus can negatively impact zinc availability.

Zinc (Zn) is important for the protein metabolism of plants, but excessive amounts of it can be hazardous. This study looked at the fundamental mechanisms of zinc transmission from soil to roots, shoots, and beyond. This section examines Zn input into soil, the existence of soluble Zn^{2+} at root surfaces, and how plants absorb and store Zn. Understanding these mechanisms can help guide agronomic and genetic solutions to combat widespread zinc deficiencies that limit crop development. Significant genetic diversity in the zinc content of plant species can alleviate human dietary zinc deficits through biofortification. Interestingly, a meta-analysis of comprehensive literature surveys revealed that evolutionary mechanisms affecting plant families contribute to some of the genetic variance in shoot Zn concentration (Broadley *et al*., 2007).

As indicated by Umair Hassan *et al*., (2020), zinc (Zn) is an essential micronutrient crucial for enhancing crop versatility to drought stress by regulating various physiological and molecular mechanisms. Under drought conditions, Zn enhances seed germination, plant water relations, cell membrane stability, osmolyte accumulation, regulation of stomatal openings, water use efficiency, and photosynthesis, leading to improved overall plant performance. In addition, Zn reduces drought effects by interacting with plant hormones, increasing stress-related protein expression, and activating antioxidant enzymes. Zinc is required for the function of proteins and other macromolecules. Zinc, a protein component, acts as a functional, structural, or regulatory cofactor for a wide range of enzymes. Zinc insufficiency commonly causes physiological disturbances due to reduced enzyme function. Zinc deficiency, for example, reduces the activity of critical photosynthetic enzymes, inhibiting photosynthesis. It also enhances membrane permeability by blocking enzymes that remove harmful oxygen radicals. Recent research suggests that zinc has a function in stabilizing RNA and DNA structures, maintaining DNA synthesis enzyme activity, and controlling RNA breakdown enzymes. Thus, zinc has the capacity to impact gene expression (Brown *et al*., 1993).

Zinc, on the other hand, is required for ribosome formation and function. Zinc is an active component in metabolic processes and interacts chemically and physiologically with other elements. Phosphorus is the primary component that restricts zinc absorption by plants. High amounts of soil phosphorus reduce zinc intake, perhaps due to physiological effects related to phosphate fertilization. Competition between copper and zinc for absorption sites in plant roots can reduce zinc availability when copper concentrations are high (and vice versa), especially with copper fertilization.

Zinc deficiency can hinder the transport of iron (Fe) from roots to shoots, leading to iron deficiency. Adequate zinc levels in plants can mitigate the negative effects of boron (B) deficiency, which otherwise slows plant growth by reducing boron uptake in young leaves and branch tips (Mousavi *et al*., 2012). According to Rudani *et al*., (2018), Zinc deficiency affects nearly all crops, particularly those grown in calcareous, sandy, peat, and soils with high levels of phosphorus and silicon. Samreen *et al*., (2017) studied various mung bean varieties—Ramazan, Swat, NM92, and KMI—grown hydroponically in sand-filled pots and supplemented with zinc (Zn) nutrient solutions. They applied three Zn concentrations (0, 1, and 2 μM) to each variety. The application of higher doses of zinc increased plant growth, chlorophyll, protein, and zinc levels of plants compared to the control. Zn supply increased from 1 to 2 m of plant, and phosphorus content in plants decreased, suggesting a Zn/P complex formation in plant roots that may inhibit phosphorus uptake. Mung bean recorded the highest amounts of copper and magnesium, while iron exhibited competitive interactions with zinc. Increasing Zn levels from the control to 2 μM did not significantly affect the content of potassium (K), sodium (Na), and manganese (Mn) in the plants. The optimal approach for enhancing mung bean growth and quality criteria was applying zinc at 2 m concentrations in the nutrient solution. According to reports, zinc fertilization significantly improved allometric and yield-related characteristics. Grain yield ranged from 439 to 904 kg/ha under control conditions and increased to 536 to 1462 kg/ha after zinc fertilization. Zinc concentration in grains varied from 15.50 to 45.60 mg kg^{1} without zinc fertilization and from 18.53 to 64.23 mg kg^{1} with zinc fertilization. The ability for zinc biofortification is different between all genotypes. Genotypes NM-28 and NM-121-25 had the highest and lowest grain zinc levels, respectively. Because of their high zinc absorption capacity, genotypes NM-28 and NM-2006 may be useful in breeding efforts targeted at boosting zinc concentration in grains (Haider *et al*., 2021).

Plants treated with zinc sulfate showed higher peroxidase activity, vigor, total soluble sugars, chlorophyll-a, chlorophyll-b, and total chlorophyll content. The nutritional qualities of the fruits remained stable, with no nutrient loss observed in the plants. The study revealed that zinc sulfate seedling growth, photosynthetic pigments, and nutritional value (Bukhari *et al.,* 2021). Tiwari *et al*., (2025), A study investigating the effects of mineral supply on the nutritional quality (phytoconstituents and micronutrients) of carrot roots was undertaken. Maximum values of carotene and total flavonoids were recorded under the foliar application of $ZnSO_4$ @ 0.5 % (T_3), which was at par with application of $ZnSO_4$ @ 1.0 % (T_4). However, the maximum value of total phenol concentration (6.59±0.34 mg GAE/g DW) was recorded under foliar application of $ZnSO_4$ @ 1.0 % (T_4), which was at par with $ZnSO_4$ @ 0.5 % (T_3). Zinc and boron application influenced the mineral content of carrots. During plant growth, adding small amounts of zinc and boron to the feeding solutions affected the Cu, Mn and Zn concentration, in roots. Applying different amounts of minerals nutrients has the potential to improve the nutritional value and morpho-physical quality of carrots.

The results revealed that seed priming with Nano-Urea (50%) in combination with NPK reduced the days to 50% germination. It was also found that NPK, when combined with Nano-Urea (100%) and Nano-Zinc (100%), reduced blooming days to 50% while increasing the number of leaves per plant, leaf length, and leaf area. Furthermore, the combination of Nano-Urea (50%) and Nano-Zinc (100%) with NPK resulted in the maximum plant height, branch number and leaf width. In terms of rat-tail radish pod yield, the combination of NPK and Nano-Urea produced the maximum pod length and diameter (100%). The combination of Nano-Urea (100%) and Nano-Zinc (100%) with NPK resulted in the highest number of pods per plant. It was also found that NPK, when combined with Nano-Urea (100%) and Nano-Zinc (100%), resulted in the maximum highest pod yield per plant, pod yield per plot and pod yield per hectare. The quality attributes include soluble protein content, carotenoid concentration, total phenolic content, and chlorophyll content. The highest TSS was obtained when NPK was combined with 100% Nano-Zinc. When NPK was combined with seed priming of 100% Nano-Urea and 100% Nano-Zinc, ascorbic acid and total flavonoid content were at their highest levels (Preeti *et al*., 2024).

Tiwari *et al*., 2024 was observed that in comparison to control, the foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% significantly improved root diameter, average root weight, yield, sucrose content, total sugar, sweetness index, and total sweetness index in carrots. The maximum chlorophyll content (9.29 CCI) in carrot leaf was observed by foliar application of Boron @ 0.2% + $ZnSO_4$ @ 1.0%, which is statistically at par with foliar application of Boron @ 0.1% + $ZnSO_4$ @ 1.0% (9.27 CCI). However, the highest glucose and fructose content was observed with a foliar application of Boron @ 0.1%. The highest nitrate (351.08 mg/100 g) content was recorded in the combined foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5). Among the treatments, maximum values of sulfur (210.73 mg/100 g) in carrot root were observed in Boron @ 0.2% + $ZnSO_4$ @ 0.5%.

This reveals that zinc sulfate is an effective fertilizer for boosting growth, yield, and nutraceutical potential in *M. charantia*. The results showed that applying micronutrients at various doses considerably increased plant growth and yield when compared to the control. Treatment T_3 (zinc 4 ppm) had the greatest growth characteristics, including plant height, number of leaves per plant, bolting%, neck thickness, polar and equatorial diameters, and form index. These treatments performed similarly to treatment T_6 (Boron 0.75 ppm), which likewise showed substantial differences from the other treatments, including the control. Treatment T_3 performed exceptionally well in plant height (71.87 cm) and bulb yield (155.39 q ha-1), with statistically significant outcomes when compared to the control and other treatments (Rohidas *et al*., 2011). The study found that foliar application of T_7-zinc at 30 ppm greatly improved potato growth, yield, and quality parameters. The maximum plant height (22.87 cm and 31.91 cm) and leaf counts (132.45 cm and 199.03 cm) observed 45 and 75 days after planting, respectively was found in T_7-zinc at 30 ppm. Furthermore, T_7-zinc at 30 ppm produced the maximum tuber yield (18.89 t ha^{-1}), carbohydrate content (19.52 g/100 g), and total soluble solids (TSS) of 7.55% (Singh *et al*., 2018). Ali *et al*., (2015) examined effect of zinc and boron on yield in BARI hybrid tomato plants to improve yield. Treatments involved: T_0 (control), T_1 (25 ppm $ZnSO_4$), T_2 (25 ppm H_3BO_3), and T_3 (12.5 ppm $ZnSO_4$ + 12.5 ppm H_3BO_3). The foliar spray of 12.5 ppm $ZnSO_4$ + 12.5 ppm H_3BO_3 significantly improved plant height (106.9 cm), number of leaves (68.9/plant), leaf area (48.2 cm^2), number of branches (11.9/plant), fruit weight (60.4 g), and yield (1.9 kg/plant, 25.7 kg/plot, and 58.3 t/ha) compared to the control. Plants treated with 12.5 ppm $ZnSO_4$ + 12.5 ppm H_3BO_3 also flowered earlier (49 days) and had the smallest percentage of disease-infested plants (9.4%). The combined foliar application of zinc and boron had a more significant impact on summer tomato growth and yield than either nutrient applied alone (Ali *et al*., 2015).

Veer *et al*., (2018) studied 10 micronutrient treatments alongside control. At 30, 60, 90, and 120 days after transplanting, the recommended dose of fertilizer and Boron at 35 kg/ha (T_7) produced significantly taller plants with longer leaves. Treatments with

RDF matched with zinc sulfate at 25 kg/ha (T_4) and copper sulfate at 25 kg/ha (T_{10}) showed critical development in plant level and leaf length. The most extreme number of leaves/plants was kept in treatments T_4 (RDF + Zinc Sulfate 25 kg/ha), trailed by T_{10} (RDF + Copper Sulfate 25 kg/ha). At 30, 60, 90, and 120 days after transplantation, treatments T_{10} (RDF + Copper sulfate 25 kg/ha) also produced the widest leaves, followed by T_4 (RDF + Zinc sulfate 25 kg/ha), T_7 (RDF + Boron 35 kg/ha), T_9 (RDF + Copper sulfate 20 kg/ha), and T_6 (RDF + Boron 30 kg/ha). According to Veer *et al*., (2018), the control treatment T_1 (RDF-NNPK 120:60:60 kg/ha) displayed the smallest leaf width at all times of observation. Yadav *et al*. (2017) described the effects of zinc and boron application on G-282 garlic (*Allium sativum L.)* yield, yield attributes, and storage quality. Zinc and boron play critical role in improving garlic yield, and among the six treatments tested, treatment T_5— foliar application of a micronutrient mixture (Fe-2.5%, B-0.50%, Zn-3.0%, Cu-1.0%, Mn-1.0%) at 0.5% concentration at 45 and 60 days after planting (DAP) exhibited higher result associated with others. Foliar application of micronutrient mixture at 0.5% concentration at 45 and 60 DAP also led to the highest overall bulb yield (70.08 q/ha and 66.31 q/ha respectively). According to Islam *et al.,* (2012), the interaction between zinc and boron had a substantial impact on the production of garlic cloves. The greatest clove production was recorded i.e. 7.53 t/ha, with the highest gross return, gross margin, and benefit-cost ratio (3.95), reached with the treatment of 2 kg Zn and 1 kg B per hectare. The optimal doses estimated were 2.11 kg Zn and 1.35 kg B per hectare, in addition to a standard application of 155-35-125-20 kg N-P-K-S per hectare, to maximize yield. Further increased in zinc and boron levels beyond these optimum doses were responsible for decline in clove yield. According to Razaq *et al*., (2019), the various amounts of zinc and boron were applied during the experiment. Treatments included 3+0.50 ppm, 4+0.75 ppm, and 5+1 ppm. T3 (Zinc 5 ppm @ 0.0123 g/ha) resulted in the highest number of leaves (8.45) and highest dry leaf weight (13.06 g). T7 (3+0.50 ppm @ 0.029 g + 0.0074 g/ha) showed the greatest bulb weight per plant (57.03 g) and average yield/ha (0.83 t). T5 (Boron 0.075 ppm @ 0.042 g/ha) showed the highest plant height (58.66 cm) and maximum phenolic content (1.77 mg/g). According to Alam *et al*., (2019), applying micronutrients (Zn and Fe) with a basal dose of N, P, and K (100, 75, and 50 mg/kg) produced the best growth traits. These included plant height, number of leaves per plant, bulb diameter, cloves, clove weight, and bulb yield compared to the control. The combined application of Zn and Fe resulted in a 6% and 4% more yield. All treatments positively affected growth traits and yield. The application of Zn and Fe significantly improved their concentrations in garlic tissues. Overall, the combination of both micronutrients outperformed other treatments by improving growth traits and bulb yield. Application of micronutrients like zinc and boron to onion crops significantly improved TSS, yield, and nutrient uptake. Treatment T6 (STBFR + soil application of boron at 1 kg/ha and zinc at 5 kg/ha) resulted in the largest bulb diameter (6.79 cm), bulb weight (72.57 g), and bulb yield (243.0 q/ha) among all treatments (Prusty *et al*., 2020). Adding zinc sulfate significantly improved the antioxidant activity, bioactive components, and nutritional content of cowpea (*Vigna unguiculata* L.).

The zinc and boron dosages enhanced the zinc content in grain. The management of zinc 0.125 g edaphic resulted in a maximum zinc level of 50.0 mM. An edaphic zinc dosage of 12.5 g enhanced total phenols, but a foliar zinc dose of 50.0 mm increased phenols, flavonoids, and antioxidant activity. Zinc sulfate, applied both to the soil and as a foliar spray, significantly enhanced grain weight and size, zinc content, total phenols, and antioxidant capacity (Sánchez-Palacios *et al*., 2023). According to Ozaki *et al.,* (1999), Zn competes antagonistically with Rb, Cs, Sr, Mn, and Co for binding sites in the roots. However, Zn uptake is not affected by this competition. Zinc (Zn) promotes crop resistance in drought stress by regulating many physiological and molecular processes. Zinc application to drought-stressed crops increased seed germination, plant water relations, and membrane stability. Zinc treatment significantly improves stomatal control, water usage efficiency, and photosynthesis. Additionally, Zn interacts with plant hormones, enhances stress protein expression, and activates antioxidant enzymes to mitigate drought effects (Umair Hassan *et al*., 2020). According to Korkmaz *et al*., (2018), foliar Zn spray can significantly boost the total phenolic content, antioxidant activity, and sugar content in potato tubers.

2.4 Role of boron on plant biosystem

Essential plant nutrients such as boron are consumed by roots as boric acid. It maintains the cis-diol complex molecules, which are required for metabolism, cell envelope development, and biochemical transport. Boron had a small range of insufficiency and toxicity, and its absence impairs plant function. Boron is transported across plasma membranes using various methods, thereby increasing the absorption, and maintaining growth under restricted boron availability. Fertilizers can correct deficiencies; however, boron requirements vary among species to species. Boron (B) plays an important role in the plant life cycle, influencing metabolic and morphological processes. B deficiency or toxicity can affect plant activities throughout both the vegetative and reproductive stages. Optimal concentration of boron is essential for normal growth and development across these phases. Mousavi & Raiesi (2022) reported that boron (B) was crucial for plant cell wall strength, development, cell division, fruit and seed development, sugar transport, and hormone regulation. In soils with neutral to alkaline pH, B as boric acid (H_3BO_3) and the borate anion (BOH_4) bind strongly to iron and aluminum oxyhydroxides, clay minerals, organic matter, and calcium carbonate, resulting in low soil B levels under normal conditions. While mobile in soil, B is immobile in the phloem of most cultivated species. According to Botelho *et al*., (2022), adequate boron concentrations are essential for meristem development, root growth, and overall plant growth. Despite its mobility in soil, B has a narrow range between deficiency and toxicity in plants, which is narrow compared with other micronutrients, limiting its application because of potential leaching and toxicity risks.

Boron (B) is an indispensable nutrient for vascular plants and is crucial in various stages of their growth. Although its acknowledged relevance, the precise processes that support its critical function remain difficult to identify. B is considered to have an important role in cross-linking the rhamnogalacturonan II complex in plant cell walls, particularly between pectic polysaccharides (Brini & Landi, 2022). The purification and identification of the first boron-polyol transport molecules shed light on boron's mobility in the phloem. The isolation and characterization of boron-polysaccharide complexes in cell walls gave clear evidence of boron's function in crosslinking pectin polymers. According to Blevins & Lukaszewski (1998), inhibition and regrowth of proton discharge in plant culture medium after boron removal and restoration indicated its significance in membrane activity. Boron's rapid effects on membrane function are the result of interactions with membrane components. Boron also binds apo plastic proteins to cis-hydroxyl groups in cell walls and membranes, which may disrupt metabolic pathways and inhibit manganese-dependent enzyme activity. Boron promotes calcium absorption and utilization in plants. It also promotes protein synthesis. Zinc is a component of several enzymes, including those that break down growth hormones (auxins). Zinc improves phosphorus uptake and increases plant resistance to heat and cold stress. Zinc acts as a catalyst in the formation of chlorophyll (Sidhu *et al*., 2019).

Tariq and Mott, (2006). The current investigation was founded on the concept that Boron (B) alters other micronutrients in soil-plant systems. The results showed that there were substantial treatment impacts on the growth response of radish plants, with the highest yield reported at 0.5 mg L-1 of added B. Higher amounts of B supply resulted in toxic consequences and significant production losses. Plants' concentrations of B, Zn, and Cu rose whereas Fe, Mn, and Mo declined. The overall absorption of all micronutrients except B declined as B levels in the nutrient solution increased, and the reaction was quite similar to that of radish plants. In general, low and high amounts of added B had an interaction influence on micronutrient concentrations and overall absorption. Furthermore, the Zn/Cu ratio increased while Mn/Zn and Mn/Fe dropped, although Fe/Cu showed a contradiction with rising B levels in the nutritional solution.

Sharaf-Eldin *et al*., (2019) studied the effects of boron (B) spraying on sweet potato plants, applying it once (60 days after transplantation, DAT), twice (60 and 90 DAT), or at different concentrations (0, 10, 20, 30, 40, and 50 ppm). They found that applying B at 40 or 50 ppm at 60 and 90 DAT significantly improved vegetative growth traits like plant length, branch count, and leaf area. These treatments also enhanced growth parameters such as leaf area index, absolute growth rate, and net assimilation rate. Additionally, the study showed enhancements in tuberous root characteristics such as diameter, length, and form index, alongside increased yield and average marketable yield percentage. The use of boron in combination with the recommended amount of fertilizer (RDF) has been investigated for increasing potato production. Compared to traditional farmer techniques and RDF alone, using RDF combined with 18 kg of Boron improved potato yield by 306.00 q/ha, exceeding them by 15.00 q/ha or 5.15% and 14.70 q/ha or 5.05%, respectively.

Armin and Asgharipour (2012) studied to assess the impacts of boron foliar application timing on sugar beet root quality and yield. Treatments were applied at 3 different times (30, 45, and 60 days after planting) and four different concentrations (0%, 4%, 8%, and 12%), corresponding to 0, 0.35, 0.70, and 1.22 kg of water-soluble boron/ha. Results showed that neither the application timing nor the boron focus fundamentally impacted root yield, sucrose content, potassium, sodium, amino acids, or decreasing sugars compared with the control.

Boron application further developed root yield by 12.12% and sucrose by 26.35% compared with the control. In particular, the spraying of 12% boric acid 60 days after planting resulted in the highest sugar content and root yield. Foliar applications of bio stimulants and lithovit, with or without boron, significantly enhanced potato growth. Improvements included plant height, branch number per plant, shoot fresh and dry weight, leaf area per plant, tuber number, and tuber yield per plant. Using bio stimulants and lithovit with boron greatly improved tuber quality. To maximize yield and quality, it is recommended to spray potato plants twice with 500 mg/L seaweed extract and 1000 mg/L chelated boron at 50 and 60 days after planting (Farouk, 2015). The result demonstrated that foliar spraying of different levels of boron significantly affected plant height, number of leaves, fresh and dry weight of plants, and leaf area in potato. Additionally, there was a notable increase in average tuber weight, dry shoot yield, and overall tuber yield. Foliar application of boron (60 mg/L) increased potato tuber production by 17.39%. Whereas in the second location, foliar application of 90 mg/L B increased dry shoot yield by 33.47% and 30.02%, respectively. At 60 mg/L B foliar spray concentration, the highest average tuber weight was 267 g in the first location and 275 g in the second location. The application of foliar B significantly improved the quality of potato tubers, including dry matter, protein, and starch percentages. Foliar B application also enhanced the uptake of N, P, and K. In terms of plant growth, total tuber yield (19.905 mg fed-1), dry shoot yield, and overall NPK uptake, the potato variety Valour proved superior. The uptake of N and K was also significantly influenced by the potato variety. However, there was no statistically significant increase in P absorption, B concentration, tuber dry matter, protein, or starch content (El-Dissoky & Abdel-Kadar, 2013). The four nutritional levels studied were: M3: RDF + 0.1% Boron spray at the bud initiation stage; M_1: 75:40:40 NPK kg ha^{-1}; M_2: RDF + $ZnSO_4$ at 10 kg ha^{-1}; and M_4: Boron (0.1%) spray at the bud initiation stage plus RDF + $ZnSO_4$ at 10 kg ha^{-1}. The combination of RDF + $ZnSO_4$ at 10 kg ha^{-1} + 0.1% Boron spray at the bud initiation stage was most effective, resulting in a maximum plant height of 33.80 cm, 34.30 leaves per plant at the bud initiation stage, an inflorescence length of 93.80 cm, 363 siliqua per plant, a plant weight of

26.30 g, a plant length of 5.34 cm, and a high number of siliqua seeds per plant (Deepika & Pitagi, 2015). The experiment involved foliar spraying with four different levels of boron (0%, 0.1%, 0.2%, and 0.5%) and zinc (0%, 0.1%, 0.2%, and 0.5%). The application of 0.5% boron significantly enhanced onion growth (plant height of 63.93 cm and number of leaves per plant at 7.25), yield (30.74 t/ha), and quality (total soluble solids of 13.45 °B and pyruvic acid at 5.94 mol/g). Among the numerous zinc concentrations, concentration of 0.5% resulted in the best growth characteristics for onion, with a plant height of 67.25 cm, 7.75 leaves per plant, a yield of 33.34 t/ha, and total soluble solids of 14.57 °B (Manna *et al*., 2014). The various treatments included: control (T0), soil utilization of zinc (T1), soil use of boron (T2), foliar use of zinc (T3), foliar use of boron (T4), soil use of both zinc and boron (T5), foliar use of both zinc and boron (T6), soil use of zinc and foliar use of boron (T7), and soil use of boron and foliar use of zinc (T8).

Onion growth and yield contributing parameters were observed to be significantly influenced by zinc and boron application methods. Foliar application of boron was found to be more effective than soil application (Miah *et al.,* 2020), while soil application of zinc was found to be more effective than foliar application. Similarly, applying boron at 1.50 kg/ha (B_3) resulted in significantly higher value for plant height (64.67 cm), leaf count (10.08), and leaf length (41.08 cm) than the control. Zinc at 7.5 kg/ha (Z_3) resulted in the greatest result for polar diameter (6.31 cm), equatorial diameter (6.32 cm), and average bulb weight (82.64 g). In terms of zinc application, study showed that zinc at 7.5 kg/ha (Z_3) showed the highest value for polar diameter (6.31 cm), equatorial diameter (6.32 cm), average bulb weight (82.64 g), and total bulb yield (275.50 q/ha). Boron application at 1.500 kg/ha (B_3) yielded similar results, with maximum values for polar diameter (5.95 cm), equatorial diameter (6.14 cm), average bulb weight (81.15 g), and total bulb yield (270.29 q/ha) as reported by Bhat *et al*., (2018). Solario, Osho, Odysseo, and Arlequin pepper cultivars were examined in a greenhouse over 70 days and treated with five different boron concentrations. The experiment included 200 plants, 10 for each boron treatment and cultivar. The researchers discovered that boron toxicity decreased carbohydrate levels in four commercial pepper cultivars growing in Greece and other countries. The amount of carotenoids, flavonoids, and phenols in the peppers was affected by both the cultivar and the boron treatment. The quantities of carbohydrates, phenols, flavonoids, and antioxidants increased as the fruit ripened (Sarafi *et al*., 2018). The findings of this investigation revealed that zinc 1% and 0.5% produced the highest amounts of total and free phenols. Furthermore, the maximal boron dosage (0.5%) resulted in considerably increased superoxide dismutase (SOD) activity than the control (Denre *et al*., 2016). Hegazi *et al*., (2018) found that application of boron especially helpful in increasing boron concentration in leaves, buds, and fruits. The control treatment exhibited the highest levels of total phenol in leaves and buds, but these levels decreased drastically as the rate of boron level increased. Higher boron concentration resulted in considerable increases in total chlorophyll, chlorophyll a and b, and total soluble carbohydrates, with the maximum growth occurring at 200 mg/L. The control treatment had the highest levels of indole acetic acid (IAA) and abscisic acid (ABA) in leaf and bud tissues, which reduced with greater boron availability. However, gibberellic acid (GA3) levels increased after boron treatment at a boron rate of 200 mg/L. The study examined the nutritional composition of carrot storage roots, with an emphasis on antioxidant potential, vitamin C, carotenoids, and phenolic acids, to determine the impacts of cultivar and minerals supply. The addition of boron (B) and/or calcium (Ca) to feeding solutions altered mineral accumulation, including phosphorus (P), potassium (K), magnesium (Mg), sulfur (S), and sodium (Na) ($p < 0.05$). Without additional B or Ca, there was a 33–50% increase in carotenes and a 45%–70% increase in vitamin C. Additionally, carrots grown without B supplementation had significantly higher levels of total phenolic acids compared to those grown with B supplementation (Singh *et al.,* 2012). Carrots have an important amount of hydroxycinnamic acids and their derivatives, with chlorogenic acid contributing 42.2% to 61.8% of the total phenolic compounds in carrot tissues. The phenolic content decreases in the following order: peel > phloem > xylem. Despite making up only 11.0% of the carrot's fresh weight, the peel contributes 54.1% of the total phenolics per 100 g of fresh carrots. The phloem and xylem both produced 39.5% and 6.4% of total phenolics, respectively. The antioxidant and radical-scavenging capabilities of various tissues follow the same pattern as their phenolic content and are closely connected to total phenolic levels. Phenolic extracts are more effective in scavenging radicals than pure chlorogenic acid, vitamin C, or β-carotene. This shows that phenolics are critical to carrot antioxidant activities and that additional hydroxycinnamic derivatives, such as di-caffeoylquinic acid, may greatly boost chlorogenic acid's antioxidant benefits (Zhang *et al*., 2004).

2.5 Effect of different packaging materials on performance of horticultural crops during storage

Effect of different packaging materials on weight loss of horticultural crops during storage: Storage The worldwide market for high-quality fresh fruits and vegetables is fast increasing due to a growing middle class, urbanization, more disposable income, and shifting consumer preferences. According to Stanaway *et al*., (2022), the market for fresh fruits and vegetables is estimated to reach USD 200 billion by 2027, up from USD 144 billion today. Fruits and vegetables are important for a nutritious and balanced diet, being rich in dietary fibre, essential vitamins, and minerals that help treat many sicknesses and deficiencies (Chen *et al*., 2022). However, fresh produce is highly perishable and can spoil for various reasons after harvest. The quality and storage capacity of fruits and vegetables are influenced by numerous pre-harvest factors, such as fertilization, irrigation, soil type, planting distances, and other variables. Post-harvest losses, also known as food loss and waste (FLW), refer to the significant loss of fruits and vegetables from farm to fork, which occurs globally at a rate of 25–50%. According to Bancal and Ray (2022), this loss accounts for nearly one-third of global food production. Furthermore, agricultural research and policy face a significant challenge in providing safe food for over 9.1 billion people by 2050. Food production is expected to rise by 60% by 2050 to meet global demand for food (Parfitt *et al*., 2010). To address the global problem of food loss and waste (FLW), the research topic "Advances in Pre- and Post-harvest Applications to Reduce Qualitative and Quantitative Food Loss and Waste" was created. This subject aims to improve awareness of pre- and post-harvest practices that can help minimize the worldwide FLW of fresh fruits and vegetables. The low-cost solar-powered cold storage method for improving the shelf life of tomato fruits for small-scale farmers in Tanzania. The authors emphasize that inadequate post-harvest practices result in the loss of around half of the world tomato supply. Poor storage facilities are a key source of significant post-harvest losses, which have a negative impact on farmers' lives and reduce the agriculture industry's economic contribution (Rutta *et al.,* 2022). The study looked at the limitations of deploying solar-powered cold storage technologies in Tanzania. The findings show that high investment costs, insufficient expertise, farmers' poor income, and customer preference for non-refrigerated products are all barriers to the adoption of solar-powered cold storage technologies. According to Rutta *et al*., (2022), poor storage facilities are the principal source of large post-harvest losses, which are severe. The traditional expertise of the inhabitants of Ladakh for keeping certain veggies is unique. Vegetable gardening is not conducted in Ladakh during the winter because of the subzero temperatures. To satisfy their winter veggie demands, tribal people have devised effective storage methods for crops such as cabbage, potato, onion, radish, and carrot that are compatible with the region's ecological and socioeconomic circumstances. Cabbage is kept in home basements, tuber and root crops in underground pits, and onions hanging from storehouse ceilings. These technologies allowed vegetables to be preserved in good condition for 5–6 months at low temperatures. Although improvements in technology have been made, these conventional, zero-energy technologies have been developing. However, they are still chosen because of their inexpensive cost and long-term efficacy (Ali *et al.,* 2012). Ladakh's cold desert areas are especially unusual, with dramatic temperature changes, a thin atmosphere with strong UV radiation, and a lack of oxygen supply. Cultivation is not feasible in Ladakh during the winter due to freezing temperatures, resulting in an extensive shortage of fresh vegetables and an imbalanced diet. To solve this scarcity, farmers have created low-cost conventional methods for preserving vegetables and grains that are acceptable for the region's ecological and socioeconomic conditions. Ladakh people's everyday existence focuses heavily on indigenous knowledge and skills. This study investigates traditional storage methods in the Leh district of Ladakh. According to Tsewang *et al*., (2023), given the multiple climatic concerns that hilly areas confront today, supporting traditional practices for sustainable agriculture and food security is important. The paper highlights common storage structures in the Ladakh area, such as Pang-Nga, Sadong, and Tsodbang, which are used to store foods including potatoes, radishes, carrots, cabbage, and grain. Charches, Thingches, and Khyghches are specific ways for storing onions during the winter. This study investigates the possibility of securing a consistent supply of locally grown potatoes during the landlocked winter months in Ladakh. From January to May, potato tubers were preserved in semi-underground storage at temperatures ranging from 0.2°C to 13.6°C and a relative humidity of 87-96%. After 5 months of storage under harsh winter conditions, tubers had the highest total sugar concentration, recorded at 8.54 mg/100 g. Vitamin B_6 levels were 0.276 mg/100 g in CIPC-treated potatoes and 0.190 mg/100 g in untreated potatoes, representing roughly 15% of the required daily intake. The study found that potatoes stored in zero-energy, semi-underground storage retain outstanding nutritional value after five months and are suitable for consumption (Singh *et al*., 2021). The traditional method of potato storage in the Ladakh area has various drawbacks. Tubers frequently decay owing to improper temperature and humidity in storage pits, sprout in March, and shrivel after April, leaving them unfit for food. An effective, refined storage technology is needed to prevent the spoilage of valuable food and ensure the year-round availability of locally produced potatoes. This would increase the income of local people and meet their food and nutrition security needs. Due to the shortage, potatoes for the civilian population and Armed Forces deployed in this region must be airlifted from other parts of the country, as roads are closed from October to June.

2.6 Physio-chemical parameters affected during storage

Ozturk and Polat (2016) were evaluating the physical and chemical properties of different potato cultivars (Binella, Granola, Banba, Natascha, Toscana, Slaney, and Marfona) at the end of the storage. The researchers investigated weight loss and studied chemical parameters such as specific gravity, dry matter, starch content, protein content, and chip efficiency. At the conclusion of storage, each cultivar decreased in weight at the extension of storage. Some potato cultivars improved in chemical qualities, while others declined. At the conclusion of storage, the average changes documented across all potato types were 2.03% in weight, 0.06% in specific gravity, 1.46% in dry matter, 2.95% in starch content, and 7.85% in protein content. To investigate the influence of various packaging materials on the qualitative features of potato tubers, with a focus on their physicochemical and functional aspects.

According to Abbasi *et al*., (2016), packing materials have a substantial impact on various essential quality metrics. A long-term storage of potatoes exhibited a lower amount of ascorbic acid levels, weight loss, glucose, glycoalkaloid levels, polyphenol oxidase, and peroxidase activity. During storage, both total phenolic levels and radical scavenging activity exhibited a downward direction. Among the packaging materials examined, low-density polyethylene and polypropylene showed the highest overall retention of important quality features during the 63-day storage duration. Yuan *et al*., (2021) investigated the effect of micro-perforated packing on the qualitative characteristics of Pak-Choi (*Brassica rapa* sub sp. chinensis) kept at 20°C and then shifted to 4°C after seven days. After 3 days, the micro-perforated packaging maintained high oxygen levels (12.5% O_2 and 8.9% CO_2) via 12 micro-perforations of 100 mm diameter. The control group had the most weight loss and discoloration, and packaging without holes produced an unpleasant Odor. Micro-perforated packaging helps to avoid yellowing by reducing chlorophyll-degrading enzyme activity, boosting total polyphenol content, improving antioxidant capacity, and keeping the flavor of Pak-Choi. Processing and packaging are the two most important steps of the food business. Proper packaging extends the shelf life of fresh and freshly cut fruits and vegetables. Key factors in this extension include temperature, moisture, and the controlled environment of gases such as oxygen, carbon dioxide, and ethylene. If both temperature and packaging conditions are optimal, the aging of fruits and vegetables can be significantly slowed down (Ščetar & Kurek, 2010). Europe requires an advanced logistical system to ensure a round the year supply of fresh fruits and vegetables. This study analyses and compares the most common transportation packaging methods used in Europe—single-use wooden and cardboard boxes and reusable plastic crates—evaluating their impacts on the environment, economy, and society. Albrecht *et al*., (2013) suggested methods to enhance the sustainable life cycle performance of all three packaging technologies. Single-use hardwood boxes and plastic crates have better environmental performance. However, there is potential for sustainability enhancement in all transport packaging technologies, notably in system aspects like end-of-life treatment. Polypropylene film proved to be the most effective treatment for minimizing pod weight loss compared to stretch film (Shehata *et al*., 2015). Snap bean pods packed in polypropylene or stretch film exhibited a lower percentage of weight loss compared to those that were unpacked during storage across both seasons. The impact of seven packing materials on the post-harvest quality of tubers from three different potato cultivars was investigated. The packaging materials examined were clear perforated and non-perforated high-density polyethylene (HDPE) bags, black perforated and non-perforated low-density polyethylene (LDPE) bags, nylon gunny sacks, khaki bags, and net bags. Among these solutions, black perforated low-density polyethylene (LDPE) bags proved to be the most successful in preserving potato quality. They produced the minimum sprouting, weight loss, tuber greening, and decay as compared to the other materials tested (Nyankanga *et al.,* 2018).

According to Soomro *et al.*, (2016), a study found that a hardwood-packed structure with a raised platform and all-around ventilation created the ideal environment for storing onion bulbs for 90 days. Compared to nylon net bags and open ground storage, the wooden structure on an elevated platform with all-around ventilation yielded the best results, minimizing losses during the storage period. The application of nano clay packing after the decontamination process preserved the sugar content and resulted in a favourable degree of weight loss, according to the physicochemical tests. The application of nano clay may greatly extend the shelf life of grated carrots, according to microbial data. For films containing 3% nano bentonite and minimally processed carrots, a 12-day shelf life was recommended as opposed to 5 days in earlier studies (Ghorbani *et al.*, 2021). Radish roots (*Raphanus sativus* L. var. Kwandong) were packed at 0°C using a number of packaging techniques, including paper carton boxes (control), plastic crates (PC), and plastic crates with micro-perforated HDPE film (HDPE + PC). Radish roots packed in HDPE film recorded significantly less minimum weight loss (3%) than controls (10%) or unwrapped samples (18%). The combination of curing, HDPE film, and plastic crates (Curing + HDPE + PC) caused higher amounts of soluble solids and firmness. Furthermore, film-wrapped samples had a longer commercial shelf life, with fewer black spots, surface shrinkage, and fungal infections. According to Chandra *et al.*, (2018), samples wrapped in HDPE film have a shelf life that is more than one month longer than the control and two months longer than unpackaged samples. Compared to other packaging methods and storage environments, Modified Atmosphere Packaging (MAP) with PP film in a chilled environment significantly extended the shelf life of pointed gourds up to 16 days while preserving their texture, colour, ascorbic acid content, and marketability. In contrast, using LDPE film with pinholes and PP film as MAP storage extended the shelf life of pointed gourds by up to 4 days under ambient conditions (Sahoo *et al.*, 2015). Non-perforated polybags were effective in reducing physiological weight loss and decay while maintaining higher levels of fruit firmness and color, thereby extending the shelf life of Aonla fruits (Singh *et al.*, 2009). Additionally, corrugated fibre board boxes with newspaper cuttings significantly lowered the injury level to the fruits. Plastic packing efficiently maintains cucumber quality (Owoyemi *et al.*, 2021), but it has adverse effects on the environment. Biodegradable modified atmosphere packaging (MAP) with various perforation rates was examined as a viable alternative to conventional plastic packaging. The study found that packing protected cucumbers from weight loss and shrinking. However, biodegradable MAPs with microperforations that created a modified environment of 16–18% O_2 and 3-5% CO_2 were the most efficient. This packing strategy minimizes pitting, wart formation, yellowing, and decay. Thus, micro-perforated biodegradable packaging might replace plastic packaging, increasing cucumber storage life under prolonged shelf conditions and in simulated farm-to-fork supply chain scenarios.

According to Akomolafe and Awe (2017), packaging produce in polyethylene bags immediately after washing and disinfecting can address the issue of microbial contamination for bitter kola, apple, date, carrot, and eggplant fruits sold at motor parks and busy roads in Akure and Ado Ekiti, South Western Nigeria. However, cola nuts placed in various plastic bags were discolored with time. The study indicates that wrapping bitter kola, eggplant, dates, and carrots in polyethylene might reduce germ infection and improve shelf life when sold in supermarkets. Storing mangosteen fruit in an LDPE bag with a 1-MCP sachet greatly delayed physiological changes, preserving calyx and pericarp color, fruit firmness, and lowering weight loss%. However, the 1-MCP treatment and packaging did not affect the ratio of total soluble solids concentration to titratable acidity (TSS/TA). Additionally, this method not only delayed ripening and senescence of mangosteen stored at 13°C for 30 days but also reduced natural infection by postharvest fungi (Vo *et al*., 2016).

Hassan *et al*., (2022) investigated the nutritional value of pointed gourd (*Trichosanthes dioica* Roxb.) stored at 4°C and room temperature (30°C) using modified atmosphere packaging materials such as non-perforated polyethylene, polypropylene packets, brown paper bags, and no packaging. Pointed gourd packaged in a perforated bag, non-perforated polyethylene, and polypropylene bag stored higher quantities of beta-carotene, vitamin C, and greenish color (lower L* and higher h*) following storage at both temperatures. The study found that pointed gourd packaged in perforated and non-perforated polyethylene and polypropylene retained higher levels of beta-carotene, vitamin C, and a greenish hue (lower L* and higher h*) after storage at both temperatures. According to Mahajan *et al*., (2015), shrink film was more effective than unwrapped control fruits in preserving various attributes such as total soluble solids, sugars, acidity, and ascorbic acid content throughout the shelf life. Additionally, it contributed to reducing weight loss, firmness degradation, and decay incidence. Modified atmosphere packaging (MAP) is its ability to manage fruit senescence, associated biochemical and physiological changes. Peach packed in paper-moulded trays and wrapping in heat-shrinkable film shows improving shelf life and maintaining quality during storage. The quality parameters of Nema-Netta variety of tomatoes were influenced by different packaging materials and storage conditions. The study included treatments such as unpackaged tomatoes stored at ambient and cold temperatures, as well as tomatoes packaged in stamped paper (SP) + polyvinyl chloride (PVC), expanded polystyrene (EPS) + PVC, expanded polystyrene (EPS) + flow wrap, and polypropylene (PP). Over 28 days, firmness, physiological weight loss (PWL), pH, titratable acidity (TA), and total sugars were measured at 7-day intervals. Cold storage conditions ranged from 8 to 12 degrees Celsius (78 to 80% RH), while ambient storage conditions ranged from 22 to 26 degrees Celsius (68 to 72% RH).

According to Dladla and Workneh (2023) packaging technique and storage conditions had an important impact on physiological weight loss, fruit hardness, pH, TA, and total sugars. Tomatoes packed in EPS trays with PVC cover showed better preservation than alternative packaging solutions. Combining efficient packing and cold storage created a perfect developing for preserving tomato quality. Packaging materials such as low-density polyethylene (LDPE), biaxially oriented polypropylene laminated with low-density polyethylene (BOPP/LDPE), and oriented nylon laminated with low-density polyethylene (ONY/LDPE) have an impact on the microbial changes and storage quality of fresh-cut cabbage stored at 2°C. According to Nur Aida *et al.*, (2007), the packing materials influenced sensory perception, surface color, chemical analyses, and gas production (CO2 and C2H4) but not soluble solids content (TSS) or browning. LDPE has proven to be more effective than conventional packaging in retaining sensory quality and CO2 production during storage. According to the findings, LDPE is an acceptable packing material for freshly cut cabbage since it preserves sensory quality and keeps microbiological counts low for thirteen days of storage. Sharma *et al.*, (2020) investigated the impact of various packaging materials—polypropylene (PP), perforated polypropylene (PP(P)), low-density polyethylene (LDPE), perforated low-density polyethylene (LDPE(P)), brown gunny sacks (BS), and white nylon gunny sacks (WS)—on post-harvest quality parameters of tubers stored at both refrigerated (8°C) and non-refrigerated (25°C) temperatures. Lower weight loss and higher accumulation of total phenolics and antioxidant activity were recorded in low-density polyethylene and polypropylene bags at different temperatures. The presence of perforation helps to increase potato firmness at both temperatures. For long-term storage, PP(P), LDPE(P), BS, and WS are advised, whereas PP and LDPE are ideal for short-term storage.

2.7 Effect of storage on physiological and biochemical changes in horticultural crops

According to Sharma and Lee (2016), during the initial 90 to 120 days of storage at 4°C, there was an accumulation of fructose and glucose, while sucrose levels remained constant. Conversely, at 10°C and 25°C, fructose and glucose concentrations gradually decreased, while sucrose concentration steadily increased. Odebode and Unachukwu (1997) was reported that two to four days after infection, the total soluble sugar content in rotting carrot roots significantly decreased. Paper chromatography showed that healthy carrot roots contained glucose, maltose, sucrose, lactose, and galactose, whereas only lactose and galactose were present in infected roots. Additionally, infected carrot roots exhibited reduced concentrations of ascorbic acid, total nitrogen, crude protein, crude fibre, fat, and minerals as the storage time progressed. According to Nyman *et al*., (2005), storage had no effect on dry matter content but did change dietary fibre solubility, fructose concentration, and sucrose content. After storage, the 'Amarant' carrot cultivar had a higher sucrose-to-monosaccharides ratio than the other cultivars, although the 'Lonto' cultivar lost more dry matter than the others.

This study investigated changes in carbohydrate metabolism in tubers from 11 Indian potato cultivars stored for 150 days at room temperature, 15°C, and 4°C. While low-temperature storage had minimal impact on the levels of starch and maltose, it significantly increased the concentrations of reducing sugars, total soluble sugars, fructose, glucose, and the ratio of hexoses to sucrose. Additionally, sucrose levels in the tubers decreased at 4°C. According to Galani *et al.,* (2017), there is a significant positive correlation between fructose and glucose, as well as between reducing sugars and total soluble sugars. The effect of storage temperature on the ripening, shelf life, and chemical composition of custard apple (*Annona squamosa* L.) was studied. During storage, custard apple was observed a gradual decrease in fruit firmness and starch content, alongside a consistent rise in total soluble solids (TSS) and sugars. These changes occurred more rapidly at 25°C and 20°C than at 15°C and 10°C. In fruits stored at various temperatures, acidity and ascorbic acid levels initially increased slightly during the early stages of ripening before subsequently declining (Prasanna *et al*., 2000). Across all storage methods, orange carrots maintained a relatively stable total antioxidant activity. Purple carrots showed a substantial drop ($P < 0.01$) in antioxidant activity. Additionally, the overall carotenoid concentration in both orange and purple carrots reduced after storage (Alasalvar *et al*., 2005). According to Sohany *et al*., (2016), Red onion bulbs were kept without wrapping at ambient conditions (25˚C ± 3˚C and 75% RH) and within polyethylene pouch at 2.5˚C, 6˚C, 7˚C and 13˚C for 60 days of storage period. The greatest decrease (23.25%) in weight was observed throughout storage for onions stored at ambient conditions. TSS was observed to increase in all samples until 40 days of storage and then decreased up to 60 days. Lowest TSS (14.89 ˚B) was found in onion stored at ambient conditions at the end of storage. Changes in TSS content were natural phenomenon that occur during storage and it is correlated with hydrolytic changes in carbohydrates during storage. The reduction in TSS during storage indicate faster metabolic rates at higher temperature as also reported by Mahajan *et al*., (2006). Total soluble solids content increased in initial stage followed by reduction. A decreasing trend in the reducing and non-reducing sugar of passion fruit was observed under all the treatments (Kishore *et al*., 2011). The gradually occurring increase in TSS (Total Soluble Solids) recorded over the conclusion of the study suggests that Aloe vera gel treatments reduced carrot respiration rate during storage. The initial increase in TSS might be attributed to starch hydrolysis into sugar, but successive decreases could be attributed to sugar conversion into organic acids and a slower rate of respiration (Mirani *et al*., 2022). Edible coating slows the breakdown of complex sugars into simple sugars by controlling the respiration rate. The total soluble solids (TSS) of vegetables increase during storage due to the breakdown of starch into soluble sugars or hydrolysis of cell walls (Tiwari *et al*., 2022 and Tiwari *et al*., 2023). The impact of cold storage on the phenolic compounds of 19 fruits and vegetables, sourced from local Indian markets and kept in a refrigerator at 4°C for 15 days, was investigated. Pomegranate exhibited the highest levels of titratable acidity, and refrigeration did not significantly increase titratable acidity, which was the main contributor to total phenolics in the fruits and vegetables. Storage led to a substantial decrease in ascorbic acid, which was largely correlated with total phenolics (Galani *et al*., 2017).

According to Tabikha *et al*., (2010), the primary components in unconventional fruit and vegetable juice blends undergo changes during cold storage (5-7°C) over three months. The results revealed that moisture, total sugars, non-reducing sugars, β-carotene, total soluble solids, and pH value of the juice blends decreased, whereas total solids, reducing sugars, and total bacterial counts increased after three months of cold storage. Titratable acidity of orange was reduced with storage periods at ambient temperatures. Day and night temperatures tend to increase acid loss in oranges, with acidity decline related mostly to temperature and continuous respiration during storage. A fast respiration rate reduces citric acid accumulation in plant cell vacuoles and causes acids to be used more quickly during metabolism. Although titratable acidity decreased over time, storage conditions had no significant effect ($p>0.05$) on titratable acidity in orange samples (Orange, 2014). Singh and Sharma, (2017) reported that the stability of ascorbic acid in consumable items is influenced by factors such as temperature, pH, sunlight, and the presence of metals like copper and iron. However, storage conditions have a significant impact on ascorbic acid retention in foods. Ahmed *et al*., (2008) was reported that the quality of citrus juice was determined during the end of storage periods. The amount of ascorbic ac id reduced considerably at all storage times with the degree of loss varying based on processing techniques, storage length, and light exposure.

According to Lee *et al.,* (1986) was observed changes in provitamin A carotenes during carrot preservation. Alpha- and beta-carotene levels gradually increased over 100-125 days before dropping. Furthermore, beta-zeacarotene and gamma-carotene, which have been identified as beta-carotene precursors in the biosynthetic pathway of numerous fruits and vegetables, peaked at 125 and 50-70 days, respectively. According to several researches, temperature and air humidity are the most important factors influencing carrot storage performance. Belitz *et al*., (2004) emphasis the vital importance of good post-harvest handling and storage, suggesting that improper storage might result in a loss of 5-40% of carotenoids. Carrots lose more β-carotene when stored in cellars compared to cold storage. Polyphenol chemicals in carrots help to determine colour, bitterness, flavour, and rheological qualities. These chemicals improve the nutritional value of carrots and provide antioxidant protection. The improvement in polyphenol content varies according to the carrot variety and genotype. Polyphenol compounds are susceptible to oxidation during storage in the presence of oxygen, resulting in a decrease in content. Microorganism-driven biodegradation mechanisms are responsible for the drop in polyphenol content during storage. After six months of storage, the content of polyphenol components in Nante carrots declined by 64.6% for caffeic acid, 37.9% for chlorogenic acid, and 81.5% for vanillin (Augšpole *et al*., 2017). Baltazari *et al*., (2020) reported that storage duration had significant effects on the vitamin C, total flavonoids, total sugars, and reducing sugars in both Msasa and Jaffa orange fruits. Both vitamin C and total flavonoids decreased with the duration of storage. The total sugars and reducing sugars were increased at both Msasa and Jaffa oranges with storage time, regardless of storage conditions or postharvest treatments used. Potatoes have been stored at five different temperatures (4°C, 8°C, 12°C, 16°C, and 20°C), with samples collected at regular intervals (at least five times) to assess several quality parameters. The result suggested that potatoes become softer and darker over time, with higher temperatures accelerated these changes. During storage, ascorbic acid (AA), pH, and starch (S) concentrations decreased, whereas reducing sugars (RS) and total sugars (TS) increased. The respiration rate also increased with temperature and storage time (Nourian *et al*., 2003). Tedeschi *et al*., (2023) studied the decrease in sulfur content after 6 months that has related to a decline in bioactive effects. However, the amount of antioxidant maintained constant during the storage period. The result shows refrigeration successfully extended the shelf life of garlic bulbs.

The plastic packaging likely slowed spoilage because it does not support the growth of microorganisms responsible for spoilage, unlike raffia and wooden crates (Saeed *et al*., 2010). To studied the effects of storage conditions and packing materials on tomatoes' shelf life and quality. Tomatoes stored in the natural environment without packing (control) lost the weight (11.68%) of 24 days interval, whereas tomatoes stored in a refrigerator with HDPE wrapping lost the weight in minimum (1.67%). Organic acid levels typically decrease during maturity because they are substrates for respiration. Significant differences in firmness values were noted due to storage conditions. Although a decrease in firmness was observed over storage days, this trend was not linear. Generally, reducing the storage temperature (refrigeration) slows the metabolic activity of the stored product, including firmness (Sualeh *et al*., 2016). The green synthetic zinc oxide nanoparticles (ZnO-NPs) and Arabic gum may preserve the post-harvest freshness of mandarin fruits (El-Beltagi *et al*., 2023). The fruits were coated with an edible ZnO-NP and Arabic gum combination for 3 minutes after stored at 5 °C and 95% relative humidity for 40 days. Among the experiments application of ZnO-NPs and Arabic gum, used as an edible coating, were extremely successful in lowering physiological variations and preserving the quality of mandarin fruits (cv. Kinnow). Specifically, 0.5% ZnO-NPs mixed with Arabic gum significantly reduced weight loss, cold damage, and electrolyte leakage when compared to the control. Additionally, applying 1% ZnO-NPs reduced rind pitting. All treatments enhanced antioxidant enzyme activity and preserved the phytochemical and antioxidant content of the fruits compared to the controls stored in cold conditions.

Cabot *et al*., (2019) highlight the essential role of zinc as a micronutrient in growth, development, and defence across all living organisms. The review focuses on how competition for zinc influences host–assailant interactions in both plant and animal systems. It presents a framework for the defence strategies plants employ under varying zinc concentrations. the macro and micronutrients involved in plant defence, however the functions of superoxide dismutase (SODs) and zinc finger proteins as major components of plant defence systems. Gupta *et al*., (2012) conducted a meta-analysis to explore the role of zinc finger domains in resistance (R) proteins from various crops. The result show 70 R genes from various crops showed 26 proteins with zinc finger domains and nucleotide binding site-leucine-rich repeat (NBS-LRR) domains. They found 34 zinc finger domains across R proteins in nine crops and classified them into 19 separate groups. The zinc finger domains varied in size from 11 to 84 amino acids, while the proteins containing these domains ranged from 263 to 1305 amino acids. The study highlights the significant role of resistance proteins, which use NBS and LRR domains to detect pathogen signals. The co-occurrence of NBS-LRR and zinc finger domains suggests an important role for these domains in host–pathogen interactions. The effects of boron (B) and zinc (Zn) on potato plant defence against early blight (Machado *et al*., 2018). They injected Alternaria grandis isolates into potato plants after 40 days of showing, then measured disease incidence and severity seven days later. The highest incidence of early blight varied from 16% to 41% was observed in plants treated with boron alone followed by the control. The lowest incidence of early blight was found in plants treated with zinc or zinc-boron combination. The study indicates that zinc plays a crucial role in reducing both the incidence and severity of early blight. Huber and Haneklaus (2007), emphasize the importance of mineral nutrients in agriculture for enhancing plant yields, quality, and health. Proper application of these nutrients is crucial for efficient production and maintaining a healthy ecosystem. Plant nutrition influences various aspects of plant health, including its histology, disease resistance, and pathogen virulence. Mineral nutrients often serve as the first line of defense against plant diseases, impacting every level of the disease "pyramid." Effective nutrient management, including amendments, improved genetic efficiency, and environmental adjustments, is essential for successful agricultural production and controlling plant diseases.

Khoshgoftarmanesh *et al*., (2010) found that zinc (Zn) supplementation could reduce the risk of wheat infection with Fusarium root rot. Zn enhanced cell membrane integrity and decreased oxidative damage to membrane lipids, as evidenced by the presence of non-protein SH groups in the roots. The result membrane permeability was increased and helped the crop tolerate Fusarium solani. While there was no clear link between Zn efficiency and the severity of Fusarium root rot, various wheat genotypes exhibited variable degrees of tolerance to both Zn insufficiency and Fusarium infection. Zinc (Zn) protects plants from oxidative stress by inhibiting the generation of reactive oxygen species (ROS) caused by membrane-bound NADPH oxidase. Iron concentration in Zn-deficient plants typically rises, exacerbating free radical production. This condition renders plants more susceptible to photooxidative damage because Zn-deficient leaves are extremely sensitive to light and can rapidly develop chlorosis and necrosis when exposed to high light. Zinc protects various important cell components, including membrane lipids, proteins, chlorophyll, SH-containing enzymes, and DNA, against oxidative damage. Thus, Zn plays an important role in the plant's defense against ROS and helps preserve cellular integrity (Cakmak, 2000). To study involving foliar spraying of zinc and boron over two seasons, fruits were collected and stored for 2 months under two different storage conditions: ambient temperature storage (ATS) at 25 ± 2 °C and low temperature storage (LTS) at 15 ± 2 °C with 60%–70% relative humidity (RH). The results showing that sweet oranges stored at low temperature (15 ± 2 °C) and maintained better fruit quality compared to ambient temperature. Whereas, the application of zinc and boron significantly enhanced fruit juice content, total soluble solids (TSS), ascorbic acid (AA), and non-reducing sugars (NRS). Specifically, fruits treated with high zinc (1%) and low boron (0.02%) concentrations exhibited higher levels of juice content, TSS, and AA. However, with extended storage times, there was an increase in weight loss, disease incidence, and TSS, while reducing sugars (RS) decreased. Both fruit juice, AA, and NRS levels diminished with longer storage durations (Sajid *et al.,* 2012).

Recent advances in boron research have significantly enhanced our understanding of its role in plants. The discussion regarding boron mobility in the phloem was largely clarified by the identification of boron–polyol transport molecules. Evidence of boron's role in cross-linking pectin polymers emerged with the isolation and characterization of boron–polysaccharide complexes from cell walls. Furthermore, boron's participation in membrane activities was proven by inhibiting and then recovering proton release after boron was removed and restored into plant culture medium. Membrane components that bind to boron may be responsible for the fast changes in membrane function observed during boron variations. Furthermore, boron may affect metabolic pathways by binding to apoplastic proteins on cell walls and membranes and interfering with manganese-dependent enzymatic activities (Blevins & Lukaszewski, 1998). Islam *et al*., (2017) studied about the application of boron (B), calcium (Ca) and silicon (Si) on quality and shelf life of 'Unicorn' cherry tomatoes at maturity stage. The tomatoes were stored at three different temperatures (5°C, 11°C, and 24°C) using modified atmosphere packaging (MAP) and oxygen transmission rate (OTR) film. The results showed that the combination of B + Ca + Si caused the lowest respiration rates, ethylene production rates, lower weight loss, and longest shelf life. This treatment also increased fruit firmness during harvest. After storage, tomatoes treated with B + Ca + Si had considerably lower amounts of soluble solids, lycopene, and colour formation than control tomatoes. However, these treated tomatoes had increased titratable acidity and vitamin C levels. Thus, the B + Ca + Si treatment significantly slowed the development of cherry tomatoes, retained their firmness, and extended their shelf life.

CHAPTER-3

MATERIAL AND METHODS

The present experiment was investigated at the Agriculture Research Unit, Defence Institute of High-Altitude Research-DRDO, Leh during the cropping season year 2020 and 2021 to study the effect of preharvest application of micronutrients on the performance of carrots and their shelf life under different storage conditions at cold desert trans-Himalayan Ladakh region. The experiment was conducted with an aim to study the effect of micronutrients (Zinc and Boron) on the growth, yield, and quality of carrots as well as to investigate the changes in the quality and physiological values of carrots during long-term storage. Detailed information about the experiment site, materials and methodology are briefly given below:

3.1 Experimental Site:

Geographically, Defence Institute High Altitude Research (DIHAR) -DRDO, is located at Leh-Ladakh at height of 3000 m above sea level (MSL) in the temperate zone of the north Himalayan at 25° 56 latitude and 80° 52 longitudes.

Figure 3.1. Experimental site (DIHAR-DRDO, Leh-Ladakh, India). Kaushal *et al*., 2023

The present study was conducted during the *summer* and *rabi* seasons of 2020-2021 and 2021-2022 at the Agriculture Research Unit, DIHAR-DRDO, located approximately 2.5 km away from Leh Airport. The Defence Institute of High Altitude Research (DIHAR) of the Defence Research and Development Organization (DRDO) has been working on various aspects of vegetables in the region for over five decades. With the help of new technologies, vegetables can be stored for long periods of time and consumed in the region.

3.2 Climatic condition:

At an average elevation of more than 3000 m, Ladakh's high mountain region has ragged topography and heavy snowfall for six months a year, making the region critical for Agriculture (Stobdan *et al*., 2018). Extreme temperature changes, minimal precipitation, primarily in the form of snow, high wind velocity, plant density, a thin atmosphere with significant UV radiation, and fragile environments characterize this region (Fig. 3.1). The temperature drops down -20 to -30 ºC during winter. The radiation level in this region ranged from 6 to 7 Kwh/mm due to the high altitude and low humidity, with a longer photoperiod (Singh *et al*., 2019). Only five to six months (April to September) are suitable for plantation and harvesting; therefore, different storage practices are important to increase the shelf life and meet the requirements for the remaining five to six months during winter. Data were recorded in weather acquisition system of DIHAR-DRDO (Fig. 3.2).

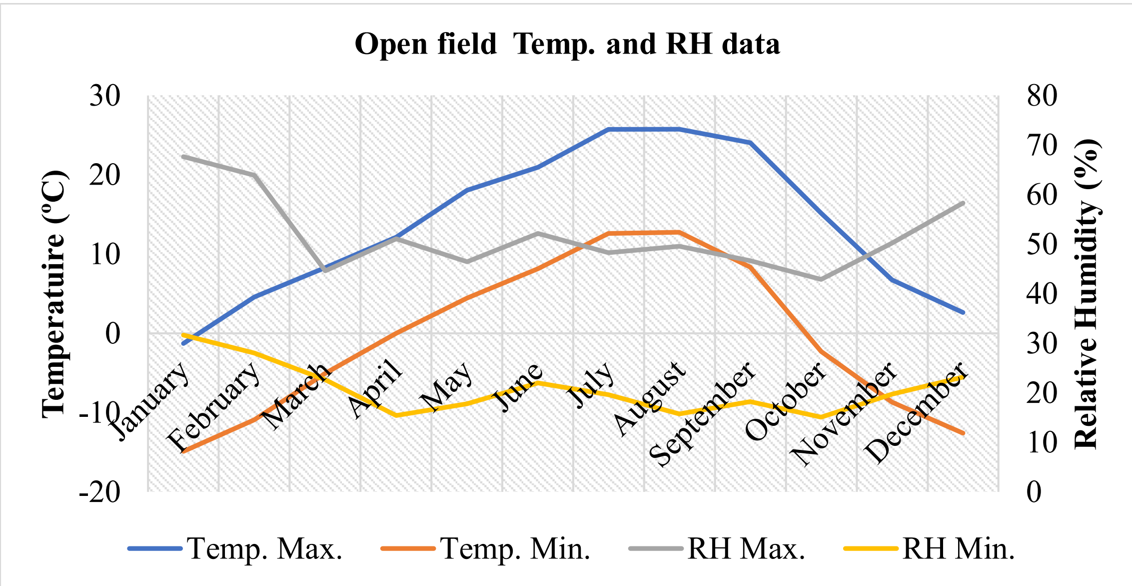


Figure 3.2. Average metrological data during field trail (2020-2022)

3.3 Soil of the experiment site:

The soil's chemical characteristics were examined using the methodology described by Page *et al*. (1982). Prior carrot cultivation, soil samples were collected from 0 to 30 centimetres deep. Soil samples from each replication treatment were collected, aggregated, and shade-dried. Then, any noticeable organic material, such roots, leaves, and twigs, was removed. Field samples were physically sieved via a 2 mm mesh sieve. After blending the replicates, a composite sample for each treatment was created. The pH level of soil was measured using a pH meter (Hanna HI 8424 pH meter, Europe) in a 1:2.5 soil suspension, and the electrical conductivity of the soil was measured with a conductivity meter (Sn X24560 thermo scientific, Indonesia). Walkley and Black (1934) estimated organic materials during wet digestion. The available soil N was determined using the Kjeldahl technique [(K-355, Buchi Labortechnik, Switzerland) (Kjeldahl, 1883). The available soil P was determined by NaHCO3 extraction (Olsen and Sommers, 1982) and colorimetric estimate at 880 nm. The available soil K was determined using flame photometry (Jenway PFP7, Bibby Scientific Ltd., UK). Metals in soil such as Mg, Zn, Cu, Fe, and Mn were identified using Lindsay and Norvell's (1978) DTPA extraction approach.

The soils of the experimental field were sandy and coarse textured (Singh *et al*., 2019). However, Zn contents also depend upon soil type, e.g., sandy soils contain relatively less nutrients whereas clayey soils are enriched. The soil pH was estimated before the experiment and was determined as the maximum value of soil pH having 7.76 ± 0.2. The type of soil was sandy having EC- 1.36 ± 0.13 ms/cm, organic carbon- 0.64 ± 0.01%, and available P- 6.03± 3.4 ppm and K- 132.25 ± 7.4 ppm, Zn- 1.41 ± 0.2 ppm, Fe- 2.38 ± 0.3 ppm, B- 2.04 ± 0.1 ppm, Cu- 1.04± 1.0 ppm, Mn- 0.58 ± 0.2 ppm.

3.4 Experimental materials:

3.4.1 Crops and cultivar

Carrot (*Daucus carota* L.) is cultivated across India. Carrot juice is high in carotene and is frequently utilized for flavoring butter and other dishes. Orange carrots are high in carotene, a precursor to vitamin A, and contain a significant amount of thiamine and riboflavin. Carrots are divided into two groups: tropical or Asiatic and temperate or European. The temperate-type carrot cultivar Early Nantes was used for the present studies. They are juicier, have a larger core, a heavier top, and can mature considerably earlier than the other variety. Carrots of the Early Nantes variety were obtained from the DIHAR-DRDO Agriculture Research Center for the open field testing. Almost cylindrical roots that end immediately in a short, thin tail 12-15cm long and fine textured; orange flesh with self-colored cored; maturity 90-110 days.

3.4.2 Application of micronutrients

Zinc Sulfate (Multiplex) and Boron (TATA) were purchased from the market in Chandigarh (Fig. 3.3). Zinc Sulfate Monohydrate and Solubore Boron were used as sources for zinc and boron elements, respectively. Micronutrients zinc and boron were diluted with water before their addition. Foliar application of Zinc Sulfate and Boron in different concentrations were done at an interval of 45 and 90 days of sowing. The application of a combination of diluted micronutrients was done in the following ratio given in Table 3.4.2.1.

Figure 3.3. Micronutrient used during field trial

3.4.3 Storage structure

During the storage trial, three types of storage structures (room storage, underground passive storage and trench storage) were used to estimate the storage behaviour of carrots. The underground passive storage structure was rectangular in shape with interior depth 3 m (0.8 m aboveground level and 2.2 m belowground level), 3.6 m width and 6.7 m length. The roof was constructed with wooden material and masonry walls. All treatments with three replications stored in different storage condition. Temperature data was recorded with the help of Tiny tag datalogger (Fig. 3.4).

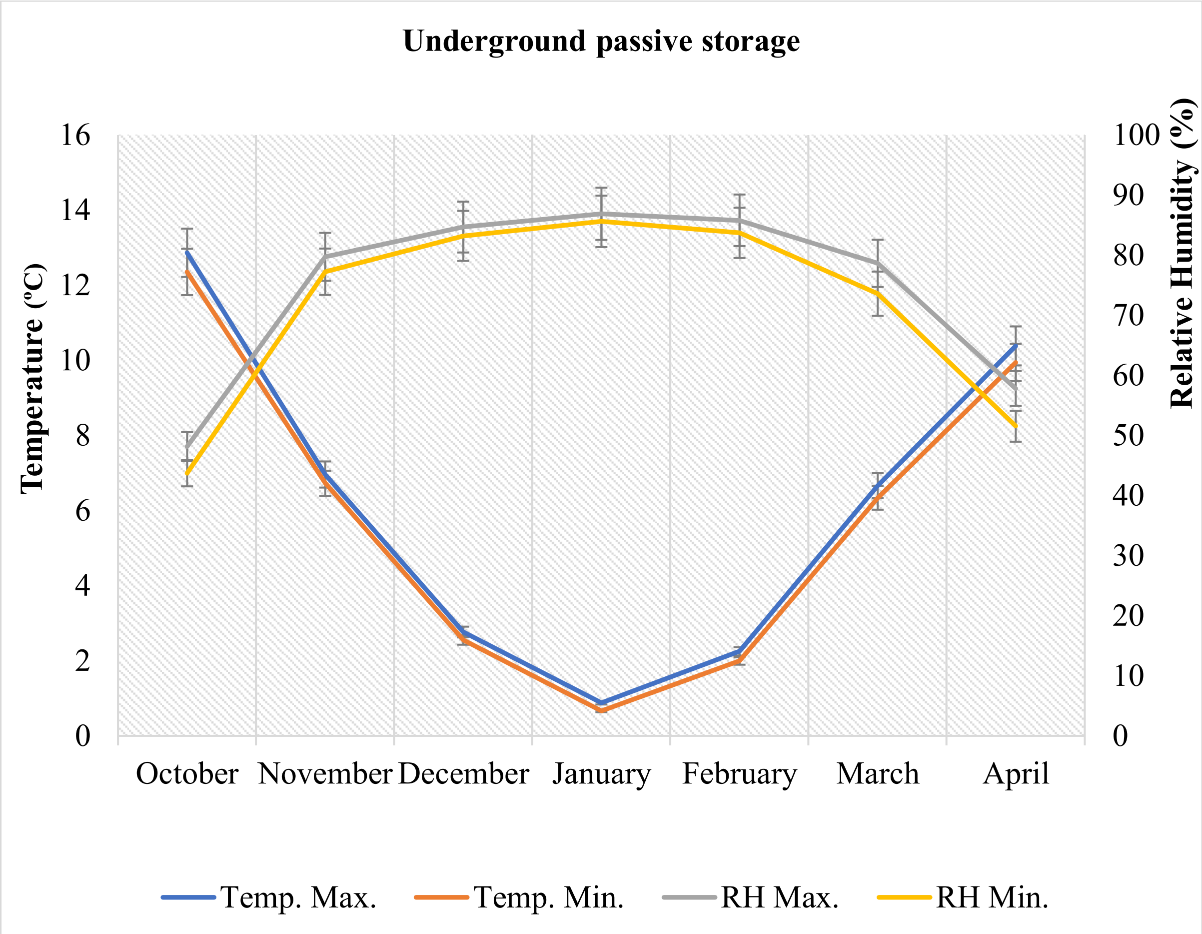


Figure 3.4. Underground passive storage temperature and relative humidity data

A cone shaped trench storage locally known as Sadong is constructed at ground level in a well-drained location. The size of the trench was 180 cm depth, 120 cm surface diameter and 150 cm basal diameter. The trench is made in October ending soon after crop harvesting. All treatments with three replications and stored in a trench storage. Temperature and humidity data in the trench storage was recorded with the help of tiny tag data logger (Fig. 3.5). Shelf-life study was conducted by placing all carrot in a normal room at ambient condition. The temperature inside the room was recorded with the help of testo data logger (Fig. 3.6).

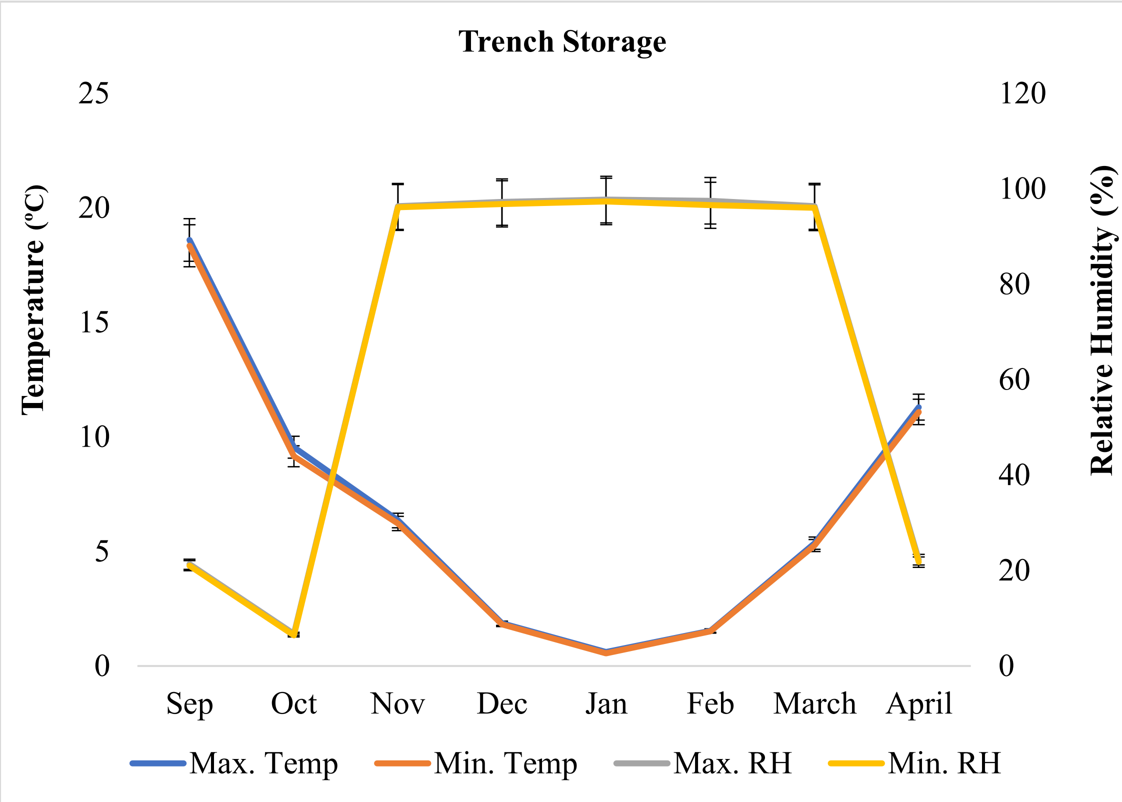


Figure 3.5. Trench storage average temperature and relative humidity data

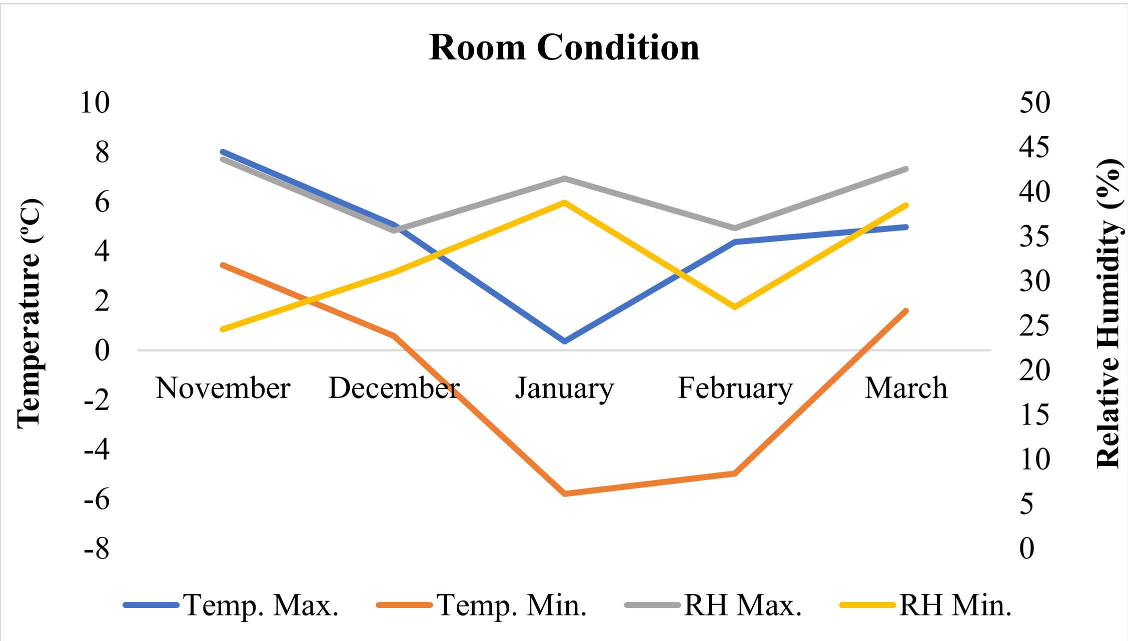


Figure 3.6. Average room temperature and relative humidity data

3.4.4 Packaging Materials

Carrot roots of uniform size and shape, insect/pest free, and without any sign of injury were selected for the storage trial, and were stored in plastic crate, wooden box, leno bag, perforated polyethylene bag, and cotton bag. In perforated polyethylene bag, temperature and relative humidity data were recorded with the help of Testo datalogger (Fig. 3.7). During the storage trial in the cold desert conditions, low humidity was the key strategic issue. All the samples with treatment were stored in triplicates in underground passive storage of Agriculture Research Unit, Leh, DIHAR-DRDO, where temperature and RH were continuously recorded. Physio-chemical changes in the samples during the storage were analyzed in triplicates after every 30 days using analytical grade chemicals and reagents.

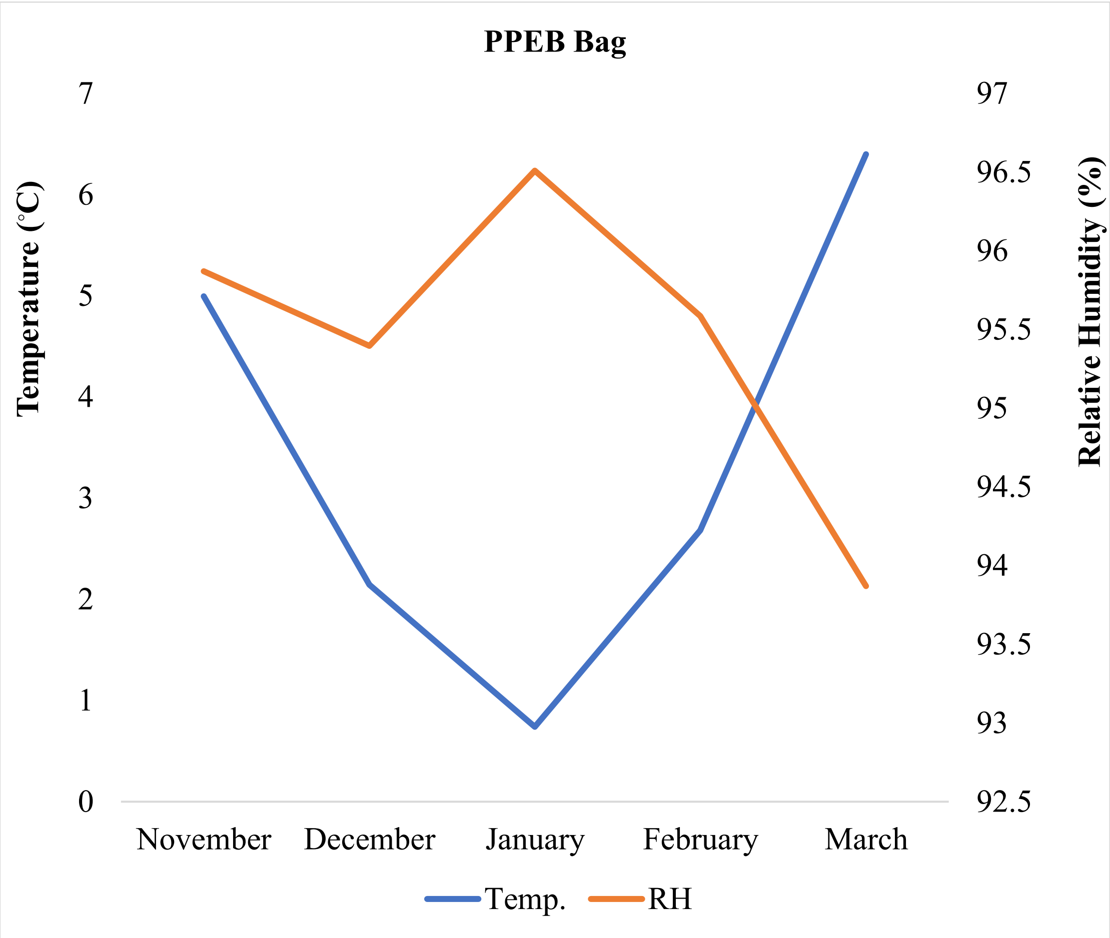


Figure 3.7. Temperature and relative humidity data of perforated polyethylene bag

3.4.5 Experimental procedure:

The experiments were laid out in RBD with three replications and nine treatments.

3.4.5.1 Details of treatments:

Table 3.4.5.1.1 Treatments, combination, and ratio of different applications.

S. No.	Treatments	Symbols
1.	Control	T_0
2.	Boron @ 0.1%	T_1
3.	Boron @ 0.2%	T_2
4.	$ZnSO_4$ @ 0.5%	T_3
5.	$ZnSO_4$ @ 1.0%	T_4
6.	Boron @ 0.1% + $ZnSO_4$ @ 0.5%	T_5
7.	Boron @ 0.2%+ $ZnSO_4$ @ 1.0%	T_6
8.	Boron @ 0.1%+ $ZnSO_4$ @ 1.0%	T_7
9.	Boron @ 0.2%+ $ZnSO_4$ @ 0.5%	T_8

3.4.5.2 Experimental design:

Table 3.4.5.2.1 Experimental details of research trial.

Sr. No.	Particular	Details
1	Crop	Carrot
2	The variety used in experiment	Early Nantes
3	Design	Randomized block design (RBD)
4	Number of treatments	9
5	Date of sowing	15 June, 2020 and 2021
6	Replication	3
7	Total number of plots	27
8	Size of one plot	4×3.9 m
9	Width of main irrigation channel	0.5 m
10	Width of sub irrigation channel	0.5 m
11	Spacing	30 ×10 cm (R × R and P × P)
12	Size of field	37 m × 14.1m (Length × Width)
13	Area of field	521.7 m^2
14	Application of micronutrients	By Zinc and Boron

3.4.5.3 Lay out:

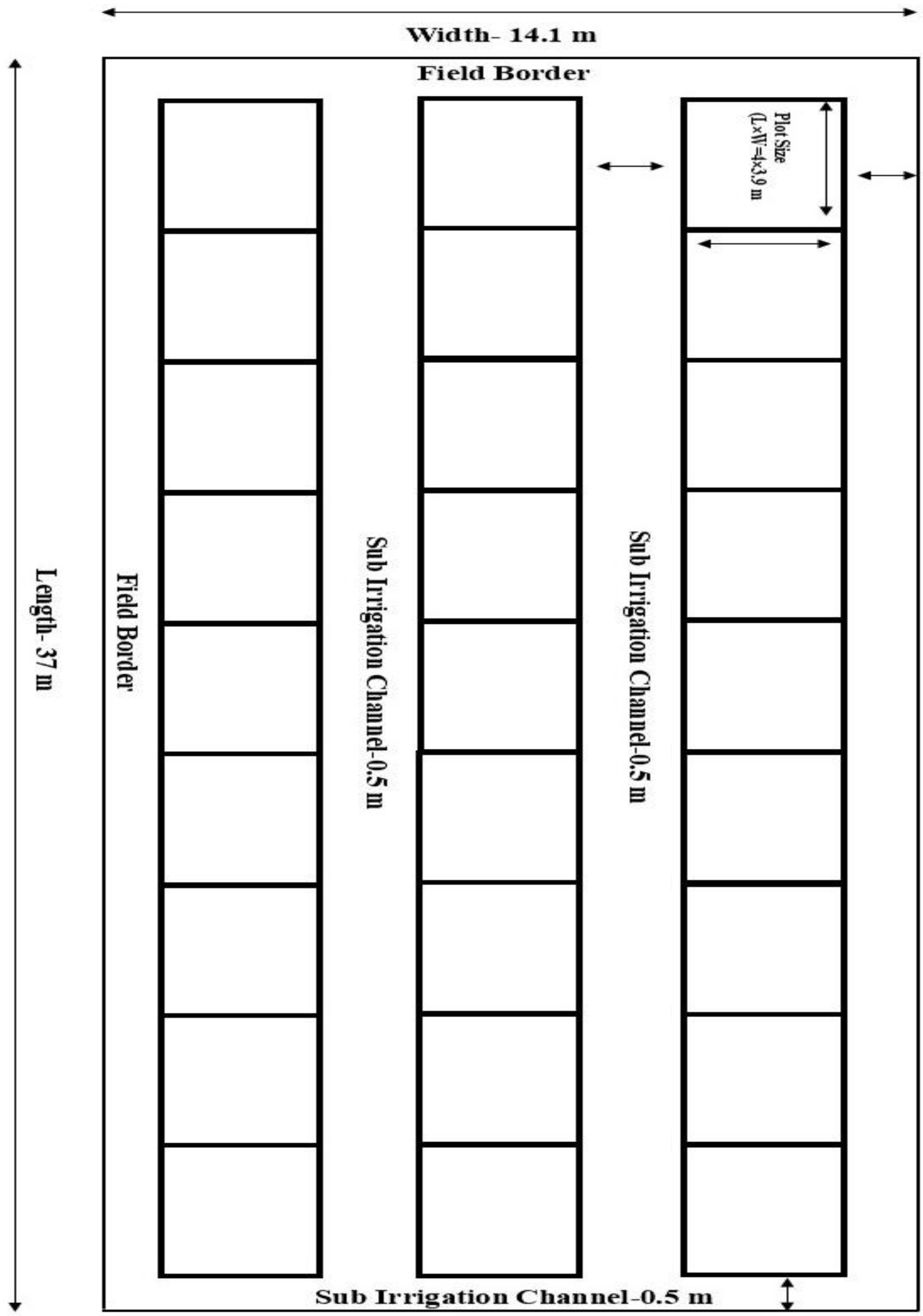


Figure 3.8: Layout of Experimental field

3.5 Cultivation practices:

The experimental field was ploughed with a tractor for the removal of stubble and weeds. Then soil was pulverized by two deep ploughings. Experiments was laid out as per design and treatments were imposed randomly. In all the plots, a recommended dose of FYM was mixed before sowing the seeds. Sufficient moisture in the soil is ensured before sowing and subsequent irrigation were given at 6-7 days interval. The micronutrients were sprayed twice after 45 days and 90 days of sowing.

3.6 Observations recorded during field trial

3.6.1 Morphological Characters:

A minimum of three plants/roots were randomly selected for recording various observations and the average was worked out.

3.6.1.1 Leaf length:

The average length of leaves was measured with a measuring scale.

3.6.1.2 Leaf breadth:

The average breadth of leaves was measured with a measuring scale.

3.6.1.3 Number of leaves per plant:

Total number of leaves per plant was counted and the mean number of leaves per plant was calculated at the time of harvesting to finalization of trial.

3.6.2 Root physical characters:

3.6.2.1 Root Length:

Three full-grown roots were randomly sampled collect at the time of final harvesting. The length was measured from the top and bottom points of the root with the help of a measuring scale. The average length of the full-grown root was calculated.

3.6.2.2 Root Diameter:

Root diameter was measured from the middle portion of the root with the help of digital vernier callipers. A random sample of three full-grown roots was taken from each plot to record the average diameter of the root.

3.6.2.3 Average root weight:

Freshly harvested roots were selected randomly and the root weight of three roots from each treatment was estimated and expressed in grams.

3.6.2.4 Root yield per hectare:

The yield of root per hectare area was calculated by multiplying the number of plants per hectare area by the average root weight and expressed in quintal (q).

Yield per hectare = (Number of plants per ha.) × (Average root weight)

3.6.2.5 Economic of treatments:

At the conclusion of the study, the cultivation cost, gross return, net return, and benefit cost ratio were calculated. Economic calculations were based on the average treatment yield as well as market rates/prices for inputs and outputs. To calculate the net returns, the cultivation costs for each treatment were subtracted from the gross returns obtained from the economic output. The benefit-cost (B:C) ratio was determined by dividing gross returns by cultivation costs for each treatment.

3.6.3 Biochemical characteristics of roots:

3.6.3.1 Total soluble solid:

Carrot juice was extracted from the juicer-grinder machine and filtered through filter paper Whatman No. 1 and total soluble solids were determined by placing drop of carrot juice on the prism of hand refractometer (ERMA). Results were read and expressed as Brix (°B) (Tiwari *et al*., 2025).

3.6.3.2 Leaf chlorophyll Content:

Leaf chlorophyll content were measured using a portable chlorophyll meter at the time of harvesting (CCM-200 plus, ADC Bioscientific, UK) for the 3 youngest completely expanded leaves per plant, and the mean of 3 plants from each subplot was recorded (Tiwari *et al*., 2024). The result was expressed as chlorophyll content index (CCI**).**

3.6.3.3 Titratable acidity:

The titratable acidity was determined as per the method suggested in Narayan *et al*., (2020). 25g of blended root pulp was homogenized and volume was made up to 250 ml in distilled water. The contents were filtered by Whatman filter paper no.1. 10ml of filtered juice was titrated against N/10 NaOH solution, using phenolphthalein as an indicator. The appearance of pink colour indicated the endpoint.

$$\text{Titratable Acidity}(\%) = \frac{\text{Titre value} \times \text{Normality of NaOH} \times 64 \times \text{Volume makeup} \times 100}{\text{aliquot taken} \times \text{weight of sample} \times 1000}$$

The total titratable acidity % was calculated in terms of citric acid and the equivalent weight of citric acid is 64g. The results were expressed in terms of percent acidity.

3.6.3.4 Ascorbic acid content:

Ascorbic acid content was estimated by homogenizing 5g root pulp with 3 per cent metaphosphoric acid as a buffer. The filtered extract was made up to 100 ml volume. Titration of 5 ml aliquot was done against 2,6-dichlorophenol indophenol dye solution till a light pink colour appeared. Ascorbic acid per 100g of fruit pulp (Tiwari *et al.*, 2016).

$$\text{Ascorbic acid } (mg/100g) = \frac{\text{Titre Value} \times \text{dye factor} \times \text{volume makeup} \times 100}{\text{Aliquote taken} \times \text{weight of sample taken for estimation}}$$

3.6.3.5 Mineral determination:

Determination of mineral content for carrot samples was done using Tiwari *et al.*, (2025) methods. Sodium, Magnesium, Iron, Copper, Manganese and Zinc elements were determined using AAS (Analytik Jena) with the help of AAS standard solution of respective elements. About 200 mg of sample was digested by heating in a microwave digester (Analytik Jena) using 8 ml acid mixture consisting of 6.0 ml nitric acid and 2 ml HCl in a Teflon digestion flask, until a clear digest was obtained. This digest was later cooled and diluted up to 50 ml volume and aliquots were used for atomic absorption spectrometry (AAS), using filters that match wavelengths for different elements. Calibration curves were prepared with their standard solution (Sigma Aldrich) for the determination of the concentration of minerals in the samples.

Figure 3.9. Determination of Minerals

3.6.3.6 Determination of inorganic anions and sugars:

The determination of inorganic anions and sugar content of the carrot samples was described by Tiwari *et al.,* (2024), with some modifications. 1.0 g of the carrot samples was homogenized in a tissue homogenizer (IKA, T10 basic ULTRA-TURRAX, Germany) at 15000 rpm in ultrapure (Type-I) water (DQ3, Millipore Waters, USA) for 2 min. Sonication of homogenized samples was done in an ultrasonic bath (Ultrasonic cleaner YJ5120-1, India) at 40°C at 30 min for sugar profiling and 55ºC at 40 min. for inorganic anions, followed by centrifugation at 15000 rpm for 15 min and filtered through Whatman No. 1 filter paper. After further dilutions, the final diluted samples were passed through 0.22 µm microporous membrane filter with 25 mm diameter. Sugar profiling (glucose, fructose, and sucrose) and inorganic anions content were analysed in Ion Chromatography (IC) system (930 compact IC Flex, Metrohm, Switzerland) using RCX-30-7µm-250/4.1mm (Hamilton, USA) column for sugar analysis and MetroSep A Supp 5-

250/4.0 column for anion analysis. Eluent 0.1 M NaOH at a flow rate of 1.0 ml.min^{-1} for sugar analysis. For the anion analysis, mobile phase of 1mM $NaHCO_3$, 3.2mM Na_2CO_3, and 5% acetone were used as eluent at a flow rate of 0.7 ml.min^{-1}, where 100mM H_2SO_4 solution was used as the suppressor solution. Ampherometeric detector was used for soluble sugar detection and for determination of nitrate, phosphate and sulfate, conductivity detector was used.

Figure 3.10. Determination of Sugar and Anions

3.6.3.7 Total carotenes:

The analysis of β -carotene is based on the extraction of crude pigment mixture in lipid solvent as described by Rangana, 1986. Take 5 g sample and crushed it gently with 10 ml petroleum ether by diluting the 3% acetone with water containing 5% sodium sulfate (Na_2SO_4). 10 ml sample was taken in a separating funnel and mixed properly with distilled. Keep it at room temperature for 5min. Repeat the whole process 3-4 times for better extraction of carotenoids. The lower-level water was drain out from separating funnel and supernatant was collected in a test tube. Take the reading in UV-Visible Spectra Max i3x Spectrophotometer at 452 nm against petroleum ether as a blank. β-carotene was used for making standard curve for the estimation of total carotenoids and expressed as μg/100g.

3.6.3.8 Sample Extraction:

A one-gram powdered dry sample was blended three times, each time added 20 ml of methanol. The mixture was rotated at 10,000 rpm for 10 minutes. Whatman filter paper grade 1 was used to further strain all extracts. The supernatant was gathered for measurement. The extraction was conducted at ambient temperature in dark conditions.

3.6.3.9 Total flavonoids content:

Flavonoid content of was determined using an aluminium chloride method (Bhardwaj *et al*., 2019; Tiwari *et al*, 2025). A 300 µl of extracts at various concentrations of the standard rutin trihydrate compound was diluted with 1200 µl of distilled water, followed by the addition of 90 µl of sodium nitrite solution (0.724 M), and the mixture was incubated for 5 min at ambient temperature. Each reaction mixture then received 90 µl of aluminium chloride (0.749 M), and the mixtures were incubated for another 6.5 minutes before 600 µl of sodium hydroxide (1.0 M) was added to each tube. By adding 720 µl of deionized water, the total reaction volume was brought up to 3000 µl. Finally, a spectrophotometer was used to measure the absorbance at 510 nm, with the results expressed as mg of Rutin Trihydrate Equivalent (RE) per gram of dry weight.

3.6.3.10 Total polyphenolic content:

Folin-Ciocalteu (FC) reagent method was used to determine the total polyphenolic content of carrot samples with minor changes (Bhardwaj *et al*., 2019; Tiwari *et al*, 2025). A standard solution was prepared by combining 9 ml of deionized water with 1 ml of extracts at various concentrations, followed by the addition of 1 ml of FC reagent. The mixture was incubated at ambient temperature for 5 min. Each reaction mixture was subsequently incubated at room temperature for 60 min in the dark until the addition of 2 ml of sodium carbonate solution (20%). The absorbances of the samples and standard were measured spectrophotometrically at 750 nm using a Molecular Devices UV-Visible SpectraMax i3x Spectrophotometer (USA). The results are reported as mg of gallic acid equivalent (GAE) per gram of dry weight. The total polyphenol content of the samples was determined using the following formula:

$$C = \frac{c \times v}{m}$$

where: C = total phenolic content, expressed as mg GAE/g dry weight, c = the concentration of the reference standard, as determined by the calibration curve, in mg/mL, v = extract volume in ml, m = mass of the extract in g.

3.6.3.11 Total antioxidant activity:

Carrot juice was extracted from a 20 g sample of roots and filtered through Whatman filter paper No. 1. Subsequently, 1 ml of copper chloride solution (1.705 g/l in distilled water) was mixed with 1 ml each of neocuproine solution (1.562 g/l in ethanol), ammonium acetate buffer at pH 7 (19.27 g/250 ml in distilled water), distilled water, and 0.1 ml of the extracted juice in a test tube. The volume was maintained to 6 mL by adding distilled water. The test tubes were then kept at room temperature for 30 minutes.

A UV-Visible Spectra Max i3x Spectrophotometer was used to determine absorbance at 450 nm in comparison to a blank reagent. Trolox was used to develop the standard curve for determining total antioxidants, which are represented as mMTE/L. The total antioxidant activity was measured using the technique published by Apak *et al*., (2004).

3.7 Observation recorded during storage trial

Biochemical parameters (TSS, acidity, ascorbic acid, total phenolic compound & total flavonoids), minerals, sugars and anions content were studied every 30 days during storage. The experimental procedure has been described as the above.

3.7.1 Weight loss (%) determination:

The weight loss was calculated by measuring the roots' initial and final weights using a digital balance and after that subtracting the initial weight from final weight and expressed as percentage (Tiwari *et al*., 2022).

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial Weight}} \times 100$$

3.7.2 Organoleptic quality:

The organoleptic quality for assessing sensory attributes of the samples was conducted by a panel of eight judges. The samples were rated on the Hedonic Rating Scale as given below (Amerine *et al.,* 1965).

Table 3.7.2.1 Hedonic scale rating score

Organoleptic score	Rating
9	Like extremely (LE)
8	Like very much (LVM)
7	Like moderately (LM)
6	Like slightly (LS)
5	Neither like nor dislike (NLNDL)
4	Dislike slightly (DS)
3	Dislike moderately (DM)
2	Dislike very much (DVM)
1	Dislike extremely (DE)

3.8 Statistical analysis:

A sample of three plants was selected to record the observations for each character. The mean value for each plot from all replicates was used for the detailed statistical analysis. The statistical analysis encompassed all experimental data using SPSS 22.0 (SPSS Corporation, Chicago, Illinois, USA) and MS Excel 2022. Results are presented as mean ± standard deviation. One-way analysis of variance tests (ANOVA) was employed to assess statistically significant differences among the harvested carrots, with a significance level set at $p < 0.05$.

CHAPTER-IV

RESULTS AND DISCUSSIONS

The present investigation entitled "Effect of preharvest application of micronutrients (zinc & boron) on performance of carrot (*Daucus carota* L.) and its shelf life under different storage conditions in cold desert trans-Himalayan Ladakh region" was conducted at Agriculture Research Unit, Division of Vegetable Science, Defence Institute of High Altitude Research-DRDO, C/o 56 APO, Leh-Ladakh with the objective to work out the cultivation processes for enhancing yield, quality and subsequent storage studies of carrot.

4.1 Objective-1: To investigate effects of foliar application of micronutrients (zinc and boron) on yield and quality attributes of carrot.

The result of the field experiment conducted during summer season 2020 and 2021. To study the effect of zinc and boron on growth, yield and quality parameters of carrot (*Daucus carota* L.) is presented in this chapter.

All the data of first objectives were taken at the time of harvesting.

4.1.1 Effects of micronutrients on the growth and yield attributes of carrots at harvest:

4.1.1.1 Number of leaves per plant:

Data recorded on total number of leaves per plant has been presented in Table 4.1.1.1. It is clear from the data that application of boron and zinc significantly improved the number of leaves per plant as compared with control. Mean data showed that the maximum number of leaves/plant (13.16) was recorded in the foliar application of $ZnSO_4$ @ 1.0% (T_4), which is statistically at par with T_1, T_2, T_3, T_5, T_6, T_7, and T_8. Whereas, the minimum number of leaves/plant (9.72) was found in control (T_0). Zinc and boron is a fundamental nutrient to improve plant growth, yield, and quality by carrying out numerous physio-biochemical processes in plant cells. In fact, zinc is recognized as key element in protein synthesis and involved in nitrogen fixation. However, Boron plays a greater role in nitrogen-based synthesis or utilization and involved in RNA metabolism (Alam *et al*., 2021). The combined zinc and boron application indicating the enhanced rate of photosynthesis and improved plant vigour.

Number of leaves increased due to the foliar application of Zn and B (Tiwari *et al*., 2024).

4.1.1.2 Leaf length (cm):

The leaf length of carrot at time of harvesting has been presented in Table 4.1.1.1. It clearly showed that all the treatment significantly at enhanced leaf length over control. However, the maximum leaf length (29.61 cm) was recorded in foliar application of $ZnSO_4$ 0.5% (T_3), which was statistically at par with T_1, T_2, T_3, T_5, T_6, and T_7. While minimum leaf length (20.33 cm) at the time of harvesting was noted with control (T_0). Plant height responses by foliar application of different micronutrients were also determined by Singh and Tiwari (2013). Increase in plant height might be the involvement of micronutrients in different physiological processes like enzyme activation, electron transport, chlorophyll formation and stomatal regulation etc. which ultimately resulted in greater dry matter (Asad and Rafique, 2000; Hussain *et al*., 2005)

4.1.1.3 Leaf breadth (cm):

The leaf breadth of carrot has been presented in Table 4.1.1.1 and it was recorded at the time of harvesting. All treatments, non-significantly difference was shown in the first-year data of leaf breadth. Second years, significantly differences were observed in all the treatments and maximum leaf breadth (10.56 cm) was recorded in foliar application of $ZnSO_4$ @ 0.5 (T_3) and Boron 0.1% + $ZnSO_4$ 0.5% (T_5). Pooled data of the both years was observed non-significantly differences. As zinc and boron are important micronutrients involved in a variety of physiological processes. The improvement in leaf breadths were observed after the treatment of micronutrients. When Zn and B were applied to carrots, the maximum growth was seen compared to the control.

4.1.1.4 Root length (cm):

The foliar application of micronutrient manures influences the root length of carrot significantly. Mean data of each year was found statically significant. The highest root length (17.25 cm) was recorded with foliar application of $ZnSO_4$ 1.0% (T_4), which is statically *at par* with Boron 0.1%+ $ZnSO_4$ 1.0% (T_7) 17.17 cm and Boron 0.1% + $ZnSO_4$ 0.5% (T_5) 16.83 cm. While the lowest value of root length was recorded with control T_0 (12.92 cm). According to Brennan (2005), Zn is necessary for the synthesis of tryptophan, a precursor to IAA, and actively participates in the creation of auxin, a crucial growth hormone. Similar findings were made by Joshi and Raghav (2007) and Ahmed *et al*., (2011), who reported a substantial increase in leaf area with the application of zinc as compared to the control (without zinc and boron). The physiological processes of plants, such as cell elongation, cell maturation, meristematic tissue formation, and protein synthesis, essentially require boron (Pereira *et al*., 2021; Shireen *et al*., 2018,). The application of boron in carrot accelerates growth and crop productivity. The use of boron also encourages the roots of plants to absorb nitrogen, which promotes plant growth (Jing *et al*., 1994; Mishra *et al*., 2018).

4.1.1.5 Root diameter (mm):

The Table 4.1.1.2 showed that application of boron and zinc influenced the root diameter of carrot. The mean data of 1st year and 2nd year trials was found statically significant. The foliar application of Boron 0.1% + $ZnSO_4$ 0.5% (T_5) showed that highest diameter of root (34.59 mm) followed by Boron 0.2%+ $ZnSO_4$ 0.5% (T_8) 32.07 mm, Boron 0.1% (T_1) 31.57 mm and Boron 0.2% (T_2) 31.39 mm. The other hand, the root diameter differed significantly by the application of boron and zinc, the lowest value of root diameter was recorded with control T_0 (24.99 mm). The application of zinc might have enhanced the photosynthesis and other metabolic activities, which led increase in cell division and cell elongation. These findings are in close accordance with the findings of Begum *et al*., (2015), Singh *et al*., (2015a) and Shukla *et al*., (2015) in onion. Whereas, this may be due to the boron application which enhances the enzyme activity which in turn triggers the physiological processes like carbohydrate metabolism in plant. Similar results were reported by Abedin *et al*., (2012), Manna *et al*., (2014), and Acharya *et al*., (2015) in onion.

4.1.1.6 Average root weight (g):

The measurement of the carrot root yield parameters was carried out to check if there was the interference of each treatment on their yield and yield attributes characters. The data (Table 4.1.1.2) also evident that the foliar application of zinc and boron affects the yield and yield attribution character of carrots significantly. The highest root weight (94.95 g) was recorded with foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5) followed by $ZnSO_4$ @ 1.0% (T_4), and Boron @ 0.2%+ $ZnSO_4$ @ 0.5%

(T_7). Whereas, the lowest root weight (61.66 g) was recorded in control (T_0). Zinc is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. The increased gross and quality might be due to effect of Zn and B play a decisive role in improving the productivity of the carrot.

4.1.1.7 Root yield per hectare (q):

The average yield per hectare has been depicted in Table 4.1.1.2. It is clear from the results that all the treatments significantly enhanced yield per hectare over control. However, the maximum yield (316.50 q/ha) was recorded with the foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% followed by application of $ZnSO_4$ 1.0% (T_4) and Boron @ 0.1%+ $ZnSO_4$ @ 1.0% (T_7) found statistically similar in increasing average fruit yield per hectare. The lowest average yield 205.53q/ha was recorded in control (T_0). This could be a result of the improved growth traits brought on by the foliar spray of micronutrients, which would have increased photosynthesis and other metabolic activities, which in turn would have promoted cell division and elongation (Hatwar *et al*., 2003). Zinc and boron have an impact on plant metabolism, therefore applying zinc sulfate and Boron enhanced carrot yield. Additionally, as seen in the current study, improved vegetative development was the cause of the increased root yield.

4.1.1.7 Economics of carrot grown at trans Himalayan region:

Micronutrient treatments had a significant ($p<0.05$) effect on the benefit-cost ratio of carrot grown at trans Himalayan region (Table 4.1.1.3). In the current study it was found that treatment T_5 improved the benefit-cost ratio of carrot, as compared to T_4 and T_7. It is possible that the combined application of boron and zinc improves plant growth and production in the trans Himalayan region, and led to higher profitability (Bahadur *et al.,* 2006; Upadhyay *et al.,* 2012). Better plant growth characteristics and enhanced production in the trans Himalayan region might have been linked to higher physical indices of carrot, which may have led in better profitability (Bhusan *et al*., 2010; Son *et al*., 2018).

Table 4.1.1.1: Effect of zinc and boron on growth parameters of carrot

Treatments	No. of leaf/plant			Leaf length (cm)			Leaf Width (cm)		
	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data
T_0	10.00±1.7a	9.45±0.2a	9.72±1.3a	17.89±2.8a	22.77±0.6a	20.33±2.8a	6.33±0.3a	7.67±0.3a	7.00±0.3a
T_1	11.22±1.0ab	11.33±0.1bc	11.28±0.6ab	28.33±4.3b	27.66±0.5cd	28.00±2.8b	7.67±1.0a	9.45±0.4ab	8.56±0.3a
T_2	12.11±0.8ab	11.67±0.2c	11.89±0.6ab	30.78±2.2b	27.11±1.0bc	28.94±0.1b	9.11±1.5a	9.00±1.2ab	9.06±1.3a
T_3	12.89±1.7b	11.89±0.1cd	12.39±0.8ab	30.56±3.0b	28.67±0.7cde	29.61±1.8b	8.78±2.0a	10.56±2.2b	9.67±1.4a
T_4	13.78±1.7b	12.56±0.5de	13.16±0.3ab	30.78±2.7b	27.56±0.7cd	29.17±0.7b	9.00±2.5a	9.67±0.7ab	9.33±1.6a
T_5	11.45±1.3ab	13.22±0.1e	12.34±2.8ab	29.00±1.5b	29.33±0.6de	29.17±0.9b	7.67±1.5a	10.56±0.2b	9.11±0.7a
T_6	11.11±1.3ab	10.89±0.2b	11.00±0.9ab	29.11±1.6b	29.67±0.6e	29.39±1.6b	8.67±0.7a	8.45±1.1ab	8.55±0.3a
T_7	12.67±1.7b	12.67±0.3e	12.67±0.7ab	27.11±3.1b	27.33±0.6c	27.22±1.9b	8.22±1.0a	9.00±0.6ab	8.61±0.8a
T_8	11.22±0.5ab	12.66±0.2e	11.95±0.6ab	25.33±5.0b	25.33±0.4b	25.33±1.7ab	7.89±1.5a	9.33±0.7ab	8.61±0.8a

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5

Table 4.1.1.2: Effect of zinc and boron on yield parameters of carrot

Treatments	Root Length (cm)			Root Dia. (mm)			Average root wt. (g)			Yield/ha (q)		
	1st Year	2nd Year	Pooled data	1st Year	2nd Year	Pooled data	1st Year	2nd Year	Pooled data	1st Year	2nd Year	Pooled data
T_0	11.17±2.5a	14.67±0.3a	12.92±0.3a	26.17±0.4a	23.83±1.3a	24.99±0.4a	54.10±3.0a	69.22±1.1a	61.66±1.9a	180.34±10.0a	230.72±2.3a	205.53±3.9a
T_1	15.50±2.8cd	15.50±0.1ab	15.50±1.8ab	34.84±2.6ab	28.30±0.9de	31.57±1.2bc	76.67±18.0abc	73.56±1.7ab	75.11±8.2ab	255.56±60.0abc	245.16±2.8ab	250.36±30.7ab
T_2	14.50±3.0bcd	15.66±0.2bc	15.08±1.4ab	34.11±1.6ab	28.69±0.6cde	31.39±0.9bc	76.30±17.5abc	77.00±2.2b	76.65±9.4ab	254.33±58.5abc	256.64±4.9b	255.49±31.7ab
T_3	13.83±0.8abcd	17.00±0.3de	15.42±0.1ab	33.60±1.5ab	26.98±4.6cde	30.29±1.7b	65.00±10.9abc	92.33±1.2d	78.67±5.8abc	216.67±36.5abc	307.75±5.7d	262.21±21.1abc
T_4	17.00±0.5d	17.50±0.2ef	17.25±0.4b	30.01±1.0b	31.37±7.6ab	30.69±3.3d	84.30±7.7c	95.55±2.0d	89.93±3.6bc	281.00±25.5c	318.49±7.9de	299.74±8.8bc
T_5	15.67±0.8cd	18.00±0.5f	16.83±0.4b	35.67±0.8ab	33.51±0.9abc	34.59±0.6cd	79.80±19.5bc	110.11±1.2e	94.95±9.3c	266.00±65.0bc	367.00±10.9f	316.50±27.4c
T_6	11.83±1.2ab	16.34±0.4cd	14.08±1.2a	27.75±1.7ab	32.62±0.8e	30.18±1.0b	60.33±4.4abc	85.44±1.2c	72.89±2.4ab	201.11±14.6abc	284.79±6.1c	242.95±6.3ab
T_7	16.33±0.3cd	18.00±0.4f	17.17±0.3b	27.87±2.1ab	31.70±1.0ab	29.78±1.5b	67.13±3.9abc	106.67±2.2e	86.90±2.7bc	223.78±13.0abc	355.52±8.1f	289.65±4.1bc
T_8	13.33±1.0abc	17.67±0.1ef	15.50±0.9ab	30.86±1.1b	33.27±0.9bcd	32.07±0.2bc	58.10±13.8ab	100.55±2.0e	79.33±7.7abc	193.67±46.1ab	335.15±6.3e	264.41±26.1abc

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, $n = 3$. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

Table 4.1.1.3: Economics of different treatments of carrot grown at trans Himalayan region

Treatments	Yield (q/ha)	Rate (Rs/q)	Gross return (Rs/ha)	Total cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C Ratio
T_0	205.53	3500	719355	175748	543607	3.09
T_1	250.36	3500	876260	175928	700332	3.98
T_2	255.49	3500	894215	176108	718107	4.08
T_3	262.21	3500	917735	176548	741187	4.20
T_4	299.74	3500	1049090	177348	871742	4.92
T_5	316.5	3500	1107750	176728	931022	5.27
T_6	242.95	3500	850325	177708	672617	3.78
T_7	289.65	3500	1013775	177528	836247	4.71
T_8	264.41	3500	925435	176908	748527	4.23

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, n = 3.T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

4.1.2 Effects of micronutrients on the biochemical parameters of carrot at harvest

4.1.2.1 Leaf chlorophyll content (CCI):

Chlorophyll in carrot leaf influenced significantly by the application of different concentration of zinc and boron. Data collected on chlorophyll content of leaf have been presented in Table 4.1.2.1. It is evident form the data that all the treatments significantly increased chlorophyll content (9.29 ACI) was found in leaf when the plant treated with foliar application of Boron @ 0.2% + $ZnSO_4$ @ 1.0% (T_6), which is statically *at par* with Boron @ 0.1% + $ZnSO_4$ @ 1.0% (T_7) and Boron @ 0.2% + $ZnSO_4$ @ 0.5% (T_8). The minimum value (6.59 ACI) was observed in control (T_0). When compared to the control, an equivalent quantity of zinc applied topically increased the chlorophyll concentration. Because zinc does not directly affect the synthesis of chlorophyll but can affect the concentration of elements required in chlorophyll formation that is part of the chlorophyll molecule, such as Fe and Mg, low zinc or magnesium content may be correlated to a reduction in chlorophyll content

(Kaya and Higgs, 2002). According to Samreen *et al*., (2017) and Fie *et al*., (2018), the leaves chlorophyll contents and net photosynthetic rate seemed to decrease with reduced Zn contents. In a different experiment, it was demonstrated that exogenous zinc treatment to tomato plant leaves resulted in the accumulation of leaf chlorophyll content at both low and high concentrations (Kaya and Higgs, 2002).

4.1.2.2 Total titratable acidity:

An examination of total titratable acidity of carrot root data given in Table 4.1.2.1. revealed that all the nutrients caused a significant improvement in the acid content of carrot root except T_0, T_1 and T_7. The maximum total titratable acidity (0.39) was observed in foliar application of Boron @ 0.1% (T_2) followed by Boron @ 0.2% + $ZnSO_4$ @ 1.0% (T_6) 0.37%. The improvement in carrot quality parameters may be attributable to the increased availability of micronutrients, particularly zinc and boron, which are essential for improving fruit quality (Swetha *et al*., 2018). This could be a result of Zn and other micronutrients being added, which raised the titratable acidity in fruits (Verma *et al*., 2022).

4.1.2.3 Total Soluble Solid:

A total soluble solid was significantly affected by various treatment combinations as mentioned in Table 4.1.2.1. The maximum TSS (9.15º B) of carrot was observed under treatment T_2 followed by (9.12º B) TSS of carrot under treatment T_4. While the minimum (8.42º B) TSS of carrot was observed under treatment T_5 followed by T_0. The total soluble solid value in carrot root is greater when zinc and boron are applied topically. According to Hamzah Saleem *et al*., (2022) and Kumari *et al*., (2022), zinc and boron play crucial roles in the photosynthetic activities of the plant, which may explain the increase in qualitative parameters of carrot roots. Ballabh and Rana (2012), Manna (2013), Trivedi and Dhumal (2013), all revealed similar findings with onions.

4.1.2.4 Nitrate content:

The preharvest foliar application of zinc and boron at different levels was found to have a significant effect on the nitrate content in carrots (Table 4.1.2.2). The highest nitrate content (351.08 mg/100g) of carrot root was found in foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5) () followed by application of Boron @ 0.2% + $ZnSO_4$ @ 1.0% (T_6) 327.93 mg/100g and $ZnSO_4$ @ 1.0% (T_4) 326.92 mg/100g. The minimum nitrate (281.14) content was recorded in control (T_0).

Table 4.2.1: Effect of zinc and boron on chlorophyll, titratable acidity, and total soluble solids (TSS) of carrot.

Treatments	Chlorophyll (CCI)			Titratable acidity (%)			Total soluble solids (^{O}B)		
	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data
T_0	6.26±0.1a	6.92±0.2a	6.59±0.1a	0.30±0.0b	0.31±0.0a	0.30±0.0a	8.87±0.6b	8.23±0.2a	8.55±0.2ab
T_1	7.25±0.2b	7.46±0.2ab	7.36±0.2b	0.34±0.0c	0.45±0.0f	0.39±0.0f	8.50±0.1ab	8.87±0.2bcd	8.68±0.0ab
T_2	7.19±0.2b	7.95±0.3bc	7.56±0.1ab	0.27±0.0a	0.33±0.0bc	0.30±0.0a	8.97±0.3b	9.30±0.3d	9.15±0.3b
T_3	7.76±0.1c	8.14±0.3bc	7.95±0.1b	0.30±0.0b	0.34±0.0cd	0.32±0.0b	9.13±0.2b	8.47±0.2ab	8.82±0.0ab
T_4	7.87±0.2cd	8.12±0.2bc	8.00±0.2b	0.30±0.0b	0.40±0.0e	0.35±0.0d	9.10±0.3b	9.13±0.2bcd	9.12±0.2b
T_5	8.26±0.2d	8.65±0.3cd	8.45±0.3b	0.37±0.0d	0.31±0.0ab	0.34±0.0cd	8.03±0.8a	8.80±0.1cd	8.42±0.4a
T_6	9.27±0.2e	9.31±0.2de	9.29±0.0c	0.30±0.0b	0.45±0.0f	0.37±0.0e	9.20±0.4b	8.97±0.1bcd	9.08±0.2ab
T_7	9.07±0.2e	9.46±0.3e	9.27±0.1c	0.27±0.0a	0.34±0.0cd	0.30±0.0a	8.67±0.2ab	8.77±0.2bc	8.70±0.2ab
T_8	8.87±0.1e	9.05±0.3de	8.96±0.2c	0.30±0.0b	0.36±0.0d	0.33±0.0bc	8.87±0.6b	8.93±0.1bcd	8.90±0.3ab

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3.
T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

The amount of nitrate, phosphate, and sulfate in carrots was affected by the condition of the soil, the plant's ability to absorb nutrients, the number of soluble nutrients added to the soil, the amount of light and temperature in the environment, and other factors. In various treatments, nitrogen availability to plants had an impact on nitrate content. The nitrogen and phosphorus content of the groundnut seeds was increased both by the solitary use of zinc and boron fertilizer and by their combined application, according to Aboyeji *et al*., (2019). The good effects of zinc and boron on growth and metabolism, which in turn had a positive impact on the nitrate and phosphate content of carrots, may be the cause of our findings. The application of boron encouraged uptake of nitrogen in groundnuts which helped in promoting plant growth and development (Jing *et al*., 1994 and Mishra *et al*., 2018). The increased Zn increases photosynthesis during early plant growth and enhances protein, yields, and nitrogen fixation in mung bean plants (Ved *et al*., 2002). With the use of nitrogen fertilizers, zinc deficiency in plants can be reduced. Since the application of N fertilizers helps to promote plant growth, it is the potential to detect beneficial interactions between rising Zn and N fertilizer levels. These interactions also, to a lesser extent, help to change the pH of the root environment (Alloway, 2004).

4.1.2.5 Phosphate content:

The phosphate mentioned in Table 4.1.2.2. was significantly different ($p > 0.05$) was observed among all the treatments. However, the maximum phosphate content 956.90 mg/100g of carrot root was found in foliar application of Boron @ 0.2% + $ZnSO_4$ @ 1.0% (T_6) followed by application of $ZnSO_4$ @ 1.0% (T_4) 921.90 mg/100g and Boron @ 0.2% + $ZnSO_4$ @ 0.5% (T_8) 908.96 mg/100g. The minimum phosphate content (825.21 mg/100g) was recorded in treatments T_5. According to other investigations (Adnan *et al*., 2016), even though P reduced the Zn concentrations in the tops, the total Zn contents either increased or stayed the same. According to Saboor *et al*., (2021), P may be the cause of this P-induced Zn shortage by interfering with Zn absorption, translocation, or use. These researchers hypothesized that plant roots contained P-Zn antagonists.

4.1.2.6 Sulfate content:

The sulfate content was shown in Table 4.1.2.2. The foliar application of $ZnSO_4$ in carrot significantly showed higher sulfate content ($p < 0.05$). Among the treatments, maximum values of sulfate (661.23 mg/100g) were observed in treatment T_3 statically at par with T_4 (660.23 mg/100g). The minimum sulfate content was found in T_2

Table No. 4.1.2.2: Preharvest application of zinc and boron on anion content of carrot

Treatments	Nitrate (mg/100g)			Phosphate (mg/100g)			Sulfate (mg/100g)		
	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data
T_0	277.11±21.2a	285.16±21.9a	281.14±9.8a	913.50±21.2c	847.44±7.9a	880.47±7.1bcd	572.47±22.5c	489.23±8.4a	530.85±15.1b
T_1	284.21±28.6a	288.08±20.1a	286.15±23.2ab	853.32±28.3b	880.31±15.3abc	866.82±16.1bc	528.68±22.2b	510.53±8.6a	519.61±14.7b
T_2	317.06±14.9ab	307.47±15.2ab	312.26±14.8abc	857.51±41.9b	865.90±9.7ab	861.71±21.4abc	456.10±13.6a	496.33±7.4a	476.21±9.6a
T_3	336.40±2.0b	315.19±4.3ab	325.80±3.0cd	913.50±11.0c	874.85±21.2abc	894.18±9.7cde	637.95±13.0e	684.50±17.0d	661.23±12.8d
T_4	317.32±10.3ab	336.53±15.7bc	326.92±11.2cd	954.32±15.7c	889.48±8.9bc	921.90±6.6ef	607.58±13.6d	712.90±10.0d	660.23±2.2d
T_5	334.93±5.2b	367.22±2.6c	351.08±2.9d	797.33±32.4a	853.09±17.6ab	825.21±19.2a	544.06±6.5b	524.73±21.4a	534.40±11.3b
T_6	331.03±14.1b	324.84±17.7ab	327.93±11.5cd	953.79±29.5c	960.00±14.3d	956.90±11.3f	639.13±4.2e	563.78±15.6b	601.46±5.9c
T_7	316.81±14.8ab	309.07±15.2ab	312.95±14.9abc	830.30±14.1ab	858.56±9.5ab	844.43±11.3ab	547.22±10.1b	517.63±9.2a	532.43±8.7b
T_8	306.56±18.4ab	333.07±5.5bc	319.81±10.6bcd	913.50±25.1c	904.43±6.1c	908.96±10.9de	659.25±13.8e	606.39±6.2c	632.82±3.9d

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

(476.21 mg/100g). High levels of sulphur are present in $ZnSO_4$. It is not unexpected that Sulphur and Nitrogen are related because they both go into the production of chlorophyll and seem to be parts of proteins. The function of Sulphur in the transformation of nitrate into amino acids also connects them together. Along with magnesium and calcium, sulphur is a secondary element, but due to its role in the synthesis of amino acids and proteins, it is frequently referred to as "the fourth major nutrient." It is important to activate specific enzymes and vitamins, as well as to produce chlorophyll. After foliar treatment, carrots may contain more sulfate due to zinc sulfate's 15% sulphur concentration. Depending on the availability of sulphur to the plant, different sulfate carriers in plants move sulphur from the rhizosphere to various plant tissue.

Table No. 4.1.2.3: Preharvest application of zinc and boron on sugar content of carrot

Treatments	Glucose (g/100g)			Fructose (g/100g)			Sucrose (g/100g)			Total Sugar (g/100g)		
	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data
T_0	16.57±0.1d	12.55±0.4a	14.56±0.3a	6.45±0.4abc	5.25±0.1a	5.85±0.2a	14.19±2.2ab	12.54±0.2a	13.37±1.2a	37.22±2.6b	30.34±0.3a	33.78±1.3a
T_1	18.32±1.0e	17.48±0.3cd	17.90±0.5e	7.67±1.6c	8.06±0.2e	7.86±0.8ef	16.55±0.3cd	14.95±0.3b	15.75±0.1b	42.53±1.7cd	40.49±0.4cd	41.51±0.7e
T_2	14.36±0.2b	18.95±0.2cd	16.66±0.2cd	6.72±0.8a	7.12±0.2d	6.92±0.3cde	16.37±0.3cd	15.27±0.5b	15.82±0.4b	37.45±0.4b	41.34±0.9d	39.39±0.3cd
T_3	13.02±0.2a	17.84±0.6d	15.43±0.4b	5.71±0.6a	6.35±0.1c	6.03±0.3ab	12.75±1.9a	15.01±0.2b	13.88±0.8a	31.48±2.1a	39.20±0.9c	35.34±0.6a
T_4	14.64±0.2b	15.66±0.6b	15.15±0.2ab	6.34±0.2ab	5.80±0.1b	6.07±0.2abc	17.16±0.3d	15.50±0.2b	16.33±0.1b	38.14±0.7b	36.96±0.6b	37.55±0.1b
T_5	15.84±0.2c	16.84±0.2e	16.34±0.1c	7.51±0.1bc	7.22±0.1d	7.37±0.0def	19.56±0.2e	20.06±0.4d	19.81±0.2c	42.90±0.5d	44.12±0.6e	43.51±0.3f
T_6	15.71±0.1c	17.44±0.4cd	16.58±0.2cd	6.83±0.0abc	6.50±0.2c	6.66±0.1abcd	16.39±0.1cd	15.37±0.2b	15.88±0.1b	38.92±0.2bc	39.31±0.4c	39.12±0.3bc
T_7	17.93±0.6e	16.37±0.3bc	17.15±0.2d	7.29±0.2bc	7.82±0.1e	7.55±0.0ef	14.97±0.4bc	16.54±0.4c	15.75±0.3b	40.18±1.0bcd	40.72±0.2cd	40.45±0.6cde
T_8	13.59±0.1a	17.04±0.3cd	15.31±0.1b	5.84±0.4a	7.86±0.3e	6.85±0.1bcde	18.17±0.1de	19.44±0.3d	18.81±0.2c	37.60±0.6b	44.34±0.4e	40.96±0.1de

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

4.1.2.7 Sugars content:

Data presented in Table 4.1.2.3 showed that all the treatments significantly improved sugar contents of root over control. The maximum glucose (17.90) was recorded with the application of Boron @ 0.1% (T_1) followed by foliar application of Boron @ 0.1% + $ZnSO_4$ @ 1.0% (T_7). While minimum glucose (14.56) was observed in control (T_0). The preharvest foliar application of zinc and boron at different levels was found to have a significant effect on the fructose in carrots. Fructose was recorded as maximum (7.86) carrots under treatment T_1, which is *at par* with treatment T_7. Whereas minimum fructose (5.85) of carrot was observed in control (T_0). The sucrose content mentioned in Table 4.2.3 was significantly different ($p > 0.05$) between the foliar application of micronutrient and control. The maximum sucrose was observed in foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5), which is *at par* with Boron @ 0.2% + $ZnSO_4$ @ 0.5% (T_8). The lowest value of sucrose (13.88) was recorded in foliar application of $ZnSO_4$ @ 0.5% (T_3), which is statically at par with control (T_0). According to Gobarh, (2001), foliar application of several micronutrients significantly increased the amount of sugar. In the transport of sugar and the metabolism of carbohydrates, zinc and boron are crucial components (Camacho-Cristóbal *et al*., 2008). Because zinc and boron also have an impact on how carbohydrates are metabolized, it is likely to apply these nutrients topically that will increase the sugar content of carrot roots. According to Mekdad and Rady (2016), applying Zn considerably increased the sugarbeet recoverable sugar production and morphophysiological responses. In sugarbeet, Armin and Asgharipour's, (2012) research demonstrates that boron consumption greatly decreased root rot while also raising sugar levels due to an increase in glucose levels in root and phloem sap. According to Abd El-Rhman (2010), zinc sulfate application tends to increase total sugar and reducing sugar in pomegranate fruits.

4.1.2.8 Ascorbic acid content:

The foliar application of zinc and boron with various concentrations had no significant impact on the ascorbic acid level of carrot roots (Table 4.1.2.4). Ascorbic acid content in carrots in less than other vegetable crops like brassicas, peas, and spinach, hence are not considered to be a significant source of ascorbic acid (Favell, 1998). The levels of ascorbic acid found in the carrot roots varied from 7.17 to 9.01 mg/100g FW among the treatments. But no significant change was observed in the ascorbic acid of carrot after foliar application of zinc and boron. According to Denre *et al*., (2016), foliar applications of boron in potato lead to an increase in ascorbate concentration.

4.1.2.9 Carotene content:

It is thought that carrots are a significant dietary source of carotenoids, particularly carotenes, which are the precursors to vitamin A. In general, the colour of carrots—orange, red, and yellow—provides a decent indication of the types and quantity of carotenoids present i.e., carotenes, lycopene, and lutein respectively (Arscott and Tanumihardjo, 2010). Table 4.1.2.4 shows the concentrations of carotene found in the carrot var. Early Nantes grown under the various zinc and boron treatments. The carotene content was significantly influenced by the application of zinc and boron. The maximum value of total carotene (4298.41 µg/100g FW) was found in the foliar application of $ZnSO_4$ @ 0.5% (T_3), which was statistically at par with application of $ZnSO_4$ @ 1.0% (4294.78 µg/100g FW). A minimum value of total carotene (3533.04 µg/100g FW) was also found in the foliar application of Boron @ 0.2%. The overall phytochemical content in carrots may be affected by genetic and abiotic stresses due to the high-altitude condition. The high or low carotenoid concentration for a given treatments depends on several factors, including morphological and physiological traits of cultivar, as well as growth factors. In the present study, it was found that B affected carotenoid concentration. More specifically, a larger dose of B might have decreased the level of carotenoids in plants. Whereas, adequate doses of zinc applied in carrots, can increase carotenoids in plants. Zn treatment increases carotenoid content, stomatal conductance, antioxidant enzyme activities, chlorophyll content, while decreasing electrolyte leakage and water loss in dry conditions (Khan *et al*., 2016). According to Ahanger *et al*., (2016), zinc has many functions in plants as it is a structural catalytic and co-catalytic component of over 300 enzymes including carbonic anhydrase, carboxy-peptidase, alcohol dehydrogenase, Cu/Zn superoxide dismutase, fructose 1,6 bisphosphatase and aldolase. Zn serves as a cofactor of various antioxidant enzyme that protect plant from reactive oxygen species and application of Zn enhances carotenoids content that have important role to overcome photo oxidative damage.

Table No. 4.1.2.4: Preharvest application of zinc and boron on ascorbic acid and carotenes content of carrot

Treatments	Ascorbic acid (mg/100g FW)			Carotene (µg/100g FW)		
	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data
T_0	6.30±0.00a	8.00±0.86a	7.17±0.43a	4088.40±134.73cde	4122.86±95.23c	4105.64±51.64d
T_1	6.30±0.00a	8.50±0.87a	7.42±0.43a	3779.87±42.60ab	3614.10±59.48ab	3696.98±12.80b
T_2	6.73±0.74ab	8.50±0.85a	7.63±0.69a	3625.57±77.88a	3440.49±71.68a	3533.04±42.68a
T_3	8.03±0.76ab	10.00±0.86a	9.01±0.69a	4319.83±112.90e	4277.72±89.21c	4298.78±91.94e
T_4	8.03±0.75ab	9.00±1.50a	8.51±1.08a	4319.87±77.04e	4268.98±67.72c	4294.41±24.81e
T_5	8.47±0.74b	9.50±0.84a	8.97±0.69a	3857.00±70.69abc	3672.19±151.73ab	3764.59±61.53b
T_6	8.03±0.76ab	9.00±1.50a	8.51±0.47a	4011.27±95.50bcd	3846.44±17.24b	3928.86±47.55c
T_7	8.47±0.75b	9.50±0.85a	8.97±0.69a	4242.70±60.93de	4173.76±35.66c	4208.23±48.30de
T_8	8.47±0.75b	9.50±0.86a	8.97±0.69a	3857.00±122.61abc	3773.20±85.28b	3815.10±25.45bc

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

4.1.2.10 Total flavonoids content (TFC):

In contrast to ascorbic acid, the flavonoids content was significantly different among the treatments. TFC, following Zn application alone, produced significantly higher value in foliar application of $ZnSO_4$ @ 0.5% compared to boron. The highest TFC (1.75±0.22 mg RE/g DW) was recorded in the foliar application of $ZnSO_4$ @ 0.5% (T_3), which was statistically at par with $ZnSO_4$ @ 1.0 %. While the lowest TFC value 0.87, 0.90, and 0.90 mg RE/g DW content was found in foliar application of Boron @ 0.2%+ $ZnSO_4$ @ 0.5% (T_8), Boron @ 0.2%+ $ZnSO_4$ @ 1.0% (T6) and Boron @ 0.2% (T_2), respectively. Boron concentration seems to affect flavonoid levels. Sarafi *et al*., (2018), reported that boron toxicity considerably boosted flavonoid content in cultivar Odysseo while dramatically decreased it in cultivars Arlequin, Century, Imperial, and Salomon, showing a distinct genotypic response and harvesting time-dependent variation.

Table 4.1.2.5: Preharvest application of zinc and boron on TFC, TPC and antioxidant content of carrot.

Treatments	TFC (mg RE/g DW)			TPC (mg GE/g DW)			Total antioxidant activity (mMTE/L FW)		
	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data
T_0	1.77±0.29bc	1.44±0.34bc	1.60±0.31bc	5.27±0.35abc	5.94±1.39ab	5.61±0.86abc	58.90±1.01a	59.23±2.92a	59.06±1.92a
T_1	1.50±0.10abc	1.08±0.09abc	1.28±0.09abc	5.30±0.26abc	5.36±0.12ab	5.33±0.10abc	63.80±1.83bc	64.94±2.49ab	64.37±2.14ab
T_2	1.10±0.10a	0.71±0.08a	0.90±0.09a	3.90±0.70a	4.39±0.92a	4.14±0.81a	62.60±0.52ab	64.98±2.01ab	63.80±0.74ab
T_3	1.90±0.17c	1.60±0.22c	1.75±0.22c	5.33±0.49abc	7.21±0.31b	6.27±0.39c	63.83±1.46bc	64.53±2.74ab	64.17±2.09ab
T_4	1.97±0.06c	1.52±0.09c	1.73±0.09c	6.10±0.3c	7.09±0.33b	6.59±0.34c	66.27±1.51bc	66.99±2.40ab	66.62±1.88b
T_5	1.60±0.17abc	1.22±0.11abc	1.41±0.13abc	5.90±0.53bc	6.13±0.21ab	6.00±0.37bc	67.43±1.45c	68.17±2.52b	67.81±1.92b
T_6	1.10±0.36a	0.73±0.39a	0.90±0.36a	4.40±1.15ab	4.60±0.98a	4.50±1.00ab	67.47±0.25c	67.40±3.05b	67.44±1.63b
T_7	1.20±0.10ab	0.89±0.13ab	1.05±0.11ab	5.27±0.15abc	5.36±0.12ab	5.32±0.09abc	66.27±1.80bc	66.58±3.93ab	66.42±2.87b
T_8	1.03±0.25a	0.72±0.24a	0.87±0.24a	4.20±0.62a	4.63±0.47a	4.42±0.52ab	65.10±1.21bc	64.98±2.46ab	65.03±1.32b

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

This could be explained by the increased photosynthesis and sugar accumulation followed by Zn sprays, which might promote the synthesis of phenolic compounds, particularly flavonoids (Solfanelli *et al*., 2006).

4.1.2.11 Total phenolic content (TPC):

With respect to phenols, the total phenol content in carrot roots improved significantly ($p > 0.05$) with foliar application of Zn and B separately or in combination (Table 4.1.2.5). Total phenolic contents increased with foliar application of zinc, as compared to the control. Data shows that total phenolic contents were significantly affected by foliar application of zinc treatments. The maximum value of total phenol concentration (6.59±0.34 mg GE/g DW) was recorded under foliar application of $ZnSO_4$ @ 1.0% (T_3), which was on at par with $ZnSO_4$ @ 0.5% (6.27 mg GE/g DW). A reduction in total phenol concentration was observed as the boron application rate increased comparing with the control. Whereas, minimum TPC (4.14 mg GE/g DW) was observed in foliar application of Boron @ 0.2% (T_2). It indicates that a specific level of boron causes the greatest reduction in the concentration of phenols (Dong *et al*., 2022). However, our result match with (Song *et al*., 2015) who also noted increased accumulation of total phenols in berry upon foliar application of Zn.

4.1.2.12 Total antioxidant activity:

To determine the nutritional value of fruits and vegetables, antioxidants are important indicator (Wu *et al*., 2004). Hancock & Viola, (2005) reported that vitamin C acts as an antioxidant in plants and are responsive to environmental stress factors such as light, temperature, salt and drought, atmospheric pollutants, metals, or herbicides. The maximum antioxidant (67.81 mMTE/L FW) was observed in foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5), which is statistically at par with $ZnSO_4$ @ 1.0% (T_4), Boron @ 0.2%+ $ZnSO_4$ @ 1.0% (T_6), Boron @ 0.1%+ $ZnSO_4$ @ 1.0% (T_7), and Boron @ 0.2%+ $ZnSO_4$ @ 0.5% (T_8). While the lowest value (59.06 mMTE/L FW) of antioxidant was found in control (T_0). When applying zinc in a foliar way, it was observed that the antioxidant capacity increased with the doses, with the highest antioxidant activity was showing the dose of $ZnSO_4$ @ 0.5% foliar. Majdoub *et al*., (2017) was reported that the antioxidant capacity increases with the foliar application of zinc.

4.1.2.13 Micronutrients (Mn, Cu, Zn, Na, Fe):

The micronutrient concentrations (Cu, Zn, Mn) are presented in Table 4.1.2.6, where significant differences ($p \geq 0.05$) were observed between the foliar doses of different concentrations. The manganese concentration ranged between 1.30-1.84 mg/100g, with the lowest value found with the $ZnSO_4$ @ 0.5% (T_3), while the Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5) foliar dose produced the highest value (1.84 mg/100g). The copper concentration was highest (0.62 mg/100g) in control compared to all the treatments. While the minimum concentration of copper was observed in foliar application of Boron 0.2%+ $ZnSO_4$ @1.0% and Boron @ 0.2%+ $ZnSO_4$ @1.0%.

The sodium and iron values were presented in Table 4.1.2.7, although there was no significant difference ($p \geq 0.05$) observed in carrot roots, values ranged between 310.73 to 406.43 mg/100g and 8.66 to 10.24 mg/100g, respectively. The application of the Boron @ 0.2%+ $ZnSO_4$ @ 0.5%, Boron @ 0.1% + $ZnSO_4$ @ 0.5% and $ZnSO_4$ @ 0.5% foliar doses of zinc and boron produced highest zinc concentrations of 11.17, 10.24, and 10.16 mg/100g, respectively, while the Boron @ 0.1%, Boron @ 0.2% foliar dose and the control had the lowest zinc contents, with values of 5.38, 5.54 and 5.49 mg/100g, respectively. Zinc was the best absorbed micronutrient in the trial. As reported by Gupta *et al*., (2016), Zn is better transported by phloem than xylem, due to chelation of Zn2+. Zn doses in the solution did not affect individually was reported in different studied. Many studies have revealed a negative association between Zn and cationic micronutrients such as Cu, Fe, and Mn. This relationship occurs because of the competition between cations for absorption sites (Baxter, 2009: Assunção *et al*., 2013). In this study, it was discovered that zinc and boron had a negative association with copper. In this investigation, there was no evidence of any contradiction between Zn and other cationic micronutrients such as Fe and Mn. The absorption of Cu and Mn in carrot roots was affected only by B doses and by B doses combined with Zn. The amount of Fe in carrot was found to increase by increasing the boron concentration in the solution. Esringü *et al*., (2011) found comparable results in strawberry, where the Fe content in the roots increased with a applied minimum concentration of B and subsequently declined with a higher concentration. These findings indicate that B has certain affinity for Fe and there may be a synergetic interaction between the nutrients. Rajaei *et al*., (2009), also observed significant increase in the concentration of Fe with the increment in B levels in *Citrus* *aurantifolia.* This study of foliar application of Zn and B was not influenced by the absorption of Fe content of carrot roots (Table 4.1.2.7). Results support past studies (Kurešová *et al*., 2017; Saadati *et al*., 2016; Chakerolhosseini *et al*., 2016) that micronutrient content in apple leaves and fruit increases after foliar applications of micronutrient. Khorsandi *et al*., (2009) found increased Zn concentration in leaves and fruit juice when sprayed with $ZnSO_4$ in pomegranate. About the accumulation of Zn in the edible part of carrot, it was found that, due to increase in the Zn content in the soil, the plants generally have higher concentrations of this element to Kabata-Pendias & Mukherjee, (2007), demonstrating that fertilization practice can increase the availability of Zn to plants, which is potentially absorbed. According Kabata-Pendias, (2007), regardless of Zn dose applied in the soil, the highest concentrations are observed mainly in roots, which have low translocation to the shoot. Zinc is minimally translocated to the shoot due to a natural impediment present in its roots (Andrade *et al.,* 2008), so the carrot has a high potential for enrichment with this element in the edible part, justifying the considerable metal accumulation found in this work. Zinc oxide also presents an increasing accumulation, but would require a larger dose, which is a disadvantage to this source because it is little soluble. Sandall, (2015) mentioned that the $ZnSO_4$ is the Zn source most used as fertilizer, which, being an inorganic compound relatively soluble in soluble and effective in granular form, should be applied in the areas of soil with low levels of this mineral. The maximum amount of Zn, Cu and B in roots correlates to their increased concentration in leaves arising from foliar application of Zn and B fertilizers. These findings suggested that micronutrients may have been transferred by the phloem to other areas with strong metabolic activity for any reason (Kurešová *et al*., 2017). It is interesting to note that, although Mn is deemed to be imperfectly mobile element (White and Ding, 2023), we observed highest concentration in root when fertilized with Zn and B. This enhanced concentration of micronutrients in root after foliar sprays of Zn, and B and their combination is highly desired because of the widespread micronutrient deficiencies in the food chain (Miller and Welch, 2013).

Table No. 4.1.2.6: Combined and individual effect of boron and zinc on accumulation of Cu, Zn, and Mn in carrot

Treatments	Cu (mg/100g)			Zn (mg/100g)			Mn (mg/100g)		
	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data
T_0	0.79±0.06c	0.44±0.11a	0.62±0.06b	5.73±0.12a	5.24±1.16a	5.49±0.66a	1.05±0.11a	1.68±0.28a	1.36±0.19ab
T_1	0.34±0.01a	0.52±0.17a	0.43±0.08ab	5.37±0.15a	5.40±0.56ab	5.38±0.22a	1.12±0.21a	1.66±0.20a	1.39±0.14ab
T_2	0.50±0.01b	0.53±0.24a	0.51±0.12ab	5.07±0.06a	6.00±0.58ab	5.54±0.33a	1.60±0.14a	1.79±0.11a	1.69±0.10ab
T_3	0.47±0.02ab	0.46±0.12a	0.46±0.06ab	10.47±0.31d	9.86±0.56ab	10.16±0.44c	1.04±0.40a	1.56±0.24a	1.30±0.08a
T_4	0.34±0.02a	0.47±0.15a	0.41±0.07a	7.27±0.12b	7.02±0.69ab	7.14±0.31b	1.10±0.16a	1.67±0.14a	1.39±0.04ab
T_5	0.46±0.01ab	0.54±0.10a	0.50±0.05ab	11.12±0.29d	9.31±0.41b	10.24±0.16c	1.87±0.66a	1.81±0.12a	1.84±0.39b
T_6	0.32±0.02a	0.50±0.10a	0.41±0.05a	9.07±0.32c	7.24±0.63ab	8.16±0.37b	1.80±0.33a	1.68±0.23a	1.74±0.16ab
T_7	0.42±0.14ab	0.46±0.09a	0.44±0.05ab	8.03±0.21c	7.91±1.04ab	7.97±0.57b	1.06±0.14a	1.70±0.27a	1.38±0.18ab
T_8	0.46±0.01ab	0.52±0.17	0.49±0.08ab	11.97±0.49e	10.37±0.20b	11.17±0.32c	1.11±0.23	1.73±0.06a	1.42±0.13ab

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, $n = 3$. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

Table 4.1.2.7: Combined and individual effect of boron and zinc on accumulation of Na and Fe in carrot

Treatments	Na (mg/100g)			Fe (mg/100g)		
	1st Year	2nd Year	Pooled Data	1st Year	2nd Year	Pooled Data
T_0	325.00±25.00ab	296.47±9.88ab	310.73±16.88a	9.06±0.95a	8.25±0.01a	8.66±0.47a
T_1	341.67±14.43ab	341.06±6.50de	341.36±4.69a	9.95±0.85a	9.63±0.05e	9.79±0.45a
T_2	400.00±50.00ab	347.35±7.60de	373.68±22.34a	10.69±2.03a	9.90±0.02f	10.30±1.01a
T_3	416.67±125.83ab	333.05±12.06cd	374.86±58.49a	10.08±1.91a	8.99±0.01c	9.54±0.95a
T_4	358.33±14.43ab	287.55±6.12a	322.94±10.28a	10.83±1.53a	8.80±0.03b	9.82±0.77a
T_5	466.67±52.04b	346.19±3.42de	406.43±24.31a	10.61±1.01a	9.87±0.00e	10.24±0.51a
T_6	308.33±14.43a	354.61±5.00e	331.47±5.10a	10.14±2.10a	9.00±0.01c	9.57±1.05a
T_7	358.33±14.43ab	316.25±7.96bc	337.29±5.88a	9.82±0.70a	10.57±0.04g	10.20±0.36a
T_8	350.00±25.00ab	318.19±4.66c	334.10±12.65a	10.91±1.05a	9.40±0.03d	10.15±0.53a

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

Figure 4.1. Cultivation of carrot at trans Himalayan region

4.2 Objective 2. To study about comparative evaluation of traditional and modified storage structures for physio-chemical changes of carrot with storage time.

4.2.1. Weight loss% of carrot:

Weight loss of carrot treated with preharvest micronutrient and stored in room conditions, underground passive storage, and trench storage at ambient temperature is shown in Table 4.2.1. Carrots were stored in three trenches. Physical characteristics of carrots had shown uneven results in each trench. Two has shown completely rotten, sprouted, and shrunken carrots and other that has shown better result is represented in Table 4.2.1. farmers with trenches have also briefed regarding the uncertainty of unsuccess ratio of these traditional stores (trench storage) in Ladakh. Underground passive storage maintained relatively lower temperature and higher humidity compared to the room condition.

It is clear from the figures 4.1, weight loss% was shown at passive storage. After 30 and 60 days of storage, 6.2% and 6.46% weight loss were observed, respectively. Whereas minimum weight loss (5%) was recorded in the 90 days. It increased upto 9.6% in the 120 days and sudden weight loss (16.66%) was recorded in 150 days of storage. It assures that passive underground store has maintained suitable environment for the storage of carrots up to 120 days but during month of march sudden increase in temperature caused extreme weight loss%.

Trench storage observed significantly minimum weight loss of carrot roots compared with room condition. The carrot roots stored in trench storage maintained the lowest average weight loss (9.64%) and weight loss in different treatments ranged between 6.86 % and 10.74 % during the storage period, whereas in case of room condition, treated carrot roots showed maximum average weight loss (56.23%) after 20 days of storage. Minimum humidity was found in the room conditions which was the main reason for the reduction in the weight of carrots. The increase in weight loss under different storage conditions is obvious due to respiratory activity leading to moisture loss (Salisbury & Ross 1992). This study has shown that the use of passive store for storage of carrot roots maintains their freshness, delays respiration process and increase the storage life better than in the other conditions. Moreover, Underground passive storage not only maintain the storage temperature but also increases the

Table 4.2.1: Effect of treatments and storage structure on weight loss (%) of carrot roots

Weight loss%									
Treatments	**1st Year**			**2nd Year**			**Pooled data**		
	RC	**PS**	**TS**	**RC**	**PS**	**TS**	**RC**	**PS**	**TS**
	(20 Days)	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**
T_0	58.73±3.69a	55.37±4.71a	12.84±4.13a	56.10±14.45a	49.97±9.11a	8.64±1.43a	57.41±5.4a	52.67±6.9d	10.74±2.4bc
T_1	57.40±2.68a	39.93±0.26de	7.99±1.22bc	59.75±3.26a	36.13±0.78a	11.84±1.23a	58.57±0.3a	38.03±0.5a	9.91±0.5abc
T_2	59.70±2.63a	40.93±0.94cd	11.39±0.09bc	62.97±10.09a	58.35±7.11a	9.38±0.99a	61.33±3.9a	49.64±3.2cd	10.39±0.5abc
T_3	54.52±4.21a	43.99±0.19a	6.36±0.14a	61.02±23.79a	40.66±5.42a	7.40±1.07a	57.77±12.0a	42.32±2.6abcd	6.88±0.5a
T_4	57.59±3.14a	41.18±5.56bc	15.05±0.11ab	43.83±11.76a	44.34±0.93a	7.40±1.13a	50.71±7.3a	42.76±2.7abcd	11.22±0.6c
T_5	51.82±4.24a	41.50±0.47e	15.02±4.79c	66.47±21.61a	36.17±0.75a	10.44±0.58a	59.14±9.8a	38.84±0.3ab	12.73±2.7c
T_6	53.37±4.05a	47.92±5.54cd	9.27±0.12ab	54.37±10.54a	47.05±6.19a	5.67±1.25a	53.87±6.1a	47.48±5.8abcd	7.47±0.6ab
T_7	56.96±7.35a	44.08±3.92b	10.71±0.18ab	52.65±8.39a	53.54±1.03a	10.49±1.48a	54.80±7.4a	48.81±1.8bcd	10.60±0.7bc
T_8	67.02±5.47a	41.43±1.80bc	7.29±0.16a	37.84±5.68a	37.60±6.77a	6.43±1.19a	52.43±0.4a	39.51±3.0abc	6.86±0.6a
Mean	57.46±5.59	44.04±5.48	10.66±3.57	55.00±14.48	44.87±8.84	8.63±2.22	56.23±6.64	44.45±5.94	9.65±2.27

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

relative humidity of the storage which is essential for maintaining the freshness of the roots. It was found that treatments had no significant impact on the weight loss % in room condition during the observation period until 20 days, whereas, the shelf life of carrots increased by 150 days in passive and trench storage conditions. Among all the storage conditions, weight loss % was the least in trench storage. Considering the statistical results, it was found that weight loss % was less in carrots treated with T_1, T_3, T_6 and T_8 concentrations in passive and trench storage. The two-way interaction between treatments with storage was significant ($P \geq 0.05$ on days 20 and 150) for the changes in weight loss of roots.

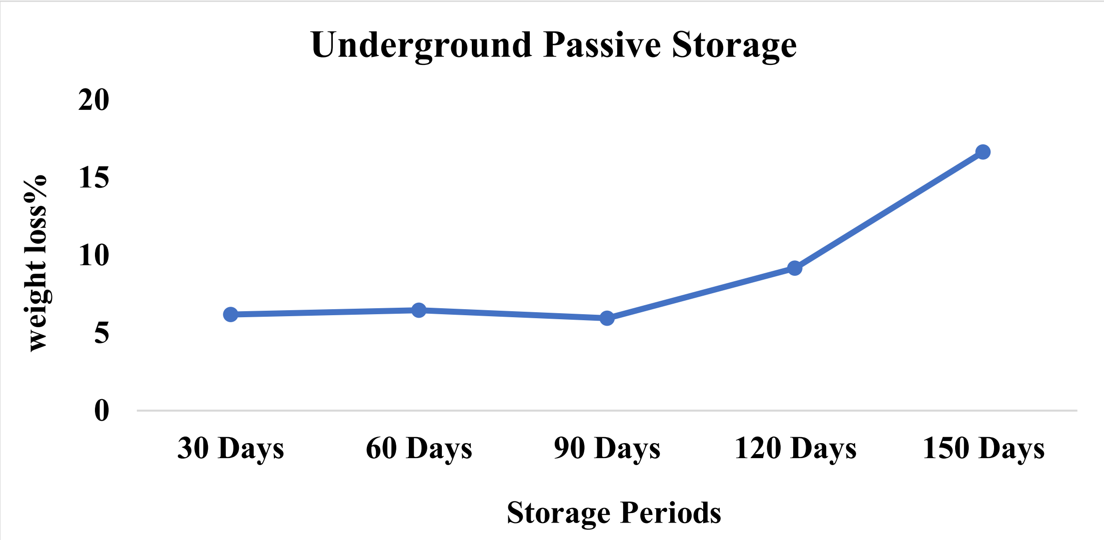


Figure 4.1: Effect of underground passive storage on weight loss (%) of carrot

Preharvest zinc sulfate ($ZnSO_4$) and boron spray has proven to effectively improve the storability of roots. Weight loss is primarily due to the metabolic activities, respiration, transpiration and depends upon water pressure gradient between tissues of root, surrounding atmosphere, as well as stage of ripening and storage temperature (Ma *et al*., 2014). Cell wall degrading enzymes activities including polygalacturonase, cellulase and β-galactosidase are major factors resulting in degradation of cell wall components and fruit softening (Bu *et al*., 2013). Moreover, cellulose and pectin, the main structural compounds of the cell wall, gradually degrade during the ripening and senescence process of fruits (Wang *et al*., 2023). Epidermal cell layer and cuticle reduce the transpiration process. A previous study showed that pectin biosynthesis and its modification in the cell wall were strongly regulated in response to Zn exposure in tomato cells (Muschitz *et al*., 2015). Boron is an essential micronutrient in plants for strengthening the cell wall. It may be due to the role played by boron in the synthesis of cell wall components (Kaur *et al*., 2019). These results indicate that Zn and B treatment might help the carrot root maintain the cellular integrity of periderm by protecting the cell wall components and might aid in reducing the weight loss of carrot root.

4.2.2 Titratable acidity (%):

The changes in titratable acidity in carrots treated with 9 different treatments in all the storage structures during 20 to 150 days of storage are presented in Table 4.2.2. Storage at room condition resulted in faster decline in titratable acidity than another storage conditions. Carrot stored in trench storage after 150 days of storage range of titratable acidity was observed between 0.28- 0.32 %, whereas maximum was shown by in 0.32% and minimum was observed 0.28%, whereas in case of underground passive storage stored treated roots, the average titratable acidity (0.26%) was found to be the maximum and ranged between 0.22-0.26%. It can be inferred that the storage conditions along with treatments had an impact on acidity retention in carrots and have shown no significant differences in titratable acidity % with passing days during storage duration. Boric acid and zinc treatment retarded the rate of degradation of retained higher titratable acidity compared to the untreated carrots. The reduction in titratable acid content may be due to the consumption of organic acids in the respiratory process (Maftoonazad *et al*., 2008).

4.2.3 Ascorbic acid (mg/100g):

The ascorbic acid content of carrots subjected to different preharvest treatments is shown in Table 4.2.3. The maintain in ascorbic acid content of carrot roots during storage were significantly higher in carrot roots stored in the trench storage (4.75 mg/100g) and ranged between 3.71 and 5.53 mg/100g followed by underground passive storage (4.47 mg/100g) and it ranged between 3.44 to 5.11 mg/100g. In room condition, treated carrot roots was observed to show minimum average ascorbic acid (3.24 mg/100g) during 20 days of storage. At the end of storage in room conditions and underground passive storage, no significant difference was found in change in ascorbic acid with different treatments compared to control. On the other side statistical analysis indicated that T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0% and T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5% had shown more ascorbic acid content than other treated carrots stored in trench storage conditions. The decline of ascorbic acid concentration was enhanced by the high concentration of CO_2 in the cold storage atmosphere (Giannakourou and Taoukis, 2021). Most of the vegetables and fruit show reduction in ascorbic acid during post-harvest ripening.

Table 4.2.2: Effect of treatments and storage structure on total titratable acidity (% FW) of carrot root

Total titratable acidity									
Treatments	**1st Year**			**2nd Year**			**Pooled Data**		
	RC	**PS**	**TS**	**RC**	**PS**	**TS**	**RC**	**PS**	**TS**
	(20 Days)	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**
T_0	0.21±0.02a	0.24±0.01c	0.28±0.02a	0.21±0.03a	0.25±0.02a	0.28±0.02a	0.21±0.0a	0.24±0.0a	0.28±0.0a
T_1	0.23±0.02a	0.20±0.00b	0.28±0.02a	0.19±0.04a	0.29±0.02a	0.31±0.04a	0.21±0.0a	0.25±0.0a	0.29±0.0a
T_2	0.20±0.01a	0.20±0.00b	0.30±0.02a	0.21±0.04a	0.25±0.04a	0.32±0.04a	0.21±0.0a	0.22±0.0a	0.31±0.0a
T_3	0.22±0.02a	0.23±0.01c	0.29±0.04a	0.22±0.02a	0.25±0.04a	0.28±0.03a	0.22±0.0a	0.24±0.0a	0.29±0.0a
T_4	0.20±0.01a	0.20±0.00b	0.26±0.01a	0.22±0.04a	0.24±0.04a	0.33±0.03a	0.21±0.0a	0.22±0.0a	0.30±0.0a
T_5	0.21±0.02a	0.24±0.01b	0.31±0.01a	0.21±0.04a	0.29±0.05a	0.34±0.04a	0.21±0.0a	0.26±0.0a	0.32±0.0a
T_6	0.23±0.02a	0.20±0.00b	0.28±0.02a	0.20±0.05a	0.29±0.02a	0.35±0.06a	0.21±0.0a	0.25±0.0a	0.31±0.0a
T_7	0.22±0.02a	0.17±0.01a	0.28±0.02a	0.23±0.02a	0.27±0.05a	0.34±0.04a	0.22±0.0a	0.22±0.0a	0.31±0.0a
T_8	0.22±0.02a	0.20±0.01b	0.28±0.02a	0.23±0.02a	0.27±0.04a	0.32±0.02a	0.23±0.0a	0.23±0.0a	0.30±0.0a
Mean	0.21±0.03	0.27±0.04	0.32±0.04	0.22±0.02	0.21±0.02a	0.28±0.02	0.22±0.18	0.24±0.20	0.30±0.02

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

Table 4.2.3: Effect of treatments and storage structure on ascorbic acid (mg/100g FW) of carrot root

Ascorbic acid (mg/100g)									
Treatments	1st Year			2nd Year			Pooled Data		
	RC	PS	TS	RC	PS	TS	RC	PS	TS
	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)
T_0	2.95±1.02a	3.50±0.87a	4.01±0.11a	2.88±0.66a	3.38±0.73a	3.42±0.08a	2.92±0.5a	3.44±0.7a	3.71±0.1a
T_1	2.68±0.16a	4.00±0.87a	4.49±0.81a	2.95±0.74a	2.95±0.73a	3.32±0.14a	2.81±0.4a	3.48±0.7a	3.90±0.4ab
T_2	3.33±0.79a	6.00±1.50a	5.55±0.23a	3.29±0.25a	4.22±0.73a	4.17±0.76a	3.31±0.4a	5.11±0.8a	4.86±0.3abc
T_3	3.27±1.18a	4.50±1.50a	5.04±1.69a	3.20±0.63a	3.38±0.73a	3.70±0.79a	3.24±0.9a	3.94±1.1a	4.37±1.2abc
T_4	3.24±1.16a	5.00±0.87a	5.95±0.87a	2.87±0.64a	4.22±0.73a	4.58±0.23a	3.05±0.5a	4.61±0.8a	5.26±0.3abc
T_5	3.48±1.86a	5.50±0.87a	4.93±0.82a	3.72±0.09a	4.64±1.94a	4.45±1.19a	3.60±0.9a	5.07±1.4a	4.69±0.3abc
T_6	2.87±1.11a	5.00±2.29a	5.92±0.80a	2.91±0.65a	3.80±1.0 a	4.14±0.73a	2.89±0.9a	4.40±1.8a	5.03±0.6abc
T_7	4.15±1.32a	5.50±1.73a	6.40±0.88a	3.46±0.37a	4.65±0.73a	4.45±0.03a	3.80±0.8a	5.07±1.1a	5.43±0.4bc
T_8	3.69±1.72a	5.50±0.87a	6.02±1.04a	3.31±0.64a	4.65±0.73a	4.04±0.81a	3.50±0.5a	5.07±0.8a	5.53±0.5c
Mean	3.29±1.12	4.94±1.37	5.37±1.08	3.18±0.55	3.99±1.04	4.14±0.77	3.24±0.65	4.47±1.11	4.75±0.77

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

Losses in ascorbic acid was enhanced by extended storage, high temperature and low relative humidity (Saari *et al*., 1995). Ascorbate oxidase has been proposed to be the major enzyme responsible for the enzymatic degradation of ascorbic acid. The carrot stored at low temperature decrease enzymatic activity and delay ripening, which in turn protect the degradation of ascorbic acid (Lee and Kader, 2000). The interaction of foliar spray and storage durations indicated that there was a decrease in ascorbic acid with increase in storage durations without any response of foliar spray of zinc and boron in both seasons. The ascorbic acid is one of the most labile vitamins in fruits and vegetables that tend to decline during storage (Kaul and Saini, 2000).

4.2.4 Carotene content (µg/100g):

The carotene content depicted in Table 4.2.4 has shown significant difference ($p \leq 0.05$) in between the preharvest application of micronutrients. After keeping the treated carrot root in different storage condition, it was found that among all the treatments, passive and trench storage retain more carotene content as compared to other storage. The preharvest treated carrot roots stored in underground passive storage maintained the higher average carotene content (2980.23 µg/100g) and it was observed among the treatments range 2533.43 to 3319.16 µg/100g during the 150 days storage period. After the 150 days of storage, minimum carotene content was observed in trench storage However, in room condition, carrot roots showed average value of carotene (3018.33 µg/100g) during 20 days of storage period. The two-way interaction between treatments with storage was significant ($P > 0.05$ on days 20 and 150) for the changes in carotene of roots. A decrease in carotenoids may result from more rapid oxidation due to increased respiration during storage (Howard and Dewi, 1996). Carotenoids in carrots comprised of unsaturated molecules which are highly sensitive to isomerization, that reduces the carrot's nutritional value by causing colour loss and oxidation (Chen *et al*., 1996). Belitz *et al*., (2004) and Fikselová *et al*., (2010) noted that the loss of β-carotene content in the cellar storage on an average of 5-40%.

Table 4.2.4: Effect of treatments and storage structure on carotene (µg/100g FW) of carrot root

Carotene									
	1st Year			2nd Year			Pooled Data		
Treatments	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)
T_0	3144.17±188.3b	2314.20±71.0a	2615.59±111.8ab	3213.34±170.9b	2752.66±218.1a	2503.67±211.4a	3178.76±70.9b	2533.43±136.9a	2559.63±127.1a
T_1	3179.03±129.6b	2545.62±23.1b	2544.92±126.7a	2670.14±332.3a	2866.24±396.9a	2550.60±91.8a	2924.58±203.4ab	2705.93±198.3ab	2547.76±38.6a
T_2	3138.65±78.4b	2931.32±60.9d	2834.38±133.0ab	3234.54±91.1b	3189.69±69.8a	2696.17±94.4ab	3186.60±24.8b	3060.50±62.0cd	2715.28±39.0ab
T_3	3130.27±40.9b	2854.18±64.0cd	2810.20±166.5ab	2947.54±46.8ab	3112.00±359.8a	2858.92±175.0ab	3038.91±7.1ab	2983.09±203.6bcd	2734.56±35.3ab
T_4	2795.43±145.8a	2699.90±35.1bc	2938.13±35.4b	2871.42±249.6ab	3061.83±212.3a	2957.14±278.1ab	2833.43±144.7a	2880.86±121.4bc	2947.64±142.7bc
T_5	3085.51±104.0ab	2854.18±63.4cd	3318.29±171.2c	2878.22±118.0ab	3269.64±145.9a	2949.05±96.3ab	2981.86±89.9ab	3061.91±64.7cd	3133.67±128.2bcd
T_6	3118.84±18.0ab	3008.46±82.3de	3311.04±98.5c	2685.94±156.8a	3216.38±112.7a	3052.15±324.6ab	2902.39±71.2ab	3112.42±66.7cd	3181.59±181.8cd
T_7	3189.91±83.9b	3162.74±13.3ef	3441.34±29.9c	3085.92±28.9ab	3166.83±56.8a	3010.14±172.3ab	3137.92±32.2b	3164.79±31.6cd	3225.74±95.0cd
T_8	3147.17±141.3b	3317.02±73.9f	3439.60±122.8c	2813.96±143.1ab	3321.30±173.6a	3281.69±168.7b	2980.57±83.7ab	3319.16±63.3d	3360.65±145.5d
Mean	3103.22±149.5	2854.18±298.2	3028.17±354.3	2933.45±246.3	3106.29±259.0	2884.39±285.1	3018.33±147.0	2980.23±252.4	2956.28±295.7

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

4.2.5 Antioxidant activity (mMTE/100g):

Total antioxidant activity obtained during storage is presented in Table 4.2.5. According to this experimental study, it was observed that the carrots stored in trench had recorded maximum average antioxidant (56.37 mMTE/100g) followed by underground passive storage (50.51 mMTE/100g). In room condition, treated carrot roots were found to have lowest average antioxidant (48.84 mMTE/100g) during 20 days of storage periods. Among trench storage, the highest average antioxidant content (59.01 mMTE/100g) was found in T_6- Boron @ 0.2% + $ZnSO_4$

@ 1.0% treated carrots. According to Two Way ANNOVA, it can be stated that treatments and storage had significant effect on antioxidant content

Table 4.2.5: Effect of treatments and storage structure on total antioxidant activity (mMTE/100g FW) of carrot root

Total antioxidant activity									
Treatment	1st Year			2nd Year			Pooled		
	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)
T_0	46.10±1.41a	48.50±0.80a	51.34±2.18a	48.59±1.86ab	49.34±0.34a	53.80±1.25a	47.35±1.5ab	48.92±0.3a	52.57±1.6a
T_1	48.26±1.82ab	49.84±1.98ab	52.63±2.08ab	49.78±0.74abc	51.07±1.41ab	56.15±1.98a	49.02±1.1bcd	50.46±1.7abc	54.39±2.0ab
T_2	47.54±1.93ab	50.43±0.24ab	55.00±1.83abc	53.09±1.17cd	50.70±0.32ab	57.09±2.01a	50.32±0.4cd	50.56±0.2abc	56.05±1.9ab
T_3	48.18±0.74ab	51.24±0.25ab	55.66±0.97abc	49.15±1.18ab	51.21±0.47ab	56.85±3.26a	48.66±0.4abcd	51.23±0.3bc	56.26±1.5ab
T_4	44.80±1.52a	50.42±1.72ab	57.27±2.79bc	47.66±1.64a	49.70±0.93a	57.26±0.89a	46.23±1.1a	50.06±1.1abc	57.26±1.4ab
T_5	46.55±0.87ab	50.31±0.46ab	56.15±1.06abc	54.24±0.68d	49.96±0.67a	58.69±1.18a	50.39±0.2cd	50.13±0.3abc	57.42±0.5ab
T_6	50.01±0.45b	51.90±0.91b	57.85±1.50c	51.59±0.71bcd	52.47±0.66b	60.16±1.68a	50.80±0.4d	52.18±0.2c	59.01±1.1b
T_7	46.99±1.32ab	50.31±0.66ab	56.16±1.69abc	49.39±0.28ab	49.62±1.10a	58.23±2.58a	48.18±0.5abc	49.96±0.9ab	57.19±1.5ab
T_8	47.54±1.21ab	51.53±0.73b	58.33±0.76c	49.73±1.68abc	50.69±0.39ab	56.00±6.55a	48.64±1.3abcd	51.11±0.2abc	57.16±3.4ab
Mean	47.33±1.80	50.50±1.29	55.60±2.67	50.36±2.31	50.53±1.15	57.14±2.96	48.84±1.63	50.51±1.09	56.37±2.35

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

During low temperature storage, boron treated root showed higher antioxidant potential than untreated. Different effects of cold storage on antioxidant activity of fruits and vegetables have been reported by various authors: stability of antioxidant activity during postharvest storage was observed in apricots, plums, and grapes (Kevers *et al*, 2007) and in tomatoes (Toor and Savage 2006); increase in Antioxidant Activity during storage was shown during refrigerated storage of celery (Viña and Chaves, 2006) and small fruits (Piljac-Žegarac and Šamec, 2011). Antioxidant activity varies with the species, the method of evaluation, and the extraction solvent (Deng *et al*., 2013). Decrease of antioxidant activity during storage can be attributed to a decreased level of total phenolics, phenolic acids, vitamin C and other compounds like anthocyanins, carotenoids, and flavonoids when the fruits and vegetables stored for long time (Galani *et al*., 2017).

4.2.6 Total phenolic content (mg GAE/g):

Total phenolic content of carrots with different treatments and storage conditions presented in Table 4.2.6. Among all the storage conditions, trench had shown better results than room condition. The carrot roots stored in trench storage maintained the higher average TPC (1.67 mg GAE/g) and range varied 0.67 - 2.33 mg GAE/g during the storage period. In room condition, carrot roots were observed average TPC (1.65 mg GAE/g) during 20 days of storage periods. It was found that TPC in room storage had no significant effect on carrot roots given different treatments. In underground passive and trench storage, treatments T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5% was found highest TPC (2.84 and 2.60 mg GAE/g) during 150 days of storage period. Boron deficiency often leads to increased activity of polyphenol oxidase (PPO) enzyme that catalysis the oxidation of phenolic compounds (Pfeffer *et al*., 1998). The slower rate of degradation of phenolic apparently indicates that boric acid plays an important role in delaying the activity of polyphenol oxidase enzyme due to delay in the respiratory activity of the fruit (Tomas-Barberan *et al*., 1997). It has been reported that the phenolic acids content dropped during ripening of fruit (Li *et al*., 2023).

Table 4.2.6: Effect of treatments and storage structure on total phenolic content (mg GAE/g DW)) of carrot root

Treatments	TPC								
	1st Year			2nd Year			Pooled Data		
	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)
T_0	1.39±0.71a	1.72±1.05abc	1.35±0.48ab	1.91±0.80a	1.39±1.06abc	1.71±0.76ab	1.65±0.5a	1.55±1.1abc	1.53±0.6abc
T_1	2.06±0.31a	2.05±0.48abc	2.05±0.55ab	1.76±0.98a	1.68±0.46abc	2.61±0.22ab	1.91±0.5a	1.87±0.5abc	2.33±0.4abc
T_2	1.20±1.15a	0.74±0.34a	0.81±0.51	1.25±0.69a	0.39±0.33a	0.9±0.43ab	1.22±0.6a	0.56±0.3a	0.86±0.5ab
T_3	1.77±0.21a	2.78±0.43bc	2.51±0.48b	1.12±0.90a	2.38±0.42bc	2.53±0.56ab	1.45±0.5a	2.58±0.4bc	2.52±0.4bc
T_4	2.05±0.74a	1.23±0.09a	1.75±0.44ab	1.90±1.03a	0.86±0.11a	1.91±0.44ab	1.97±0.4a	1.04±0.1a	1.83±0.4abc
T_5	1.56±0.64a	3.03±0.56c	2.53±0.76b	2.00±1.26a	2.66±0.50c	2.68±0.87b	1.78±0.9a	2.84±0.5c	2.60±0.7c
T_6	1.36±1.47a	1.31±0.33a	0.6±1.26a	2.70±0.73a	0.94±0.32ab	0.76±0.29a	2.03±0.5a	1.12±0.3ab	0.68±0.3a
T_7	1.98±0.60a	1.29±0.17a	1.39±0.27ab	1.27±0.94a	0.87±0.15a	1.67±0.40ab	1.63±0.5a	1.08±0.2a	1.53±0.3abc
T_8	0.94±0.64a	0.92±0.59a	0.56±0.07a	1.53±0.80a	0.54±0.54a	0.78±0.26ab	1.23±0.3a	0.73±0.6a	0.67±0.1a
Mean	1.59±0.77	1.67±0.88	1.51±0.90	1.72±0.90	1.30±0.87	1.73±0.93	1.65±0.55	1.49±0.88	1.67±0.89

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

4.2.7 Total flavonoids content (mg RTE/g):

The TFC of treated carrot under both storage condition was found to be maximum in trench stored roots (Table 4.2.7). The treated carrot roots stored in trench storage maintained the higher average TFC (0.46 mg RTE/g) during 150 days of storage. The TFC of treated roots in underground passive storage slightly decline and it ranged among the treatments 0.10 to 0.93 mg RTE/g, followed by trench storage (0.43 mg

RTE/g) stored roots. Under room storage, the stored carrot recorded minimum average TFC (0.44 mg RTE/g). On the other side statistical analysis indicated that treatments T_5 (Boron @ 0.1% + $ZnSO_4$ @ 0.5%) had shown more TFC content, which was statistically at par with treatment T_3 ($ZnSO_4$ @ 0.5%) than other treated carrots stored in trench storage.

Table 4.2.7: Effect of treatments and storage structure on total flavonoids content (mg RTE/g DW) of carrot root

TFC									
Treatments	1st Year			2nd Year			Pooled Data		
	RC	PS	TS	RC	PS	TS	RC	PS	TS
	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)
T_0	0.63±0.19a	0.75±0.29bc	0.76±0.32cd	0.55±0.11a	0.70±0.26b	0.62±0.39bc	0.59±0.0abc	0.72±0.3b	0.69±0.4bc
T_1	0.69±0.34a	0.54±0.11abc	0.64±0.07bcd	0.41±0.20a	0.47±0.09ab	0.52±0.11abc	0.55±0.1abc	0.51±0.1ab	0.58±0.1abc
T_2	0.41±0.20a	0.22±0.12a	0.21±0.08abc	0.51±0.24a	0.16±0.13a	0.07±0.00ab	0.46±0.2abc	0.19±0.1a	0.14±0.1ab
T_3	0.78±0.65a	0.99±0.26c	0.98±0.14d	0.60±0.21a	0.88±0.26b	83±0.21c	0.69±0.2c	0.93±0.3b	0.90 ±0.2c
T_4	0.58±0.29a	0.56±0.19abc	0.53±0.15abcd	0.23±0.14a	0.48±0.20ab	0.38±0.14abc	0.40±0.1abc	0.52±0.2ab	0.36±0.1abc
T_5	0.86±0.07a	0.85±0.15c	0.97±0.08d	0.43±0.54a	0.78±0.13b	0.84±0.17c	0.64±0.3bc	0.81±0.1b	0.91±0.1c
T_6	0.30±0.31a	0.23±0.23ab	0.13±0.37ab	0.11±0.07a	0.15±0.20a	0.01±0.0a	0.21±0.2ab	0.19±0.2a	0.07±0.0a
T_7	0.37±0.20a	0.22±0.08a	0.29±0.11abc	0.06±0.04a	0.17±0.06a	0.15±0.03ab	0.21±0.1ab	0.19±0.1a	0.32±0.1ab
T_8	0.24±0.17a	0.14±0.08a	0.07±0.19a	0.06±0.03a	0.06±0.07a	0.0±0.0a	0.15±0.1a	0.10±0.1a	0.03±0.0a
Mean	0.54±0.33	0.50±0.34	0.51±0.37	0.33±0.28	0.43±0.33	0.38±0.37	0.43±0.24	0.46±0.33	0.44±0.37

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

4.2.8 Anion content (nitrate, phosphate, sulfate) mg/100g:

Nitrate content was depicted in Table 4.2.8. It had been observed that nitrate content was highest in trench storage as compared to room and underground passive storage conditions. The treated carrot roots stored in trench storage maintained the higher average nitrate content (266.98 mg/100g). The nitrate of treated roots in trench storage slightly declined and range among the treatments was 228.45 to 287.26 mg/100g, whereas in case of underground passive storage treated roots, the nitrate was found to sharply declined and the range between treatments was observed 186.91 to 234.34 mg/100g during 150 days of storage. Under room condition, the treated carrot stored roots recorded average nitrate (232.45 mg/100g) and ranged was observed between 195.27 to 256.56 mg/100g during 20 days of storage. Maximum average nitrate content in trench storage was found to be 287.26 mg/100g in treatments T_3- $ZnSO_4$ @ 0.5% which is highest among all the treated and stored carrots.

Phosphate content was presented in Table 4.2.9, It can be said that phosphate content in carrots had shown no significant difference with different treatments whereas storage had shown significant relation on phosphate content. The treated carrot roots stored in trench and underground passive storage maintained the higher average phosphate content 547.60 mg/100g and 546.80 mg/100g compared to room storage. The phosphate content of carrot roots stored in room storage was found maximum (580.87 mg/100g) and it ranged among the treatments 559.86 to 599.23 mg/100g in different treatments during 20 days of storage.

Treatments and storage conditions had shown significant relation with sulfate content as presented in Table 4.2.10. Among all the treatments, underground passive storage had shown no change in sulfate content with the treatments given. The treated carrot roots stored in underground passive storage maintained the higher average value of sulfate content (355.04 mg/100g) compared to trench storage (309.06 mg/100g). The sulfate of treated roots in room storage was found maximum and it was ranged among the treatments 268.18 to 394.62 mg/100g across given treatments during 20 days of storage. Amongst all the treatments and storage conditions, the highest average sulfate content was found in T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5 treated carrots i.e. 408.70 mg/100g in underground passive storage.

Table 4.2.8: Effect of treatments and storage structure on Nitrate (mg/100g DW) of carrot root

Nitrate									
Treatments	**1st Year**			**2nd Year**			**Pooled data**		
	RC	**PS**	**TS**	**RC**	**PS**	**TS**	**RC**	**PS**	**TS**
	(20 Days)	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**
T_0	182.84±14.25a	169.41±7.11ab	215.44±8.89a	207.69±5.26a	243.84±14.37bc	241.46±5.44a	195.27±6.5a	206.62±8.9abc	228.45±4.3a
T_1	205.88±8.02ab	176.75±47.51abc	238.17±2.19ab	222.14±4.50ab	212.87±33.14ab	254.71±3.45ab	214.01±4.1ab	194.81±19.8ab	246.44±1.3b
T_2	238.24±22.52b	157.67±4.35a	268.71±16.31bc	264.36±6.54c	216.15±29.28ab	292.35±8.92c	251.29±12.2d	186.91±14.5a	280.53±7.9d
T_3	245.46±20.36b	185.36±6.91abcd	274.51±26.78c	267.67±8.29c	279.29±6.87c	300.02±3.69c	256.56±6.4d	232.32±6.9c	287.26±12.2d
T_4	234.66±15.26b	192.21±3.95abcd	264.53±8.79bc	255.27±6.53c	247.51±8.86bc	300.53±6.82c	244.97±4.6cd	219.86±2.8bc	282.53±1.9d
T_5	227.74±13.14ab	211.13±6.01bcd	259.33±5.62bc	258.82±3.84c	257.55±7.14bc	289.50±5.13c	243.28±6.9cd	234.34±5.5c	274.41±3.3cd
T_6	236.50±22.77b	188.86±6.31abcd	265.65±5.84bc	257.60±3.36c	249.39±5.94bc	303.72±6.45c	247.05±12.9cd	219.13±2.6bc	284.69±6.1d
T_7	215.61±14.87ab	233.97±5.84d	252.10±8.06bc	233.89±5.09b	182.90±19.00a	271.58±5.01b	224.75±5.2bc	208.43±12.0abc	261.84±1.5bc
T_8	204.18±14.73ab	223.03±12.99cd	243.28±7.44abc	225.56±6.98b	208.54±10.89bc	269.97±6.57b	214.87±10.6ab	215.78±11.9abc	256.63±6.7b
Mean	221.23±24.17	193.15±28.08	253.52±20.53	243.67±21.34	233.11±32.30	280.43±21.84	232.45±21.3	213.13±17.7	266.98±20.0

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

Table 4.2.9: Effect of treatments and storage structure on Phosphate (mg/100g DW) of carrot root

Phosphate									
Treatments	1st Year			2nd Year			Pooled Data		
	RC	PS	TS	RC	PS	TS	RC	PS	TS
	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)
T_0	522.51±7.40abc	400.18±1.83ab	486.51±27.36a	663.51±27.68a	642.81±86.91a	664.76±9.65a	593.01±10.18a	521.49±44.37ab	575.63±8.97a
T_1	497.31±1.89ab	439.28±68.48ab	497.99±29.81a	645.81±35.64a	663.36±6.92a	659.15±42.17a	571.56±18.76a	551.32±37.65ab	578.57±35.58a
T_2	528.60±29.33abc	448.61±1.98ab	507.40±61.16a	641.52±32.48a	657.12±55.28a	594.95±34.51a	585.06±30.90a	552.87±28.28ab	551.18±34.40a
T_3	495.14±8.05a	470.58±55.18ab	501.02±61.40a	624.57±12.35a	656.03±7.28a	598.13±29.13a	559.86±5.56a	563.31±30.45ab	549.58±45.19a
T_4	522.81±8.73abc	490.95±54.39b	451.77±14.44a	649.58±30.07a	636.99±36.84a	576.12±8.44a	586.20±13.38a	563.97±23.25ab	523.94±4.03a
T_5	521.05±17.80abc	458.03±30.55ab	412.87±32.76a	655.48±3.91a	631.41±76.32a	600.71±62.22a	588.26±7.34a	544.72±29.49ab	506.79±36.42a
T_6	505.80±11.51abc	510.15±74.29b	431.03±43.23a	624.57±39.84a	656.85±14.06a	655.34±48.03a	565.19±14.32a	583.50±44.07b	543.18±17.07a
T_7	541.73±26.30bc	351.84±0.53a	498.50±59.46a	617.25±22.24a	616.06±64.29a	605.90±26.39a	579.49±24.23a	483.95±32.38a	552.20±25.36a
T_8	544.10±5.60c	487.23±44.09b	492.44±10.99a	654.37±13.17a	624.82±73.76a	622.31±19.63a	599.23±5.86a	556.02±36.40ab	557.37±15.06a
Mean	519.89±21.39	450.76±60.89	475.50±48.29	641.85±27.11	642.83±48.81	619.71±42.82	580.87±18.69	546.80±40.02	547.60±32.96

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

Table 4.2.10: Effect of treatments and storage structure on Sulfate (mg/100g DW) of carrot root

Sulfate									
Treatments	1st Year			2nd Year			Pooled data		
	RC	PS	TS	RC	PS	TS	RC	PS	TS
	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)
T_0	284.86±8.56a	262.77±18.77a	268.47±7.63a	266.71±4.07a	419.35±62.58a	200.77±101.94a	275.79±5.90a	341.06±37.96a	234.62±53.49ab
T_1	275.92±4.54a	275.80±33.04a	285.85±4.62a	260.43±1.53a	370.20±22.64a	217.43±40.94a	268.18±2.99a	323.00±6.24a	251.64±18.16abc
T_2	295.88±2.26a	327.29±37.89a	273.67±8.90a	351.38±29.47cd	352.66±3.99a	183.67±62.95a	323.63±15.86bc	339.97±17.36a	228.67±27.03a
T_3	328.08±12.83b	269.57±28.80a	354.09±10.69b	291.00±8.61ab	418.45±61.76a	242.24±84.60a	309.54±6.02b	344.01±44.64a	298.16±45.09abcd
T_4	364.44±1.42c	317.53±114.36a	352.41±4.93b	371.48±8.90cd	499.87±91.34a	265.62±80.83a	367.96±5.04de	408.70±74.84a	309.02±42.02abcd
T_5	380.31±8.51cd	276.45±49.19a	339.02±9.28b	293.19±33.67ab	374.29±5.90a	362.04±110.32a	336.75±15.82bc	325.37±24.30a	350.53±50.57bcd
T_6	370.75±15.25c	312.49±75.50a	396.93±14.71c	379.73±26.18d	426.71±57.84a	336.29±83.96a	375.24±17.88e	369.60±14.98a	366.61±44.95cd
T_7	358.34±8.97c	329.69±29.19a	385.20±2.60c	326.72±2.76bc	455.81±62.02a	339.75±99.31a	342.53±3.44cd	392.75±19.61a	362.47±50.87cd
T_8	401.58±10.86d	305.40±85.45a	404.38±1.85c	387.65±4.94d	396.42±65.26a	355.32±66.75a	394.62±7.82e	350.91±71.04a	379.85±34.29d
Mean	340.02±44.35	297.44±56.38	340.00±51.11	325.37±49.74	412.64±64.10	278.13±97.50	332.69±42.54	355.04±44.80a	309.06±67.10

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3.T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

4.2.9 Micro nutrients (Mn, Zn, Cu, Na, Fe) mg/100g:

All the treatments of underground passive storage and trench storage had shown no significant change in manganese content (Table 4.2.11). The treated carrot roots stored in underground passive storage maintained the higher average value of manganese content (1.34 mg/100g) as compared to trench storage (1.29 mg/100g). The treatments and storage conditions had no significant impact on manganese content of carrots during long term storage. Zinc content after micronutrient treatments and storage was shown in Table 4.2.12. Boron @ 0.1% + $ZnSO_4$ @ 0.5%, (T_5) treatment in all the storage conditions had shown better results as compared to others. Zinc content reached a maximum value of 8.28 and 7.89 for the treatments T_5 in room and passive storage, respectively. In trench storage, maximum zinc (7.22 mg/100g) content was exhibited in treatments T_8 which was at par with T_5. The treatments and storage conditions had no significant impact on copper content of carrots during long term storage (Table 4.2.13). During the storage periods average maximum copper content was recorded in trench storage followed by passive storage. The average minimum value of copper (0.25 mg/100g) was recorded in room condition.

Sodium content after micronutrient treatments and storage content shown in Table 4.2.14. Room and trench storage showed no significant change for all the treated carrot. But in underground passive storage a significant difference of all the treatments of carrot was observed with maximum sodium (319.30 mg/100g) content in treatment T_1. While minimum sodium (255.44 mg/100g) was observed in treatments T_7, it was at par with treatments T_3 (287.47 mg/100g), T_5 (290.32 mg/100g), T_6 (292.57 mg/100g) and T_8 (271.39 mg/100g). Effect of treatments and storage on iron content in carrots is shown in Table 4.2.15. It was found that iron content in room storage had no significant effect on carrots with given treatments, whereas iron content in treated carrot was found significant in underground passive and trench storage. The preharvest treated carrot roots stored in underground passive storage maintained the higher average iron content (9.01 mg/100g) and it was observed among the treatments range 7.62 to 10.50 mg/100g during the 150 days storage period. After the150 days of storage, minimum average iron content (7.75 mg/100g) was observed in trench storage.

Table 4.2.11: Effect of treatments and storage structures on Mn (mg/100g DW) of carrot root

Mn									
Treatments	**1st Year**			**2nd Year**			**Pooled data**		
	RC	**PS**	**TS**	**RC**	**PS**	**TS**	**RC**	**PS**	**TS**
	(20 Days)	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**
T_0	1.29±0.03ab	1.20±0.23a	1.27±0.11a	1.25±0.06ab	1.32±0.03abc	1.28±0.04a	1.27±0.0ab	1.26±0.1a	1.27±0.0a
T_1	1.27±0.06ab	1.57±0.47a	1.22±0.25a	1.27±0.01abc	1.97±0.29d	1.34±0.09a	1.27±0.0ab	1.77±0.4a	1.28±0.1a
T_2	1.20±0.09ab	1.42±0.10	1.27±0.20a	1.34±0.05bc	1.11±0.21ab	1.31±0.03a	1.27±0.1ab	1.27±0.1a	1.29±0.1a
T_3	1.15±0.08a	1.51±0.52a	1.24±0.10a	1.26±0.01abc	1.15±0.24ab	1.36±0.06a	1.21±0.0a	1.33±0.3a	1.30±0.1a
T_4	1.26±0.01ab	1.03±0.08a	1.27±0.05a	1.20±0.05a	1.29±0.22abc	1.35±0.07a	1.23±0.0ab	1.16±0.1a	1.31±0.0a
T_5	1.40±0.07b	1.09±0.10a	1.22±0.08a	1.28±0.08abc	1.80±0.10cd	1.36±0.02a	1.34±0.1ab	1.44±0.1a	1.29±0.0a
T_6	1.25±0.13ab	1.56±0.83a	1.33±0.09a	1.33±0.02bc	1.08±0.20ab	1.36±0.06a	1.29±0.1ab	1.32±0.5a	1.34±0.1a
T_7	1.32±0.02ab	1.10±0.29a	1.25±0.07a	1.38±0.04c	1.02±0.03a	1.27±0.06a	1.35±0.0b	1.06±0.2a	1.26±0.0a
T_8	1.29±0.08ab	1.26±0.37a	1.25±0.10a	1.31±0.03abc	1.55±0.13bcd	1.33±0.03a	1.30±0.0ab	1.41±0.2a	1.29±0.1a
Mean	1.27±0.09	1.30±0.39	1.26±0.11	1.29±0.06	1.37±0.36	1.33±0.06	1.28±0.06	1.34±0.28	1.29±0.06

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

Table 4.2.12: Effect of treatments and storage structures on zinc (mg/100g DW) of carrot root

Zn									
Treatments	**1st Year**			**2nd Year**			**Pooled Data**		
	RC	**PS**	**TS**	**RC**	**PS**	**TS**	**RC**	**PS**	**TS**
	(20 Days)	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**
T_0	4.06±0.55a	3.95±0.26a	4.42±0.40a	4.73±0.12a	4.84±0.18a	4.62±0.16a	4.39±0.3a	4.39±0.0a	4.52±0.2a
T_1	4.45±0.61ab	5.79±0.17a	5.26±0.84ab	4.34±0.26a	6.19±0.10b	6.14±0.16bc	4.39±0.4a	5.99±0.1b	5.70±0.5bc
T_2	4.06±0.25a	4.80±1.84a	4.61±0.31a	4.31±0.28a	6.62±0.19b	5.53±0.06b	4.19±0.1a	5.71±0.8ab	5.07±0.1ab
T_3	7.21±0.26d	3.43±0.79a	4.73±0.13a	6.94±0.25c	9.27±0.23e	8.74±0.52f	7.08±0.1c	6.35±0.3b	6.73±0.3cd
T_4	6.23±0.10de	5.77±0.32a	6.20±0.69ab	5.81±0.02b	8.28±0.20c	8.30±0.29f	6.02±0.0b	7.02±0.1bc	7.25±0.4d
T_5	8.35±0.21f	4.57±1.64a	6.13±0.59ab	8.22±0.26d	11.22±0.17f	8.11±0.19ef	8.28±0.1d	7.89±0.9c	7.13±0.4d
T_6	5.35±0.17bc	4.01±0.18a	5.21±0.81ab	5.90±0.05b	7.33±0.18c	7.31±0.29de	5.62±0.1b	5.67±0.1ab	6.26±0.4cd
T_7	6.63±0.12de	5.74±0.21a	6.90±1.31b	6.87±0.41c	8.45±0.22d	6.55±0.45cd	6.75±0.2c	7.09±0.2bc	6.73±0.5cd
T_8	7.37±0.21f	4.70±1.64a	6.28±0.65ab	7.06±0.14c	9.61±0.18e	8.16±0.40ef	7.22±0.2c	7.16±0.9bc	7.22±0.5d
Mean	5.97±1.53	4.75±1.20	5.53±1.03	6.02±1.33	7.98±1.88	7.05±1.39	5.99±1.4	6.36±1.1	6.29±1.0

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage TS-Trench Storage, T-Treatments

Interaction of treatment and storage shown no significant effect on iron content. Bouzari *et al*., (2015) and previous authors have found that minerals are unaffected by the thermal treatments implemented during conventional food processing. No significant interaction of the analyzed factors was observed (Zn and B applications and the date of analysis), implicating that the use of zinc and boron in carrot cultivation does not prevent the loss of microelement concentrations in carrot roots during storage.

Table 4.2.13: Effect of treatments and storage structures on copper (mg/100g DW) of carrot root

Cu									
Treatments	1st Year			2nd Year			Pooled Data		
	RC	PS	TS	RC	PS	TS	RC	PS	TS
	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)
T_0	0.23±0.06a	0.41±0.04a	0.40±0.07a	0.27±0.04a	0.23±0.04a	0.39±0.05ab	0.28±0.0b	0.33±0.0a	0.39±0.0ab
T_1	0.27±0.07a	0.37±0.06a	0.39±0.02a	0.29±0.05a	1.32±0.11a	0.37±0.02a	0.27±0.0b	0.35±0.1a	0.38±0.0ab
T_2	0.27±0.06a	0.41±0.04a	0.34±0.04a	0.29±0.01a	0.24±0.03a	0.37±0.01a	0.25±0.0ab	0.32±0.0a	0.36±0.0a
T_3	0.31±0.02a	0.40±0.01a	0.42±0.04a	0.26±0.01a	0.25±0.06a	0.39±0.09ab	0.24±0.0ab	0.32±0.0a	0.41±0.0ab
T_4	0.22±0.02a	0.36±0.05a	0.37±0.06a	0.28±0.03a	0.22±0.05a	0.43±0.03ab	0.26±0.0ab	0.29±0.0a	0.40±0.0ab
T_5	0.23±0.03a	0.39±0.06a	0.42±0.03a	0.22±0.06a	0.28±0.07a	0.48±0.03b	0.25±0.0ab	0.33±0.1a	0.45±0.0b
T_6	0.23±0.02a	0.40±0.07a	0.40±0.03a	0.26±0.06a	0.30±0.01a	0.34±0.02a	0.26±0.0ab	0.35±0.0a	0.37±0.0a
T_7	0.23±0.04a	0.39±0.07a	0.41±0.06a	0.19±0.01a	1.33±0.11a	0.37±0.02a	0.22±0.0a	0.36±0.1a	0.39±0.0ab
T_8	0.22±0.05a	0.38±0.06a	0.40±0.04a	0.26±0.02a	0.31±0.07a	0.35±0.01a	0.25±0.0ab	0.35±0.1a	0.38±0.0ab
Mean	0.25±0.05	0.39±0.05	0.39±0.05	0.26±0.04	0.28±0.07	0.39±0.05	0.25±0.02	0.33±0.05	0.39±0.03

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

Table 4.2.14: Effect of treatments and storage structures on sodium (mg/100g DW) of carrot root

Na									
Treatments	**1st Year**			**2nd Year**			**Pooled Data**		
	RC	**PS**	**TS**	**RC**	**PS**	**TS**	**RC**	**PS**	**TS**
	(20 Days)	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**
T_0	263.79±26.07abc	223.22±36.01a	238.53±28.07a	263.66±15.19abc	305.53±7.06c	295.26±0.93a	263.73±12.3a	264.37±1 7.9a	266.90±14.2a
T_1	290.54±13.91bc	274.14±32.74a	254.31±19.50a	275.61±16.76abc	364.46±11.65e	323.46±9.57bcd	283.07±6.8a	319.30±14.4b	288.88±5.4a
T_2	282.75±23.98bc	269.36±21.09a	244.25±39.37a	239.23±6.24a	255.09±5.02a	304.91±6.59a	260.99±13.6a	262.23±13.0a	274.58±22.9a
T_3	281.43±4.54bc	246.82±36.36a	260.23±8.86a	252.85±9.68ab	328.12±3.32d	330.26±0.34d	267.15±5.9a	287.47±18.7ab	295.25±4.6a
T_4	237.08±3.59a	255.22±16.79a	251.35±17.33a	297.86±18.84c	275.68±5.54b	309.25±5.20ab	267.47±11.0a	265.45±5.7a	280.30±6.1a
T_5	255.02±2.33ab	251.09±62.77a	267.94±30.02a	293.03±26.08bc	329.39±2.84d	328.05±1.90cd	274.02±12.6a	290.24±32.7ab	297.99±15.5a
T_6	297.96±16.53c	250.67±32.75a	246.80±38.62a	278.44±9.14abc	334.48±6.63d	326.48±7.48bcd	288.20±3.7a	292.57±17.6ab	286.64±17.5a
T_7	279.22±9.33abc	267.88±35.15a	262.32±17.51a	285.16±5.33bc	243.00±3.17a	332.21±8.56d	282.19±7.2a	255.44±16.0a	297.26±12.8a
T_8	275.99±12.96abc	262.59±24.35a	267.93±26.85a	276.52±5.08abc	280.20±1.00b	312.38±6.01abc	276.26±7.6a	271.39±12.3ab	290.15±11.6a
Mean	273.75±21.97	255.67±32.95	254.85±24.56	273.60±21.64	301.77±39.41	318.03±13.47	273.68±12.1	278.72±24.5	286.44±15.2

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

Table 4.2.15: Effect of treatments and storage structures on iron (mg/100g DW) of carrot root

Fe									
Treatments	1st Year			2nd Year			Pooled Data		
	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)
T_0	5.93±0.04a	8.02±1.33a	5.78±0.97a	8.72±0.77ab	7.22±0.11a	6.96±0.73a	7.32±0.4a	7.62±0.7a	6.37±0.5a
T_1	6.84±1.25a	6.97±2.37a	6.32±1.91a	9.35±1.17ab	8.81±0.12b	8.34±0.25ab	8.09±1.2a	7.89±1.2ab	7.33±1.1ab
T_2	8.57±0.91a	7.03±0.88a	6.63±1.17a	7.82±1.02ab	11.98±0.23fg	11.68±0.70c	9.36±0.6a	9.51±0.5abcd	9.16±0.9b
T_3	8.50±1.50a	6.07±1.45a	5.49±1.80a	6.60±0.09a	10.65±0.20d	10.01±1.17bc	7.55±0.7a	8.36±0.8abc	7.75±0.9ab
T_4	8.87±2.17a	9.32±0.27a	6.70±1.44a	6.93±0.58a	11.39±0.25ef	9.91±1.27abc	7.90±1.4a	10.35± 0.2cd	8.30±1.0ab
T_5	7.74±1.81a	8.30±1.16a	5.55±1.01a	10.67±0.06b	9.89±0.06c	9.31±0.70abc	9.21±0.9a	9.10±0.6abcd	7.43±0.8ab
T_6	8.50±2.98a	8.16±0.86a	4.55±1.22a	8.13±1.45ab	11.33±0.32e	10.65±1.82bc	8.32±1.1a	9.75±0.5bcd	7.60±0.4ab
T_7	8.78±2.35a	8.45±1.97a	7.20±1.40a	8.57±1.75ab	12.55±0.23g	10.01±1.42bc	8.68±1.9a	10.50±1.1d	8.60±0.9ab
T_8	6.48±0.65a	7.85±1.49a	6.23±1.55a	9.47±1.86ab	8.21±0.31b	8.16±0.42ab	7.98±1.1a	8.03±0.7ab	7.19±0.7ab
Mean	7.80±1.80	7.80±1.51	6.05±1.41	8.47±1.56	10.23±1.76	9.45±1.63	8.27±1.1	9.01±1.2	7.75±1.1

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments

4.2.10 Sugars (glucose, fructose, sucrose) content (g/100g) of carrot under different storage conditions:

It is evident from Table 4.2.16. that reducing sugar increases with increasing storage duration. It was found that different treatments had no significant impact on the glucose content of carrot in trench storage during the observation period till 150 days. Under room storage, the treated carrot stored roots recorded average glucose (24.61 g/100g) and ranged among the treatment was observed 23.64 to 26.47 g/100g during 150 days of storage. After 150 days carrot stored in trench storage was observed maximum average glucose content (23.89 g/100g) and range was recorded among the treatment 22.92 to 24.91 g/100g.

Table 4.2.16: Effect of treatments and storage structures on glucose (g/100g DW) content of carrot root

Treatments	Glucose								
	1st Year			2nd Year			Pooled Data		
	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)	RC (20 Days)	PS (150 Days)	TS (150 Days)
T_0	27.05±0.42c	26.32±0.17e	23.61±0.20a	25.89±1.24a	24.12±1.72a	25.22±2.76a	26.47±0.7c	25.22±0.9b	24.91±1.3a
T_1	25.77±0.40bc	24.58±0.16d	23.26±0.97a	24.20±1.40a	21.60±2.84a	24.89±0.26a	24.99±0.5abc	23.09±1.4ab	24.57±0.5a
T_2	23.96±0.45ab	22.38±0.45bc	23.19±1.33a	24.22±0.68a	20.54±3.06a	24.76±1.15a	24.09±0.4ab	21.46±1.3a	23.98±1.2a
T_3	25.74±0.33bc	20.48±0.64a	22.70±0.69a	25.37±0.96a	19.75±3.76a	24.10±0.24a	25.56±0.6bc	20.11±1.8a	23.40±0.5a
T_4	24.56±1.42ab	22.42±0.46bc	22.91±1.07a	23.36±0.47a	21.32±1.55a	23.40±1.58a	23.96±0.8a	21.87±0.5ab	23.15±0.8a
T_5	24.07±0.16ab	23.15±0.65c	22.65±0.44a	23.71±0.71a	20.29±3.25a	23.19±0.16a	23.89±0.3a	21.72±1.5ab	22.92±0.1a
T_6	24.08±0.41ab	22.40±0.48bc	24.52±0.16a	23.42±0.29a	21.21±1.87a	24.39±2.09a	23.75±0.3a	21.81±0.8ab	24.45±1.1a
T_7	23.10±0.35a	23.55±0.20cd	24.70±0.29a	24.18±0.49a	20.36±3.14a	23.52±0.82a	23.64±0.3a	21.96±1.6ab	24.11±0.5a
T_8	25.43±0.86bc	21.36±0.45ab	23.38±0.33a	24.81±1.80a	20.80±0.99a	23.70±0.54a	25.12±0.5abc	21.08±0.7a	23.54±0.3a
Mean	24.86±1.29	22.96±1.70	23.66±1.02	24.35±1.18	21.11±2.50	24.13±1.34	24.61±1.0	22.03±1.7	23.89±0.9

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments, SS-Storage Structure, SOS- Sum of Squares, MS- Mean Square

Considering the statistical results, it was found that glucose was less in carrot root stored in underground passive storage. In storage periods, maximum glucose was recorded in control (T_0) among the all storage. Fructose content after micronutrient treatments and storage is shown in Table 4.2.17. It was found that treatments had no significant impact on the fructose content of carrot in room condition during the observation period till 20 days. Among the storage conditions, fructose was least in room storage (10.05 g/100g) at 20 days storage periods. The underground passive storage maintained minimum fructose content (10.27 g/100g) and range among the treatments 8.07 to 11.49 g/100g during 150 days of storage periods. In underground passive and trench storage, lowest fructose content of carrot was found in preharvest application of treatments T_3 (8.07 g/100g) and T_6 (10.04 g/100g), respectively.

Table 4.2.17: Effect of treatments and storage structures on fructose (g/100g DW) content of carrot root

Fructose									
Treatments	1st Year			2nd Year			Pooled Data		
	RC	PS	TS	RC	PS	TS	RC	PS	TS
	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)	(20 Days)	(150 Days)	(150 Days)
T_0	10.55±0.89a	11.51±0.97b	10.01±0.11ab	10.25±1.62a	11.46±0.86b	11.78±0.24a	10.40±1.3a	11.49±0.5d	10.90±0.2bc
T_1	10.54±2.20a	10.99±0.73b	10.86±0.31c	10.57±1.02a	9.92±0.40ab	11.37±0.09a	10.56±1.5a	10.46±0.4bcd	11.11±0.1c
T_2	10.90±0.38a	9.33±1.02ab	10.43±0.44bc	9.90±0.96a	9.26±1.35ab	11.63±0.34a	10.40±0.6a	9.30±0.5ab	11.03±0.4bc
T_3	10.41±0.53a	8.09±0.71a	9.71±0.21ab	9.86±0.53a	8.05±1.25a	11.05±0.32a	10.14±0.0a	8.07±0.9a	10.38±0.1abc
T_4	9.78±0.35a	11.82±1.16b	9.63±0.47ab	8.51±1.35a	10.76±0.21b	10.94±0.73a	9.15±0.8a	11.29±0.7cd	10.28±0.4ab
T_5	10.33±0.54a	11.68±0.77b	9.98±0.34ab	9.90±1.19a	10.80±0.37b	10.31±0.14a	10.11±0.3a	11.24±0.4cd	10.65±0.2abc
T_6	9.49±0.42a	10.41±0.67ab	9.35±0.14a	10.25±1.46a	9.47±0.77ab	10.72±0.69a	9.87±0.8a	9.94±0.2bcd	10.04±0.4a
T_7	9.91±0.24a	10.68±0.87b	10.14±0.15abc	9.81±1.58a	11.45±0.45b	11.41±0.20a	9.86±0.8a	11.07±0.7cd	10.77±0.1abc
T_8	9.64±0.29a	9.33±0.98ab	9.76±0.18ab	10.22±1.17a	9.88±1.31ab	11.16±0.25a	9.93±0.7a	9.61±0.7abc	10.46±0.2abc
Mean	10.17±0.86	10.43±1.43	9.99±0.50	9.92±1.18	10.12±1.30	11.26±0.46	10.05±0.8	10.27±1.2	10.62±0.4

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS- Underground passive storage, TS-Trench Storage, T-Treatments, SS- Storage Structure, SOS- Sum of Squares, MS- Mean Square

Sucrose content after preharvest application and storage is shown in Table 4.2.18. It was observed that treatments had no significant impact on the sucrose content of carrot in all storage condition. Among all storage conditions, average sucrose content was found minimum in underground passive storage (10.49 g/100g) at 150 days storage periods as compared to trench storage (11.89 g/100g).

Table 4.2.18: Effect of treatments and storage structures on sucrose (g/100g DW) content of carrot root

Sucrose									
Treatments	**1st Year**			**2nd Year**			**Pooled Data**		
	RC	**PS**	**TS**	**RC**	**PS**	**TS**	**RC**	**PS**	**TS**
	(20 Days)	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**	**(20 Days)**	**(150 Days)**	**(150 Days)**
T_0	12.19±2.12a	11.27±0.24a	11.35±0.16a	11.30±4.49a	10.13±1.48a	10.94±1.17a	11.75±3.3a	10.70±0.6a	11.14±0.5a
T_1	12.66±2.23a	13.92±0.34de	12.78±0.42bc	11.67±4.32a	10.52±0.97a	11.55±1.49a	12.16±3.3a	12.22±0.6a	12.16±0.8a
T_2	12.31±0.27a	13.40±0.22cd	12.62±0.12bc	11.12±0.66a	9.65±0.94a	12.08±1.60a	11.72±0.4a	11.53±0.4a	12.35±0.8a
T_3	12.31±0.86a	11.04±0.24a	11.52±0.13a	10.80±1.65a	10.40±1.00a	11.16±1.89a	11.55±1.2a	10.72±0.6a	11.34±1.0a
T_4	11.52±1.00a	13.05±0.38bc	12.21±0.30ab	9.87±1.93a	10.63±1.62a	11.95±1.89a	10.70±1.5a	11.84±0.7a	12.08±0.8a
T_5	12.18±0.96a	14.42±0.22e	13.27±0.52c	10.74±1.70a	10.13±1.78a	11.73±2.06a	11.46±1.3a	12.28±0.9a	12.50±1.2a
T_6	12.48±0.91a	13.54±0.27cd	12.09±0.12ab	11.39±1.14a	10.22±0.34a	11.04±1.22a	11.93±1.0a	11.88±0.2a	12.56±0.6a
T_7	12.20±1.77a	12.58±0.32b	12.06±0.47ab	11.66±3.31a	10.45±1.13a	11.56±1.46a	11.93±2.5a	11.52±0.5a	11.81±0.5a
T_8	11.31±0.74a	12.86±0.15bc	11.52±0.50a	9.06±1.45a	10.09±2.11a	11.09±1.73a	10.19±1.1a	11.48±1.0a	11.30±1.0a
Mean	12.13±1.21	12.90±1.11	12.16±0.68	10.85±2.36	10.25±1.17	11.46±1.42	11.49±1.78	11.57±0.8	11.81±0.8

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%, RC-Room condition, PS-Underground passive storage, TS-Trench Storage, T-Treatments, SS-Storage Structure, SOS- Sum of Squares, MS- Mean Square

The response of the plants to zinc and boron as a foliar spray was significant but inconsistent in relation to reducing sugar of the roots. Effects of boron and zinc on carbohydrate metabolism, sugar transport, cell wall synthesis and on lignification might persuade the carrot root quality expression (Marschner, 2012). Although glucose, fructose and sucrose together contribute more than 50% of the root dry weight (Nilsson, 1987), other constituents of importance in post-harvest metabolism during storage may be subjected to change in their relative amounts during the harvest period. Although the potential role such components may play in delaying or promoting senescence is unknown, a successful determination of 'a most suitable time of harvest' with respect to storability presupposes the identification of biochemical indicators which are easy to quantify. On complete hydrolysis of starch, no further increase in sugars occurs. Subsequent decline in sugar parameters along with other organic acids that are primary substrate for respiration was predictable (Kishor *et al*., 2018). This increase might be due to conversion of non-reducing sugar to reducing sugar, breakdown of cell wall (cellulose, hemicellulose, and pectin) and loss of moisture during storage (Brady, 1987 and Biale, 1961). Zhang *et al*., (2002) reported that total sugars were higher in the earlier stages of storage and maintained relatively constant at the end of storage that might depend upon genotypes.

Figure 4.3: Effect of different storage condition on carrot storage

4.3 Objective 3. "To Study about effect of different packaging materials to enhancing the shelf-life of carrot."

4.3.1 Weight Loss% of carrot under different packaging materials:

The percent weight loss, in general, increased with the advancement of the storage period, rather slowly in the beginning but at a faster pace as the storage period advanced (Table 4.3.1). The minimum weight loss of treated carrot root at the end of storage periods was observed in perforated polyethylene bags compared with other packaging materials. It was noticed that perforated polyethylene bag packed root observed the lowest average weight loss (10.25%) and the range among the treatments 6.67%–14.93% after 150 days of storage as compared to wooden crate where weight loss was found to be the highest and the range was observed among the treatments was 41.67% to 66.51% after 90 days. Similarly, leno bag- and cotton bag-treated carrot root were stored in 150 days, and the lowest weight loss (38.03 %) and (41.10%) were observed in treatment T_1 and T_4, respectively.

The rate of weight loss was slower in the perforated polyethylene bag-packaged root than in other packaging during the storage period. Treatment means of packaged carrot root showed significant differences between the leno bag, cotton bag, and perforated polyethylene bag, whereas all other bags differed significantly. The data on weight loss revealed significant differences among all storage intervals. The interaction between treatment means and storage intervals showed maximum weight loss (%) in wooden crate, plastic crate, and cotton bag during 90, 120, 150 days, respectively. Perforated polyethylene packaging is known to have better gas exchange properties because of its structure, which promotes desirable permeability for a better gaseous environment within the package, which is an indicator of the controlled respiration of carrot root. Because respiratory activity causes moisture loss, weight loss increases under various storage conditions (Salisbury and Ross, 1992). Because the roots' ability to breadthe inside the packaging films is reduced, there is less moisture loss in carrot roots packaged in perforated polyethylene, which contributes to the reduction in weight loss. The weight loss was put on hold by an apparent increase in the in-pack relative humidity (Rai *et al.*, 2011). Tefera *et al.*, (2007) suggested that the minimal physiological weight loss of packaged mangoes may be attributed to their gradual ripening process and their ability to prevent excessive moisture loss.

Table 4.3.1: Effect of treatments and packaging materials on weight loss% of carrot during storage

Storage periods	Packaging Materials	Weight Loss%									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	$8.68{\pm}1.0^{c}$	$5.34{\pm}2.1^{b}$	$6.57{\pm}3.2^{b}$	$3.45{\pm}4.1^{a}$	$2.91{\pm}5.0^{a}$	$5.82{\pm}6.1^{b}$	$8.25{\pm}7.1^{c}$	$9.51{\pm}8.4^{c}$	$5.24{\pm}9.1^{b}$	6.20±2.24
	CB	$8.94{\pm}1.1^{a}$	$12.89{\pm}2.3^{e}$	$10.25{\pm}3.3^{c}$	$12.62{\pm}4.1^{e}$	$9.39{\pm}5.0^{ab}$	$9.55{\pm}6.1^{b}$	$9.14{\pm}7.2^{ab}$	$10.42{\pm}8.1^{c}$	$11.07{\pm}9.2^{d}$	10.48±1.4
	PPEB	$6.72{\pm}1.1^{g}$	$4.00{\pm}2.0^{c}$	$8.74{\pm}3.1^{i}$	$2.09{\pm}4.0^{a}$	$4.31{\pm}5.0^{d}$	$4.74{\pm}6.1^{e}$	$3.64{\pm}7.0^{b}$	$7.27{\pm}8.0^{h}$	$6.41{\pm}9.0^{f}$	5.33±2.0
	PC	$12.94{\pm}1.2^{de}$	$9.70{\pm}2.1^{a}$	$14.37{\pm}3.4^{f}$	$12.20{\pm}4.1^{c}$	$13.40{\pm}5.3^{e}$	$12.55{\pm}6.1^{cd}$	$10.50{\pm}7.2^{b}$	$12.07{\pm}8.3^{c}$	$14.29{\pm}9.2^{f}$	12.45±1.5
	WC	$14.39{\pm}1.2^{d}$	$8.42{\pm}2.2^{a}$	$14.03{\pm}3.1^{d}$	$11.37{\pm}4.3^{b}$	$19.77{\pm}5.2^{g}$	$18.73{\pm}6.2^{f}$	$13.06{\pm}7.0^{c}$	$11.21{\pm}8.0^{b}$	$15.59{\pm}9.1^{f}$	14.06±3.48
60 Days	**LB**	$17.38{\pm}1.0^{c}$	$13.51{\pm}2.2^{b}$	$15.27{\pm}3.2^{bc}$	$9.28{\pm}4.2^{a}$	$8.56{\pm}5.2^{a}$	$9.41{\pm}6.2^{a}$	$14.82{\pm}7.3^{bc}$	$17.69{\pm}8.4^{c}$	$7.98{\pm}9.1^{a}$	12.66±3.89
	CB	$21.52{\pm}1.3^{bc}$	$26.30{\pm}2.8^{e}$	$18.45{\pm}3.4^{a}$	$24.52{\pm}4.2^{de}$	$19.04{\pm}5.3^{ab}$	$19.06{\pm}6.3^{ab}$	$21.25{\pm}7.2^{abc}$	$20.47{\pm}8.1^{abc}$	$22.16{\pm}9.5^{cd}$	21.42±2.6
	PPEB	$8.38{\pm}1.1^{g}$	$4.81{\pm}2.1^{c}$	$9.81{\pm}3.0^{h}$	$3.52{\pm}4.0^{a}$	$6.82{\pm}5.1^{e}$	$5.98{\pm}6.0^{d}$	$4.54{\pm}7.0^{b}$	$8.26{\pm}8.1^{g}$	$7.12{\pm}9.1^{f}$	6.58±2.0
	PC	$31.44{\pm}1.2^{c}$	$22.54{\pm}2.6^{a}$	$31.90{\pm}3.3^{c}$	$23.74{\pm}4.2^{ab}$	$31.69{\pm}5.8^{c}$	$26.34{\pm}6.5^{ab}$	$27.57{\pm}7.6^{bc}$	$27.58{\pm}8.2^{bc}$	$25.79{\pm}9.3^{ab}$	27.62±3.6
	WC	$34.29{\pm}1.8^{cd}$	$22.34{\pm}2.2^{a}$	$34.55{\pm}3.5^{cd}$	$25.41{\pm}4.8^{ab}$	$41.04{\pm}5.9^{d}$	$38.45{\pm}6.1^{d}$	$29.12{\pm}7.2^{abc}$	$32.92{\pm}8.7^{bcd}$	$29.69{\pm}9.2^{abc}$	31.98±6.3
90 Days	**LB**	$25.94{\pm}1.3^{d}$	$18.55{\pm}2.4^{b}$	$18.78{\pm}3.3^{b}$	$15.28{\pm}4.1^{a}$	$15.94{\pm}5.2^{ab}$	$13.66{\pm}6.1^{a}$	$22.47{\pm}7.0^{c}$	$22.71{\pm}8.3^{c}$	$14.12{\pm}9.1^{a}$	18.61±4.2
	CB	$29.67{\pm}1.5^{c}$	$33.93{\pm}2.7^{e}$	$24.17{\pm}3.3^{a}$	$33.48{\pm}4.1^{e}$	$24.74{\pm}5.2^{a}$	$30.06{\pm}6.3^{c}$	$28.80{\pm}7.5^{c}$	$26.20{\pm}8.4^{b}$	$31.74{\pm}9.8^{d}$	29.20±3.5
	PPEB	$8.70{\pm}1.2^{e}$	$4.81{\pm}2.0^{b}$	$9.98{\pm}3.0^{f}$	$3.52{\pm}4.0^{a}$	$8.53{\pm}5.1^{de}$	$7.57{\pm}6.1^{c}$	$4.87{\pm}7.0^{b}$	$8.39{\pm}8.1^{d}$	$7.32{\pm}9.1^{c}$	7.08±2.09
	PC	$46.54{\pm}1.6^{f}$	$34.54{\pm}2.4^{a}$	$45.46{\pm}3.5^{f}$	$35.27{\pm}4.1^{ab}$	$41.28{\pm}5.7^{de}$	$36.12{\pm}6.2^{b}$	$38.18{\pm}7.3^{c}$	$40.12{\pm}8.2^{d}$	$41.99{\pm}9.5^{e}$	39.94±4.15
	WC	$52.84{\pm}1.2^{abc}$	$41.67{\pm}2.3^{a}$	$66.51{\pm}3.0^{c}$	$44.18{\pm}4.0^{a}$	$64.58{\pm}5.8^{c}$	$60.64{\pm}6.7^{bc}$	$49.99{\pm}7.5^{ab}$	$59.26{\pm}8.1^{bc}$	$65.42{\pm}9.6^{c}$	56.12±9.8
120 Days	**LB**	$36.89{\pm}1.1^{e}$	$25.42{\pm}2.2^{ab}$	$28.90{\pm}3.4^{bc}$	$23.93{\pm}4.2^{a}$	$24.88{\pm}5.4^{ab}$	$22.01{\pm}6.5^{a}$	$31.11{\pm}7.5^{bc}$	$35.03{\pm}8.8^{de}$	$21.95{\pm}9.4^{a}$	27.79±5.48
	CB	$40.67{\pm}1.6^{abcd}$	$46.87{\pm}2.5^{d}$	$35.04{\pm}3.3^{ab}$	$42.89{\pm}4.6^{cd}$	$33.76{\pm}5.0^{a}$	$40.74{\pm}6.2^{abcd}$	$37.20{\pm}7.2^{abc}$	$36.65{\pm}8.8^{abc}$	$41.57{\pm}9.8^{bcd}$	39.49±4.5
	PPEB	$11.32{\pm}1.1^{i}$	$6.76{\pm}2.1^{c}$	$10.67{\pm}3.2^{h}$	$3.84{\pm}4.0^{a}$	$10.16{\pm}5.1^{g}$	$9.34{\pm}6.1^{f}$	$6.33{\pm}7.1^{b}$	$8.99{\pm}8.1^{e}$	$8.08{\pm}9.1^{d}$	8.39±2.3
	PC	$64.72{\pm}1.2^{c}$	$51.62{\pm}2.2^{ab}$	$59.07{\pm}3.4^{bc}$	$53.68{\pm}4.8^{ab}$	$59.27{\pm}5.2^{bc}$	$47.80{\pm}6.4^{a}$	$54.30{\pm}7.3^{ab}$	$56.36{\pm}8.0^{abc}$	$57.06{\pm}9.9^{bc}$	55.99±5.64
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	$52.67{\pm}1.9^{d}$	$38.03{\pm}2.5^{a}$	$49.64{\pm}3.2^{cd}$	$42.32{\pm}4.6^{abcd}$	$42.76{\pm}5.7^{abcd}$	$38.83{\pm}6.3^{ab}$	$47.48{\pm}7.8^{abcd}$	$48.81{\pm}8.8^{bcd}$	$39.51{\pm}9.0^{abc}$	44.45±5.94
	CB	$51.78{\pm}1.1^{abcd}$	$61.85{\pm}2.8^{d}$	$41.92{\pm}3.9^{ab}$	$55.73{\pm}4.0^{cd}$	$41.10{\pm}5.5^{a}$	$52.74{\pm}6.4^{bcd}$	$46.97{\pm}7.2^{abc}$	$43.97{\pm}8.3^{ab}$	$48.68{\pm}9.1^{abc}$	49.42±7.3
	PPEB	$14.93{\pm}1.2^{d}$	$8.30{\pm}2.6^{a}$	$11.49{\pm}3.1^{bc}$	$6.59{\pm}4.1^{a}$	$11.75{\pm}5.0^{bcd}$	$12.37{\pm}6.5^{cd}$	$8.07{\pm}7.1^{a}$	$9.72{\pm}8.2^{abc}$	$9.03{\pm}9.2^{ab}$	10.25±2.7
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Furthermore, during the ripening and mortality processes of fruits, the primary structural components of the cell wall, cellulose and pectin, gradually deteriorate (Jia *et al*., 2023). Transpiration was decreased by the cuticle and epidermal cell layer. A recent study in tomato cells revealed that Zn exposure greatly influenced the formation of pectin and its modification in the cell wall (Muschitz *et al*., 2015). This may be due to the function of boron in cell wall strength and component production (Kaur *et al*., 2019). These findings suggest that Zn and B treatment may have prevented carrot roots from losing weight by preserving the components of the cell wall and maintaining the periderm's cellular integrity.

4.3.2 Sugars (glucose, fructose, sucrose) content (g/100g):

In general, glucose followed an increasing trend corresponding to advancement in the storage period (Table 4.3.2). The treated carrot root packed in a perforated polyethylene packaging bag maintained the lowest average glucose (19.55 g/100g) and the control roots observed the highest glucose (20.75 g/100g) under the perforated polyethylene bag after 150 days of storage. The glucose of the root in the perforated polyethylene bag increased slowly, and the range was observed among the treatments 18.84 and 20.75 (g/100g) after 150 days of storage interval, whereas in the case of the leno bag-treated root, the increase in glucose was found to be sharp, and the range among the treatments was 20.11 to 25.2 (g/100g). Under a wooden box, the treated carrot packed root recorded the highest average glucose (24.62 g/100g), and the range among the treatments was 22.92–27.42 g/100g) after 90 days of storage, thereby leading to breakdown of complex sugar into simple sugar of root. In the control, the root experienced a faster increase in glucose during storage than the other treatments of the packaging materials. The depletion of carbohydrate reserves in the roots is linked to the notable increase in glucose content that we describe later in the storage period in treatments such as leno bags, cotton bags, perforated polyethylene bags, plastic crate, and wooden crate. Comparatively speaking, carrot roots packed in cotton, leno, and perforated polyethylene bags showed a delayed dormancy break compared with roots packed in other materials. As a result, by the time the storage period ended, these roots had a greater amount of glucose. The highest glucose level for the non-packaged control treatments at the end of the storage period was associated with a higher rate of advancement toward dormancy break, which is consistent with the findings of Abbasi *et al*., (2012).

Table 4.3.2: Effect of treatments and packaging materials on glucose (g/100g DW) content of carrot during storage

Storage periods	Packaging materials	Glucose									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	20.55±1.2^{d}	19.53±1.4^{bcd}	17.53±0.1^{ab}	16.19±0.1^{a}	17.54±0.2^{ab}	17.85±1.1^{abc}	17.77±0.1^{abc}	19.80±1.0^{bc}	17.50±0.1^{ab}	18.25±1.5
	CB	18.76±1.1^{c}	17.81±0.5^{abc}	16.44±0.1^{a}	16.68±0.8^{ab}	17.61±0.8^{abc}	16.51±0.3^{ab}	17.57±0.1^{abc}	17.97±0.3^{abc}	18.09±0.3^{bc}	17.49±0.9
	PPEB	17.89±0.5^{de}	17.75±0.3^{cde}	17.10±0.3^{bcd}	15.97±0.1^{a}	16.72±0.2^{ab}	16.97±0.3^{bc}	17.41±0.3^{bcde}	18.04±0.3^{e}	16.68±0.1^{ab}	17.17±0.7
	PC	18.69±1.2^{a}	19.15±0.7^{a}	19.26±0.1^{a}	20.22±0.6^{a}	19.28±0.9^{a}	18.68±0.3^{a}	19.38±0.6^{a}	19.20±0.7^{a}	19.88±0.2^{a}	19.30±0.7
	WC	24.61±0.8^{d}	23.57±0.4^{abcd}	24.21±0.6^{cd}	23.19±0.4^{abcd}	22.45±0.1^{abc}	23.19±0.7^{abcd}	22.30±1.0^{ab}	22.20±0.7^{a}	24.10±0.7^{bcd}	23.31±1.0
60 Days	LB	23.49±0.7^{e}	21.61±0.8^{d}	19.76±0.2^{bc}	17.88±0.1^{a}	19.85±0.1^{bc}	20.36±0.6^{bcd}	19.61±0.2^{bc}	20.84±0.5^{cd}	19.50±0.2^{b}	20.32±1.6
	CB	18.79±0.2^{cd}	17.99±0.4^{bc}	16.70±0.5^{a}	17.37±0.2^{ab}	18.09±0.2^{bc}	16.71±0.1^{a}	18.25±0.3^{cd}	18.59±0.2^{cd}	19.06±0.4^{d}	17.95±0.9
	PPEB	18.52±0.0^{e}	18.07±0.5^{de}	17.03±0.4^{ab}	16.37±0.2^{a}	17.09±0.4^{ab}	17.04±0.1^{ab}	17.72±0.3^{bcd}	17.98±0.1^{cde}	17.27±0.1^{bc}	17.46±0.7
	PC	21.79±1.2^{a}	21.20±0.9^{a}	22.44±0.3^{a}	22.14±1.2^{a}	21.72±1.2^{a}	21.39±0.3^{a}	20.67±1.0^{a}	21.31±0.8^{a}	20.69±1.0^{a}	21.49±1.0
	WC	25.44±1.5^{bc}	24.90±0.6^{bc}	24.85±1.2^{bc}	24.44±0.2^{abc}	23.13±0.1a^{b}	24.59±1.1^{abc}	23.79±0.7^{abc}	22.43±0.1^{a}	25.86±0.7^{c}	24.38±1.3
90 Days	LB	23.73±0.4^{d}	21.55±0.3^{c}	20.00±0.2^{b}	18.15±0.5^{a}	20.54±0.5^{bc}	20.02±0.1^{b}	20.40±0.3^{b}	20.59±0.4^{bc}	19.80±0.3^{b}	20.53±1.5
	CB	18.79±0.5^{d}	17.98±0.2^{abcd}	16.99±0.4^{a}	17.42±0.3^{abc}	18.30±0.5^{bcd}	17.13±0.6^{ab}	18.43±0.3^{cd}	18.68±0.5^{d}	19.11±0.3^{d}	18.09±0.8
	PPEB	18.55±0.4^{e}	17.85±0.2^{cde}	17.10±0.4^{abc}	16.57±0.1^{a}	16.75±0.3^{ab}	17.16±0.3^{abc}	17.41±0.2^{bcd}	17.97±0.2^{de}	17.29±0.2^{abcd}	17.40±0.6
	PC	22.35±0.2^{ab}	21.82±0.3^{ab}	22.16±0.2^{ab}	22.68±0.3^{b}	21.05±1.4^{ab}	21.07±0.9^{ab}	20.90±0.2^{a}	20.72±0.4^{a}	20.74±0.6^{a}	21.50±0.9
	WC	27.42±0.4^{e}	25.28±1.0^{cd}	23.94±0.8^{abc}	25.17±0.6^{bcd}	23.26±0.3^{ab}	24.42±0.9^{abcd}	23.24±0.2^{ab}	22.92±0.5^{a}	25.97±1.1^{de}	24.62±1.5
120 Days	LB	25.48±0.2^{f}	23.78±0.6^{e}	22.86±0.2^{de}	20.96±0.2^{a}	21.31±0.3^{ab}	22.62±1.0^{cde}	22.49±0.2^{bcd}	22.22±0.2^{bcd}	21.64±0.1^{abc}	22.60±1.4
	CB	20.04±2.2^{a}	19.09±0.2^{a}	18.72±1.2^{a}	18.54±1.6^{a}	19.94±0.4^{a}	18.53±0.1^{a}	19.05±0.1^{a}	19.75±0.2^{a}	20.08±1.4^{a}	19.31±1.1
	PPEB	19.26±0.3^{c}	19.15±0.2^{c}	18.10±1.0^{abc}	17.41±0.2^{a}	17.57±0.4^{ab}	18.19±0.0^{abc}	18.41±0.0^{abc}	18.87±0.2^{bc}	18.10±0.9^{abc}	18.34±0.7
	PC	23.12±1.3^{a}	23.23±0.9^{a}	24.34±1.2^{a}	23.28±1.2^{a}	22.91±0.9^{a}	23.04±1.7^{a}	22.06±1.3^{a}	22.88±1.3^{a}	23.04±1.2^{a}	23.10±1.2
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	25.22±0.9^{b}	23.09±1.4^{ab}	21.46±1.3^{a}	20.11±1.8^{a}	21.87±0.5^{ab}	21.72±1.5^{ab}	21.81±0.8^{ab}	21.96±1.6^{ab}	21.08±0.7^{a}	22.03±1.7
	CB	21.37±2.8^{a}	20.30±1.8^{a}	19.44±0.7^{a}	19.03±1.1^{a}	20.99±2.3^{a}	18.84±1.6^{a}	20.07±1.9^{a}	20.91±0.6^{a}	20.88±1.9^{a}	20.20±1.7
	PPEB	20.75±1.0^{a}	20.20±0.2^{ab}	19.69±0.8^{ab}	19.22±0.1^{ab}	18.97±0.8^{ab}	18.84±0.3^{a}	19.97±1.1^{ab}	19.33±0.4^{ab}	19.01±0.3^{ab}	19.55±0.8
	PC	×	×	×	×	×	×	×	×	×	0.00
	WC	×	×	×	×	×	×	×	×	×	0.00

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3.

T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Table 4.3.3: Effect of treatments and packaging materials on fructose (g/100g DW) content of carrot during storage.

Storage Periods	Packaging materials	Treatments									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	8.42±0.3^{c}	8.20±0.4^{bc}	7.69±0.1^{abc}	7.10±0.3^{a}	7.48±0.3^{ab}	8.28±0.3^{abc}	7.67±0.1^{abc}	8.06±0.4^{bc}	8.18±0.2^{bc}	7.90±0.5
	CB	7.65±0.1^{bcd}	7.82±0.1^{cd}	7.89±0.1^{cd}	7.51±0.1^{b}	7.40±0.1^{ab}	7.81±0.2^{cd}	7.92±0.1^{d}	7.64±0.1^{bc}	7.19±0.1^{a}	7.65±0.2
	PPEB	7.73±0.0^{d}	8.18±0.1^{e}	8.02±0.1^{e}	7.22±0.1^{ab}	7.39±0.1^{bc}	7.60±0.1^{cd}	7.20±0.1^{ab}	7.66±0.0^{d}	7.07±0.1^{a}	7.56±0.4
	PC	8.32±0.9^{a}	8.31±0.4^{a}	7.73±0.9^{a}	7.18±0.8^{a}	7.51±0.7^{a}	8.44±0.6^{a}	7.82±0.1^{a}	8.15±0.6^{a}	8.17±0.3^{a}	7.96±0.7
	WC	10.22±1.4^{a}	9.56±1.2^{a}	10.38±1.6^{a}	9.13±1.3^{a}	8.90±1.1^{a}	9.85±1.3^{a}	9.88±1.0^{a}	8.91±0.6^{a}	8.99±1.0^{a}	9.54±1.1
60 Days	**LB**	9.82±0.2^{e}	9.07±0.2^{cd}	8.57±0.3^{abc}	8.26±0.3^{a}	8.36±0.0^{ab}	9.48±0.0^{de}	8.65±0.3^{abc}	8.88±0.3^{bcd}	9.12±0.2^{cd}	8.91±0.5
	CB	8.09±1.0^{a}	7.98±0.9^{a}	8.32±0.5^{a}	8.05±0.0^{a}	7.85±1.0^{a}	8.03±0.5^{a}	8.03±0.6^{a}	7.90±0.9^{a}	7.71±0.5^{a}	8.00±0.6
	PPEB	7.87±0.1c	8.47±0.1^{d}	8.53±0.2^{d}	7.50±0.1^{ab}	7.54±0.0^{abc}	7.81±0.1^{bc}	7.26±0.1^{a}	7.87±0.1^{c}	7.26±0.1^{a}	7.79±0.5
	PC	9.20±0.3^{a}	8.83±0.7^{a}	9.17±0.5^{a}	8.44±0.4^{a}	8.29±0.1^{a}	8.65±0.6^{a}	8.34±0.3^{a}	8.53±0.2^{a}	8.56±0.3^{a}	8.67±0.5
	WC	10.94±0.7^{a}	10.00±1.4^{a}	10.59±1.1^{a}	10.59±0.8^{a}	9.80±1.4^{a}	10.44±1.0^{a}	10.26±1.5^{a}	9.70±1.2^{a}	9.57±1.0^{a}	10.21±1.1
90 Days	**LB**	10.11±0.1^{b}	9.42±0.3^{ab}	8.86±0.8^{a}	8.76±0.3^{a}	8.93±0.4^{ab}	9.66±0.4^{ab}	8.93±0.2^{ab}	9.13±0.2^{ab}	9.32±0.6^{ab}	9.24±0.5
	CB	8.08±1.2^{a}	8.17±0.5^{a}	8.31±0.2^{a}	7.99±1.0^{a}	7.94±0.4^{a}	8.31±0.1^{a}	8.01±1.0^{a}	7.77±1.0^{a}	7.88±0.5^{a}	8.05±0.6
	PPEB	8.35±0.1^{cd}	8.63±0.1^{d}	8.42±0.1^{cd}	7.92±0.1^{ab}	8.09±0.1^{abc}	8.33±0.2^{bcd}	7.89±0.1^{a}	8.02±0.2^{abc}	7.81±0.3^{a}	8.16±0.3
	PC	10.06±0.3^{bc}	9.92±0.2^{abc}	9.68±0.4^{abc}	9.45±0.1^{ab}	9.80±0.2^{abc}	10.19±0.2^{c}	9.62±0.0^{abc}	9.38±0.2^{a}	9.68±0.3^{abc}	9.75±0.3
	WC	10.91±0.8^{a}	10.21±1.4^{a}	10.64±1.4^{a}	10.54±1.4^{a}	9.95±1.5^{a}	10.61±1.4^{a}	10.41±1.6^{a}	9.63±0.9^{a}	9.73±1.2^{a}	10.29±1.18
120 Days	**LB**	11.04±0.4^{b}	9.73±0.5^{ab}	9.81±0.5^{ab}	9.39±0.5^{a}	10.53±0.5^{ab}	9.64±1.1^{ab}	9.89±0.2^{ab}	9.72±0.3^{ab}	10.16±0.2^{ab}	9.99±0.7
	CB	8.65±1.0^{a}	8.71±0.5^{a}	8.27±1.0^{a}	8.33±1.5^{a}	8.52±0.6^{a}	8.68±0.9^{a}	8.42±1.5^{a}	8.04±0.3^{a}	8.54±0.4^{a}	8.46±0.8
	PPEB	8.81±0.1^{d}	8.65±0.^{1d}	8.63±0.2^{cd}	7.91±0.1^{a}	8.22±0.1^{abc}	8.55±0.2^{bcd}	7.82±0.2^{a}	8.18±0.2^{ab}	7.93±0.1^{a}	8.30±0.4
	PC	10.28±0.8^{a}	10.13±1.2^{a}	10.19±1.4^{a}	9.55±0.6^{a}	9.94±0.9^{a}	10.22±0.0^{a}	9.70±1.0^{a}	9.23±0.8^{a}	9.94±1.5^{a}	9.91±0.9
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	11.49±0.5^{d}	10.46±0.4^{bcd}	9.30±0.5^{ab}	8.07±0.9^{a}	11.29±0.7^{cd}	11.24±0.4^{cd}	9.94±0.2^{bcd}	11.07±0.7^{cd}	9.61±0.7^{abc}	10.27±1.2
	CB	9.10±1.0^{a}	7.59±2.4^{a}	9.49±1.2^{a}	8.87±0.6^{a}	8.89±1.4^{a}	9.22±0.5^{a}	8.70±1.0^{a}	9.14±1.0^{a}	9.03±1.5^{a}	8.89±1.2
	PPEB	9.04±0.1^{cd}	9.16±0.1^{d}	9.06±0.3^{cd}	8.40±0.1^{ab}	8.31±0.2^{ab}	8.73±0.2^{abcd}	8.20±0.3^{a}	8.80±0.0^{bcd}	8.56±0.2^{abc}	8.70±0.4
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3.

T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

The fructose, in general, followed an increasing trend associated with advancement in storage period (Table 4.3.3). The treated carrot root packed in perforated polyethylene packaging bag maintained the minimum average fructose content (8.70g/100g) followed by 8.89 g/100g) in cotton bag after 150 days of storage. The fructose content of treated carrot root in perforated polyethylene bag slightly increased and the range was recorded among the treatments 8.20 to 9.16 g/100g) after 150 days of storage interval, whereas in case of leno bag treated root, the increase in fructose was found to be sharp and the range among the treatment was 8.07 to 11.49 g/100g. Under wooden box, the treated carrot packed root recorded highest average fructose (10.29 g/100g) and the range among the treatments was 9.63 and 10.91 g/100g after 90 days of storage. Whereas, in control, the roots experienced a faster increase of fructose during storage compared to other treatments of all the packaging materials, thereby leading to breakdown of complex sugar into simple sugar of root. The fructose content of carrot roots in both packages was significantly affected by the length of storage. Roots that were maintained for 150 days had more sugar. As storage time increased, fructose concentration increased. According to the results of the current investigation, roots maintained under ambient conditions had a higher reducing sugar content than those maintained at lower temperatures. When comparing juice stored at room temperature with juice kept at a lower temperature, Sarmah *et al*., (1981) found a significant increase in the reducing sugar content of fruit juice.

The sucrose content of the treated carrot under both packaging materials was found to be lower in perforated polyethylene-packed roots (Table 4.3.4). The treated carrot root packed in a perforated polyethylene packaging bag maintained the lowest average non-reducing sugar content, i.e., sucrose content (10.45 g/100g), followed by cotton bag (11.36 g/100g) and leno bag (11.57 g/100g) after 150 days of storage. The sucrose content of treated carrot root in the perforated polyethylene bag slightly decreased and the range was observed among the treatments 10.91–12.42 g/100g after 150 days of storage interval, whereas in the case of leno bag-packed treated roots, the increase in sucrose was found to be sharp and the range among the treatments was 10.70 to 12.28 g/100g. Under a wooden box, the treated carrot packed root recorded average sucrose (10.29), and the range was observed among the treatments12.88–13.77 g/100g after 90 days of storage. In the control, the root experienced a faster decrease in sucrose during storage than the other treatments of the packaging materials.

Table 4.3.4: Effect of treatments and packaging materials on sucrose (g/100g DW) content of carrot during storage.

Sucrose											
Storage periods	**Packaging Materials**	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**Mean**
30 Days	**LB**	11.05±1.1^{ab}	13.18±1.3^{bcd}	12.66±1.2^{abcd}	10.17±0.2^{a}	13.03±0.9^{abcd}	14.58±1.2^{d}	13.02±1.0^{abcd}	11.55±0.8^{abc}	14.19±1.1^{cd}	12.60±1.6
	CB	13.69±1.5^{a}	12.61±1.7^{a}	13.39±2.2^{a}	12.12±0.9^{a}	13.02±1.5^{a}	13.09±1.4^{a}	13.76±0.9^{a}	12.55±0.9^{a}	13.71±1.0^{a}	13.10±1.3
	PPEB	10.24±0.5^{a}	12.13±1.0^{a}	12.60±0.8^{a}	10.83±0.7^{a}	12.34±1.2^{a}	12.25±0.3^{a}	12.89±1.1^{a}	11.93±1.4^{a}	12.58±0.9^{a}	11.98±1.2
	PC	11.30±1.1^{ab}	13.14±0.9^{bcd}	12.46±0.9^{abcd}	10.44±0.5^{a}	12.87±0.8^{abcd}	14.61±1.3^{d}	13.10±0.7b^{cd}	12.00±0.2^{abc}	14.02±1.1^{cd}	12.66±1.4
	WC	17.47±1.0^{b}	15.92±0.7^{ab}	14.98±0.3^{a}	14.52±1.0^{a}	14.44±1.5^{a}	16.26±0.1^{ab}	14.74±0.8^{a}	14.21±0.7^{a}	16.43±0.3^{ab}	15.44±1.3
60 Days	**LB**	8.62±0.9^{ab}	10.55±0.5^{bc}	9.69±0.3^{abc}	8.42±1.2^{a}	9.93±0.3^{abc}	11.02±0.7^{c}	10.69±0.9^{c}	9.36±0.4^{abc}	10.80±0.6^{c}	9.90±1.1
	CB	13.78±1.6^{a}	12.66±1.2^{a}	13.17±1.8^{a}	12.24±1.1^{a}	12.52±0.8^{a}	12.78±0.5^{a}	13.47±1.8^{a}	12.92±1.1^{a}	13.71±0.8^{a}	13.03±1.16
	PPEB	11.59±0.5^{a}	13.51±1.6^{a}	13.25±0.6^{a}	11.57±0.7^{a}	13.13±1.7^{a}	13.56±2.0^{a}	13.60±1.0^{a}	12.19±1.5^{a}	13.26±0.7^{a}	12.85±1.31
	PC	13.64±0.4^{a}	14.73±1.0^{a}	15.69±0.4^{a}	14.97±0.7^{a}	16.11±0.8^{a}	15.82±0.9^{a}	15.40±1.0^{a}	15.35±0.4^{a}	15.07±1.5^{a}	15.20±1.0
	WC	13.70±1.0^{a}	14.47±0.8^{a}	13.87±0.1^{a}	14.80±1.1^{a}	13.63±1.4^{a}	14.41±1.7^{a}	14.55±1.9^{a}	13.37±1.3^{a}	13.80±0.7^{a}	14.07±1.1
90 Days	**LB**	9.23±0.1^{a}	10.88±0.3^{c}	9.45±0.2^{a}	9.91±0.6^{abc}	9.64±0.1^{ab}	10.56±0.6^{bc}	10.62±0.2^{bc}	10.14±0.5^{abc}	10.13±0.1^{abc}	10.06±0.6
	CB	13.41±1.2^{a}	12.22±0.1^{a}	13.45±0.1^{a}	11.97±0.1^{a}	12.92±0.9^{a}	12.75±1.3^{a}	13.38±1.5^{a}	12.56±1.9^{a}	13.33±2.2^{a}	12.89±1.2
	PPEB	11.93±0.7^{a}	13.09±0.5^{a}	12.66±1.0^{a}	11.59±0.4^{a}	13.07±0.1^{a}	12.94±1.6^{a}	13.56±1.0^{a}	11.86±0.1^{a}	12.36±0.1^{a}	12.56±0.9
	PC	12.76±0.5^{a}	14.53±0.9^{a}	14.15±0.8^{a}	13.54±0.4^{a}	14.12±0.1^{a}	14.65±0.9^{a}	13.90±1.0^{a}	13.55±0.5^{a}	14.13±1.0^{a}	13.93±0.8
	WC	12.92±0.7^{a}	13.01±1.3^{a}	13.20±0.7^{a}	13.77±2.3^{a}	13.54±2.1^{a}	13.23±0.8^{a}	13.66±1.9^{a}	12.88±0.8^{a}	13.49±0.6^{a}	13.30±1.2
120 Days	**LB**	10.87±0.8^{ab}	13.06±0.8^{c}	12.50±0.6^{bc}	10.42±0.3^{a}	12.33±0.8^{abc}	13.31±1.0^{c}	12.61±0.7^{bc}	11.87±0.4^{abc}	12.50±0.7^{bc}	12.16±1.1
	CB	13.30±1.8^{a}	12.30±1.4^{a}	12.81±1.6^{a}	12.00±0.9^{a}	12.03±0.4^{a}	12.21±0.5^{a}	12.92±0.9^{a}	12.68±1.3^{a}	13.58±1.6^{a}	12.65±1.2
	PPEB	11.86±0.7^{a}	13.28±0.2^{ab}	13.87±0.5^{b}	12.44±0.4^{ab}	13.26±0.6^{ab}	12.90±0.2^{ab}	13.50±0.8^{b}	13.18±0.0^{ab}	13.50±0.5^{b}	13.09±0.7
	PC	11.47±0.7^{a}	12.33±0.9^{a}	12.41±0.7^{a}	11.97±0.9^{a}	12.06±0.5^{a}	12.46±0.7^{a}	11.29±0.7^{a}	12.04±0.4^{a}	10.88±0.4^{a}	11.88±0.8
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	10.70±0.6^{a}	12.22±0.6^{a}	11.53±0.4^{a}	10.72±0.6^{a}	11.84±0.7^{a}	12.28±0.9^{a}	11.88±0.2^{a}	11.52±0.5^{a}	11.48±1.0^{a}	11.57±0.8
	CB	10.91±0.5^{a}	11.69±0.2^{a}	11.31±0.9^{a}	11.24±1.1^{a}	12.09±1.4^{a}	11.37±0.3^{a}	11.08±1.0^{a}	10.69±0.4^{a}	11.91±0.8^{a}	11.36±0.8
	PPEB	10.91±0.5^{a}	12.21±0.8^{a}	12.17±0.6^{a}	11.34±1.0^{a}	11.74±0.8^{a}	12.42±1.2^{a}	11.82±0.6^{a}	11.67±0.6^{a}	11.11±1.0^{a}	11.71±0.8
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, n = 3.T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

The sucrose content of carrot roots was significantly affected ($p < 0.05$) by preharvest treatments and packaging over a 30-day storage period (Table 4.3.4). In addition, we found that the duration of storage had a significant impact on the sucrose concentration of carrot roots. In contrast, with the exception of 30 days of storage, the impacts of preharvest treatment, packaging materials, and storage duration interactions were not significant ($p > 0.5$). During the storage period, I observed a slight decrease in the sucrose concentration of the roots. In cultivated vegetable, the main soluble sugar constituents are sucrose and fructose. Our findings corroborated of Zhang and Ge (2017), who discovered that 20 days after storage, the sucrose content of watermelon significantly increased and that sucrose was the primary soluble sugar in fully ripe fruit. While glucose, fructose, and sucrose collectively account for over 50% of the dry weight of roots (Nilsson, 1987), additional components crucial for post-harvest metabolism during storage may experience changes in their relative concentrations during the harvest season. Finding easily quantifiable biochemical indicators is necessary to determine the optimal harvest time in terms of storability, even if it is unclear how these components may contribute to or delay senescence. Once the starch is fully hydrolysed, the number of sugars does not increase. It was expected that sugar characteristics would eventually decrease along with other organic acids, which serve as the main substrate for respiration (Kishor *et al*., 2018). The breakdown of cell walls (cellulose, hemicellulose, and pectin), conversion of non-reducing sugar to reducing sugar, and moisture loss during storage could all contribute to this increase (Brady, 1987; Biale, 1961). According to Zhang *et al*., (2002), total sugars were higher throughout the first few phases of storage and remained mostly unchanged toward the end, possibly due to genetic variations. The use of sugars for respiration and other metabolic processes may be the cause of the decrease in total sugar concentration during storage. Sharma *et al*., (2015) found that after storage for up to six weeks, the sugar concentration gradually decreased. Regarding the reduction of root sugar, the plants' reaction to foliar spraying zinc and boron was notable but uneven. Carrot root quality expression may be influenced by the effects of zinc and boron on lignification, sugar transport, cell wall formation, and carbohydrate metabolism (Marschner, 2012).

4.3.3 Total soluble solid (ºB):

The TSS content slightly increased during the storage periods, and the data are presented in table 4.3.5. The carrot root was treated with different concentrations of micronutrients such as zinc and boron and registered average TSS (13.72 ºB) under a perforated polyethylene bag after 150 days of storage. In perforated polyethylene bags, TSS in treated carrot root was not significantly different during 150 days of storage. In contrast, leno bag and cotton bag packed treated root recorded higher average TSS 16.08 ºB and 16.50 ºB after 150 days of storage. The increase in TSS during the storage period could be attributed to the water loss and hydrolysis of starch and other polysaccharides to soluble sugars. Higher sugar content is typically linked to fruit and vegetable ripening (Huan *et al*., 2016). The breakdown of complex organic metabolites into simpler molecules or the hydrolysis of starch into sugars could be the cause of the modest increase in sugar during storage (Champa *et al*., 2014; Tiwari *et al*., 2023). According to Wills *et al*., (1980), the breakdown of starch and other carbohydrates into mono- and disaccharides causes an increase in the insoluble sugar content, which in turn causes an increase in TSS. A significant TSS growth of carrot during storage is evidence of declining quality (Dawange *et al*., 2016). According to Kader *et al*., (1992), packaging's main function is to slow down the metabolic processes of fruits and vegetables, thereby lowering their respiration rate. Decreased respiration also hinders the ripening process by delaying softening and other compositional changes such as TSS. When fruit was treated with high zinc (1%) and low boron (0.02%), the TSS was considerably greater (Sajid *et al*., 2012).

4.3.4 Total antioxidant activity (mMTE/100g):

Roots treated with boron exhibited greater antioxidant potential than root left untreated during low-temperature storage. According to my research, vegetables lose some of their antioxidant activity when carrot stored long time. In cotton bags, total antioxidant activity in treated carrot root was not significantly different during 150 days of storage. In contrast, perforated poly ethylene bag packed treated carrot root recorded higher average total antioxidant activity 55.09 mMTE/100g and range was observed among the treatments 51.03 to 57.94 mMTE/100g after 150 days of storage.

Table 4.3.5: Effect of treatments and packaging materials on total soluble solid (ºB) content of carrot during storage

Storage Periods	Packaging materials	Total soluble solid									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	$12.23±0.1^{d}$	$11.23±0.2^{a}$	$11.50±0.2^{abc}$	$11.30±0.3^{ab}$	$11.23±0.2^{a}$	$12.27±0.1^{d}$	$11.77±0.1^{bcd}$	$12.00±0.2^{bc}$	$11.20±0.2^{a}$	11.6±0.4
	CB	$10.53±0.1^{b}$	$10.53±0.2^{b}$	$10.33±0.2^{b}$	$10.37±0.1^{b}$	$10.40±0.1^{b}$	$10.20±0.1^{ab}$	$9.83±0.2^{a}$	$10.53±0.3^{b}$	$10.23±0.1^{ab}$	10.3±0.3
	PPEB	$9.57±0.1^{a}$	$9.40±0.0^{a}$	$9.70±0.3^{a}$	$9.60±0.1^{a}$	$9.67±0.2^{a}$	$9.47±0.2^{a}$	$9.50±0.1^{a}$	$9.47±0.3^{a}$	$9.40±0.3^{a}$	9.5±0.2
	PC	$13.60±0.1^{a}$	$12.10±0.1^{abc}$	$12.87±0.2^{d}$	$11.83±0.1^{a}$	$11.90±0.1^{a}$	$12.07±0.1^{ab}$	$12.53±0.3^{bc}$	$12.73±0.2^{d}$	$12.47±0.2^{bcd}$	12.5±0.6
	WC	$12.72±0.0^{e}$	$12.00±0.1^{bc}$	$12.36±0.1^{d}$	$11.61±0.1^{a}$	$11.64±0.2^{a}$	$11.68±0.1^{ab}$	$12.04±0.1^{cd}$	$12.06±0.2^{cd}$	$11.90±0.1^{abc}$	12.0±0.4
60 Days	LB	$13.83±0.2^{b}$	$12.77±0.2^{a}$	$13.53±0.2^{b}$	$12.53±0.2^{a}$	$13.20±0.2^{ab}$	$13.60±0.3^{b}$	$13.20±0.4^{ab}$	$13.80±0.4^{b}$	$12.63±0.2^{a}$	13.2±0.5
	CB	$11.83±0.1^{b}$	$11.90±0.0^{b}$	$11.83±0.1^{b}$	$11.40±0.1^{a}$	$11.33±0.3^{a}$	$11.30±0.2^{a}$	$11.57±0.1^{ab}$	$11.37±0.2^{a}$	$11.33±0.1^{a}$	11.5±0.3
	PPEB	$10.10±0.2^{a}$	$9.90±0.0^{a}$	$10.00±0.1^{a}$	$10.00±0.1^{a}$	$10.10±0.1^{a}$	$10.10±0.2^{a}$	$9.87±0.1^{a}$	$9.97±0.2^{a}$	$9.90±0.2^{a}$	10.0±0.1
	PC	$14.73±0.1^{b}$	$13.50±0.2^{a}$	$13.93±0.2^{a}$	$13.50±0.4^{a}$	$13.73±0.1^{a}$	$13.67±0.1^{a}$	$13.63±0.3^{a}$	$13.60±0.1^{a}$	$13.43±0.1^{a}$	13.8±0.4
	WC	$13.65±0.1^{c}$	$13.04±0.2^{ab}$	$13.41±0.1^{bc}$	$12.92±0.2^{a}$	$13.16±0.1^{ab}$	$13.28±0.1^{abc}$	$13.06±0.2^{ab}$	$13.09±0.0^{ab}$	$13.15±0.1^{ab}$	13.2±0.2
90 Days	LB	$15.20±0.2^{e}$	$13.97±0.1^{abc}$	$14.43±0.3^{bcd}$	$13.63±0.3^{a}$	$13.73±0.2^{a}$	$14.90±0.3^{de}$	$14.20±0.2^{abc}$	$14.57±0.3^{cde}$	$13.80±0.3^{ab}$	14.3±0.6
	CB	$12.57±0.2^{ab}$	$12.60±0.3^{ab}$	$12.90±0.1^{b}$	$12.37±0.2^{a}$	$12.57±0.2^{ab}$	$12.90±0.2^{b}$	$12.47±0.1^{ab}$	$12.57±0.1^{ab}$	$12.83±0.1^{ab}$	12.6±0.2
	PPEB	$10.77±0.1^{ab}$	$10.63±0.1^{a}$	$11.13±0.2^{b}$	$11.10±0.2^{b}$	$10.70±0.1^{a}$	$10.97±0.1^{ab}$	$10.90±0.0^{ab}$	$10.60±0.2^{a}$	$10.60±0.2^{a}$	10.8±0.2
	PC	$16.57±0.1^{c}$	$15.03±0.5^{ab}$	$14.93±0.3^{ab}$	$15.33±0.1^{b}$	$15.37±0.4^{e}$	$14.73±0.1^{ab}$	$15.00±0.2^{ab}$	$15.30±0.2^{b}$	$14.40±0.3^{a}$	15.2±0.6
	WC	$15.55±0.1^{e}$	$14.80±0.2^{cd}$	$14.65±0.2^{bcd}$	$14.51±0.2^{abcd}$	$14.85±0.2^{d}$	$14.70±0.1^{bcd}$	$14.35±0.1^{ab}$	$14.41±0.2^{abc}$	$14.22±0.1^{a}$	14.7±0.4
120 Days	LB	$15.90±0.2^{f}$	$14.37±0.1^{abc}$	$14.83±0.2^{cde}$	$14.03±0.2^{a}$	$14.20±0.3^{ab}$	$15.40±0.1^{ef}$	$14.73±0.3^{bcd}$	$15.03±0.2^{de}$	$14.43±0.3^{abcd}$	14.8±0.6
	CB	$14.53±0.1^{bc}$	$14.60±0.2^{bc}$	$14.37±0.1^{bc}$	$13.67±0.3^{a}$	$14.33±0.1^{bc}$	$14.67±0.1^{c}$	$13.70±0.4^{a}$	$13.53±0.3^{a}$	$14.07±0.1^{ab}$	14.2±0.4
	PPEB	$12.00±0.1^{abc}$	$11.73±0.1^{a}$	$12.33±0.2^{c}$	$12.30±0.2^{c}$	$12.10±0.1^{abc}$	$12.23±0.1^{bc}$	$12.07±0.2^{abc}$	$11.80±0.2^{ab}$	$12.17±0.2^{abc}$	12.1±0.2
	PC	$17.57±0.2^{c}$	$17.03±0.3^{bc}$	$16.17±0.3^{a}$	$16.97±0.1^{bc}$	$16.67±0.4^{ab}$	$16.20±0.2^{a}$	$16.57±0.3^{ab}$	$16.30±0.2^{ab}$	$15.97±0.2^{a}$	16.6±0.5
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	$17.00±0.1^{c}$	$15.67±0.1^{a}$	$16.03±0.1^{ab}$	$15.77±0.2^{ab}$	$15.73±0.3^{a}$	$16.93±0.3^{c}$	$15.50±0.2^{a}$	$16.30±0.3^{b}$	$15.77±0.2^{ab}$	16.1±0.6
	CB	$16.08±0.6^{b}$	$17.57±0.3^{a}$	$16.40±0.2^{a}$	$16.23±0.1^{a}$	$16.17±0.2^{ab}$	$16.90±0.3^{a}$	$16.50±0.3^{a}$	$16.37±0.4^{a}$	$16.33±0.5^{a}$	16.5±0.5
	PPEB	$13.87±0.2^{a}$	$13.50±0.1^{a}$	$13.90±0.2^{a}$	$13.93±0.1^{a}$	$13.77±0.3^{a}$	$13.87±0.5^{a}$	$13.70±0.1^{a}$	$13.60±0.3^{a}$	$13.40±0.3^{a}$	13.7±0.3
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5%

Various authors have documented the differing effects of cold storage on the antioxidant activity of fruits and vegetables. For example, studies on tomatoes (Toor & Savage, 2006) and apricots, plums, and grapes (Kevers *et al*., 2007) have shown stability of antioxidant activity during postharvest storage; studies on celery (Viña & Chaves, 2006) and small fruits (Piljac-Žegarac and Šamec, 2011) have demonstrated an increase in antioxidant activity during storage. According to Deng *et al*., (2013), antioxidant activity varies depending on the species, assessment technique, and extraction solvent. A lower concentration of total phenolics, phenolic acids, vitamin C, and other components, including anthocyanins, carotenoids, and flavonoids, when fruits and vegetables are stored can decrease antioxidant activity during storage (Galani *et al*., 2017).

4.3.5 Ascorbic acid (mg/100g):

Regardless of the various treatments applied, the root's ascorbic acid content decreased linearly over storage (Table 4.3.7). Comparing the root packed in perforated polyethylene with various packing materials, the root retained the maximum ascorbic acid concentration (5.27 mg/100g) and range was observed among the treatments 4.15 to 6.03 mg/100g. The treatment procedures also showed that, at the 5% level of significance, maximum AA retention was noted in the packaging of perforated polyethylene bags. Carrots stored in leno bags (4.47 mg/100g), cotton bags (4.81 mg/100g), and perforated polyethylene bags (5.27 mg/100g) retained more average Ascorbic acid than wooden (3.58 mg/100g) and plastic crates (3.95 mg/100g) after end of storage periods, respectively. There was no discernible change in the packaging and treatment interactions. The conversion of L-ascorbic acid into dehydroascorbic acid during storage may be the cause of ascorbic acid reduction (Mapson, 1970). There have also been reports on the impact of heat shrinkable films on preserving a higher ascorbic acid content in citrus fruits (Dam, *et al*., 2020). Significant decreases in vitamin C levels during storage have been shown in previous studies (Augustin *et al*., 1978). The most prevalent antioxidant in plant cells, vitamin C, is a superb ROS scavenger. Ascorbate peroxidase uses ascorbate, or vitamin C, to convert hydrogen peroxide to water. Ascorbate is oxidized to monodehydroascorbate during this process.

Table 4.3.6: Effect of treatments and packaging materials on antioxidant activity (mMTE/100g FW) content of carrot during storage

Storage periods	Packaging materials	Antioxidant activity									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	57.18±0.8^{a}	62.67±0.5^{bc}	60.94±0.8^{b}	62.66±1.5^{bc}	63.77±0.9^{cd}	65.27±0.1^{d}	64.53±0.7^{cd}	62.37±0.3^{bc}	62.69±0.7^{bc}	62.45±2.4
	CB	57.76±2.0^{a}	63.08±1.5^{a}	63.57±1.0^{a}	63.54±1.0^{a}	64.15±0.9^{a}	66.42±0.6^{a}	65.83±0.6^{a}	63.20±1.1^{a}	63.96±1.2^{a}	63.50±2.5
	PPEB	59.46±2.8^{a}	64.41±1.7^{ab}	63.39±1.2^{ab}	64.82±1.8^{b}	66.87±1.2^{b}	67.89±2.7^{b}	67.89±1.9^{b}	66.87±1.3^{b}	65.44±1.3^{b}	65.23±3.0
	PC	53.84±0.6^{a}	54.25±0.4^{a}	57.27±0.8^{b}	56.30±0.7^{b}	59.87±1.0^{c}	60.77±0.1^{c}	61.51±0.3^{c}	60.69±1.0^{c}	57.33±0.6^{b}	57.98±2.8
	WC	50.88±0.6^{b}	52.53±1.1^{bc}	52.78±0.2^{c}	51.09±0.9^{bc}	48.87±0.8^{a}	55.12±0.6^{d}	51.78±0.2^{bc}	51.98±0.2^{bc}	52.58±0.4^{bc}	51.96±1.7
60 Days	LB	55.16±0.2^{a}	56.95±0.3^{ab}	58.10±0.5^{b}	58.81±0.8^{b}	61.67±1.0^{c}	62.74±0.5^{c}	62.28±1.9^{c}	61.56±1.0^{c}	58.72±0.6^{b}	59.55±2.6
	CB	56.09±1.3^{a}	56.86±1.4^{ab}	59.82±0.8^{bc}	60.02±0.6^{bc}	63.11±1.5^{cd}	64.15±1.8^{d}	64.09±0.2^{d}	62.90±1.5^{cd}	59.90±0.9^{cd}	60.77±3.1
	PPEB	60.17±1.7^{a}	63.14±0.8^{abc}	61.91±0.5^{ab}	63.14±1.6^{abc}	65.59±0.8^{cd}	66.82±1.6^{d}	66.82±0.8^{d}	65.59±0.3^{cd}	64.36±0.6^{bcd}	64.17±2.4
	PC	50.99±0.4^{b}	52.06±0.6^{bc}	52.64±0.5^{bc}	51.52±0.2^{bc}	49.29±0.1^{a}	52.64±0.5^{bc}	51.58±0.3^{bc}	52.02±0.4^{bc}	52.96±1.3^{c}	51.74±1.2
	WC	48.76±0.2^{a}	52.10±0.8^{b}	47.69±0.8^{a}	49.15±0.6^{a}	51.26±0.4^{b}	48.96±0.4^{a}	51.88±0.6^{b}	48.32±1.0^{a}	52.22±0.6^{b}	50.04±1.2
90 Days	LB	55.02±1.3^{bc}	54.56±0.7^{bc}	53.61±0.6^{ab}c	51.75±1.2^{a}	51.98±0.3^{a}	54.68±0.2^{bc}	52.92±0.3^{ab}	53.47±0.8^{abc}	55.45±0.6^{c}	53.71±1.4
	CB	53.33±1.2^{ab}	55.08±0.7^{ab}	55.67±1.5^{ab}	53.51±1.2^{ab}	51.99±0.4^{a}	56.20±0.7^{b}	54.07±1.9^{ab}	54.22±1.8^{ab}	54.80±2.0^{ab}	54.32±1.7
	PPEB	55.04±0.7^{a}	59.86±1.7^{b}	59.82±1.4^{b}	61.46±0.8^{b}	63.10±2.7^{b}	62.48±1.1^{b}	63.58±1.7^{b}	62.48±1.3^{b}	62.54±1.0^{b}	61.15±2.8
	PC	48.92±0.9^{a}	52.06±0.8^{c}	48.25±0.7^{a}	48.99±0.2^{a}	51.16±0.2^{bc}	49.52±0.3^{ab}	52.25±0.6^{c}	48.30±0.7^{a}	52.09±0.7^{c}	50.17±1.7
	WC	48.69±1.0^{ab}	50.53±0.8^{bcd}	51.73±0.6^{cd}	49.84±0.4^{bc}	47.43±1.0^{a}	51.98±0.4^{d}	51.93±0.5^{d}	49.32±0.7^{ab}	50.48±0.8^{bcd}	50.21±1.6
120 Days	LB	51.71±1.3^{ab}	53.46±0.7^{bc}	50.18±0.4^{a}	52.60±0.5^{ab}	52.55±0.8^{ab}	52.21±0.4^{ab}	55.88±1.4^{c}	51.50±1.7^{ab}	52.41±0.3^{ab}	52.50±1.7
	CB	51.37±1.5^{ab}	55.08±1.5^{d}	51.78±1.5^{abc}	51.71±0.8^{abc}	54.53±1.2^{bcd}	52.63±1.2^{abcd}	55.79±0.2^{d}	51.14±0.9^{a}	54.74±0.8^{cd}	53.19±2.0
	PPEB	53.81±2.6^{a}	55.73±1.3^{ab}	56.55±1.8^{ab}	56.83±0.7^{ab}	57.78±0.5^{ab}	57.99±1.2^{ab}	59.01±1.1^{b}	56.76±2.0^{ab}	56.71±1.7^{ab}	56.80±1.9
	PC	47.09±0.8^{ab}	49.37±0.6^{bc}	48.54±0.3^{abc}	49.32±0.7^{bc}	46.84±0.8^{a}	48.48±1.4^{abc}	50.59±0.4^{c}	48.80±0.8^{abc}	49.60±0.8^{c}	48.74±1.3
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	48.92±0.3^{a}	50.46±1.7a^{bc}	50.56±0.2^{abc}	51.23±0.3^{bc}	50.06±1.1^{abc}	50.13±0.3a^{bc}	52.18±0.2^{c}	49.96±0.9^{bc}	51.11±0.2^{abc}	50.51±1.1
	CB	50.34±1.4^{a}	52.59±1.3^{a}	52.05±1.0^{a}	52.13±1.2^{a}	51.31±1.4^{a}	51.95±0.6^{a}	53.50±0.6^{a}	52.05±0.8^{a}	53.02±1.5^{a}	52.10±1.3
	PPEB	51.03±1.8^{a}	53.20±1.6^{ab}	55.33±1.1^{bc}	54.92±1.4^{abc}	56.76±1.4^{bc}	55.98±1.5^{bc}	57.94±1.0^{c}	55.32±0.9^{bc}	55.29±2.2^{bc}	55.09±2.3
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

As previously indicated, monodehydroascorbate reductase, which employs NADPH as a reductant, can recycle monodehydroascorbate into ascorbate (Foyer and Noctor, 2011). According to Goyer *et al*., (2019), the reduction in ascorbic acid content during cold storage implies that there may not be enough NADPH available or that monodehydroascorbate reductase activity is insufficient to convert all the monodehydroascorbate back to ascorbate. The interdependence of folate and vitamin C metabolism is further suggested by the roles played by folate in NADPH generation and NADPH in monodehydroascorbate recycling, as well as by the opposing trends in folate and ascorbic acid concentrations during cold storage. The relationship between foliar spray and storage times showed that, in both seasons, there was no reaction from foliar spraying zinc and boron, but there was a drop in AA with longer storage times. Among the vitamins that are most susceptible to deterioration when stored in fruits and vegetables is AA (Kader, 1992; Kaul & Saini, 2000; Zhansheng *et al*., 2006).

Table 4.3.7: Effect of treatments and packaging materials on ascorbic acid (mg/100g FW) content of carrot during storage

Storage periods	Packaging materials	Ascorbic acid									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	5.74±0.4^{a}	5.32±0.4^{a}	6.24±1.2^{a}	6.49±0.8^{a}	6.71±1.1^{a}	7.13±1.1^{a}	7.17±1.5^{a}	7.17±0.4^{a}	7.17±0.4^{a}	6.57±1.0
	CB	6.21±0.7^{a}	6.46±0.4^{a}	6.46±0.8^{a}	6.67±1.0^{a}	7.38±0.8^{a}	7.42±0.8^{a}	7.42±0.8^{a}	7.63±0.7^{a}	7.63±0.7^{a}	7.03±0.8
	PPEB	6.96±0.1^{a}	6.96±0.1^{a}	7.17±0.4^{ab}	6.96±0.7^{a}	8.09±0.4^{bc}	8.55±0.4^{c}	8.76±0.4^{c}	8.97±0.1^{c}	8.76±0.4^{c}	7.91±0.9
	PC	5.53±0.6^{a}	5.74±0.4^{a}	5.28±1.0^{a}	5.32±0.4^{a}	5.28±1.0^{a}	6.24±0.7^{a}	5.78±1.0^{a}	6.21±0.7^{a}	6.24±0.7^{a}	5.74±0.7
	WC	4.86±0.7^{a}	5.32±0.4^{a}	4.86±0.7^{a}	5.57±0.1^{a}	5.28±0.4^{a}	4.40±1.4^{a}	4.40±0.4^{a}	4.86±0.7^{a}	4.86±0.7^{a}	4.94±0.7
60 Days	**LB**	4.86±0.7^{a}	5.78±0.4^{a}	5.32±1.1^{a}	5.78±0.4^{a}	5.78±1.0^{a}	6.75±0.3^{a}	6.03±0.8^{a}	6.03±0.8^{a}	6.96±1.3^{a}	5.92±0.9
	CB	5.32±0.4^{a}	6.24±0.7^{ab}	6.24±0.7^{ab}	6.71±1.1^{ab}	6.71±0.5^{ab}	7.17±1.0^{ab}	7.17±1.0^{ab}	7.63±0.7^{b}	7.63±0.7^{b}	6.76±1.0
	PPEB	6.71±1.1^{a}	6.96±0.1^{ab}	6.71±0.4^{a}	8.09±0.4^{abc}	7.63±0.7^{abc}	8.55±0.4^{c}	8.09±0.4^{abc}	8.34±0.1^{bc}	8.34±0.1^{bc}	7.71±0.8
	PC	4.40±0.4^{a}	4.86±0.7^{ab}	5.07±0.8^{ab}	5.32±0.4^{ab}	5.07±0.8^{ab}	5.32±0.4^{ab}	5.32±0.4^{ab}	5.57±0.1^{ab}	6.24±0.7^{b}	5.24±0.7
	WC	3.69±1.0^{a}	3.94±0.4^{a}	3.94±0.4^{a}	4.15±0.8^{a}	3.94±1.1^{a}	4.40±1.4^{a}	4.40±1.4^{a}	4.36±1.1^{a}	4.61±0.8^{a}	4.16±0.9
90 Days	**LB**	4.86±0.7^{a}	5.32±1.1^{a}	5.32±1.1^{a}	6.24±0.7^{a}	5.78±1.0^{a}	6.03±0.8^{a}	5.78±1.0^{a}	6.71±1.1^{a}	6.71±1.7^{a}	5.86±1.1
	CB	5.32±0.4^{a}	5.78±1.0^{a}	5.78±1.0^{a}	6.71±0.4^{a}	6.24±0.7^{a}	7.38±0.4^{a}	6.92±1.4^{a}	7.38±0.4^{a}	7.38±1.0^{a}	6.54±1.0
	PPEB	6.46±0.8^{a}	6.46±0.8^{a}	6.92±0.0^{ab}	8.09±0.4^{bc}	7.84±0.8^{abc}	8.09±0.4^{bc}	8.55±0.4^{c}	8.30±0.0^{bc}	8.09±0.4^{bc}	7.64±0.9
	PC	3.94±0.4^{a}	4.40±1.0^{a}	4.40±1.0^{a}	4.40±1.0^{a}	4.40±1.0^{a}	4.86±1.2^{a}	5.11±0.4^{a}	4.86±0.7^{a}	5.57±0.1^{a}	4.66±0.8
	WC	3.23±0.4^{a}	2.98±0.4^{a}	3.48±0.7^{a}	3.44±0.7^{a}	3.44±0.7^{a}	3.90±0.9^{a}	3.44±0.7^{a}	4.15±0.8^{a}	4.15±0.8^{a}	3.58±0.7
120 Days	**LB**	4.15±0.0^{a}	4.86±1.2^{a}	4.86±1.2^{a}	4.86±1.2^{a}	5.78±0.4^{a}	5.32±1.1^{a}	6.21±0.7^{a}	5.99±0.8^{a}	6.46±0.4^{a}	5.39±1.1
	CB	4.40±0.4^{a}	6.24±0.7^{ab}	5.32±1.1^{ab}	5.32±1.1^{ab}	6.24±0.7^{ab}	5.78±1.0^{ab}	6.96±0.1^{b}	6.71±1.1^{ab}	7.17±1.0^{b}	6.02±0.8
	PPEB	5.78±0.4^{a}	6.71±0.4^{abc}	6.21±0.7^{ab}	6.67±0.4^{abc}	7.38±0.8^{bc}	7.13±0.4^{abc}	7.88±0.4^{c}	7.17±0.4^{abc}	7.63±0.7^{bc}	6.95±0.7
	PC	3.48±0.7^{a}	3.44±0.7^{a}	4.15±0.8^{a}	3.69±0.4^{a}	3.69±0.4^{a}	4.15±0.8^{a}	3.69±0.8^{a}	4.40±0.3^{a}	4.82±0.7^{a}	3.95±7
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	3.44±0.7^{a}	3.48±0.7^{a}	5.11±0.8^{a}	3.94±1.1^{a}	4.61±0.8^{a}	5.07±1.4^{a}	4.40±1.8^{a}	5.07±1.1^{a}	5.07±0.8^{a}	4.47±1.1
	CB	3.69±1.0^{a}	4.36±0.4^{ab}	4.86±0.7^{ab}	4.86±0.7^{ab}	5.53±0.7^{b}	4.19±0.1^{ab}	4.90±0.7^{ab}	5.53±0.6^{b}	5.32±0.4^{ab}	4.81±0.8
	PPEB	4.15±0.0^{a}	4.40±0.4^{ab}	5.32±0.4^{ab}	4.86±1.2^{ab}	5.78±0.4^{ab}	5.28±0.3^{ab}	5.57±0.7^{ab}	6.03±0.4^{b}	5.99±0.4^{b}	5.27±0.8
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate.

4.3.6 Carotene content (µg/100g):

The carotene content of the treated carrots decreased linearly as the storage period advanced (Table 4.3.8). It was noticed that perforated polyethylene packed root showed higher carotene than the other packaging materials throughout the storage period and recorded average carotene (3507.0 µg/100g) followed by cotton bag root (3320.7 µg/100g). The carotene content in perforated polyethylene bag and cotton bag packed roots, ranged was observed among the treatments 3085.5 to 3906.3 µg/100g and 2753.9 to 3620.2 µg/100g, respectively, after 150 days of storage as compared to leno bag where carotene was found to be the lowest (2980.2 µg/100g) and the range among the treatments was 2533.4 and 3319.2 µg/100g. Increased respiration during storage may cause carrots to oxidize more quickly, resulting in a loss of carotenoids (Howard and Dewi, 1996). The unsaturated molecules that make up carrot carotenoids are extremely susceptible to isomerization, which oxidizes and loses color in carrots, decreasing their nutritional value (Chen *et al.*, 1996; Belitz *et al.*, 2004) asserted that proper storage and post-harvest handling of carrots are critical, stating that improper storage might result in a 5–40% reduction in carotenoids. According to Fikselová *et al.*, (2010), the cellar's β-carotene content decreased by 19.95–27% on average. In plant tissue, β-carotene is associated with proteins that dissolve in water (Tumer & Tulek, 2021). Pretreatment, similar to osmotic dehydration, causes bound proteins to dissolve in water, releasing carotenes into the water and possibly resulting in the loss of β-carotene (Dutta *et al.*, 2005). However, because the osmotic fluid covers the carrot surface throughout the osmotic dehydration process, oxygen penetration may be reduced. According to Dermesonlouoglou *et al.*, (2007), as a result, β-carotene oxidation and losses decrease during storage. In a study published in 2022, Hassan *et al.*, (2022), investigated the effects of various modified atmosphere packaging—non-perforated polyethylene, polypropylene packets, brown paper bags, and without packaging—on the nutritional value and quality of pointed gourds (*Trichosanthes dioica* Roxb.) at room temperature (30°C) and at low temperatures (4°C). The study findings indicate noteworthy distinctions between the treatment variables in every dependent parameter examined for storage conditions at room temperature and low temperature. After storage at room temperature and low temperatures, β-carotene and vitamin C were significantly preserved in pointed gourds packaged in both perforated and nonperforated polyethylene and polypropylene (El-Beltagi *et al.*, 2023).

Table 4.3.8: Effect of treatments and packaging materials on carotene (µg/100g FW) content of carrot during storage

Storage periods	Packaging materials	Carotene									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	3153.0±95.9^{a}	3344.1±55.2^{a}	3496.7±111.4^{ab}	3479.1±175.3^{ab}	3536.1±101.9^{ab}	3760.0±189.8^{bc}	3785.9±219.1^{bc}	3944.7±141.0^{c}	4110.9±96.7^{c}	3623.4±313.0
	CB	3236.9±39.8^{a}	3441.6±74.7^{b}	3711.2±69.0^{c}	3676.6±30.6^{c}	3710.6±54.5^{c}	3913.8±25.3^{d}	3979.1±67.8^{de}	4103.2±66.7^{ef}	4191.6±88.7^{f}	3773.8±300.6
	PPEB	3595.1±79.0^{a}	3757.1±25.3^{ab}	3770.8±48.6^{ab}	3672.2±15.2^{ab}	3792.9±94.9^{b}	4011.8±65.3^{c}	4118.1±76.8^{cd}	4224.9±94.0^{d}	4276.6±65.3^{d}	3913.3±246.6
	PC	3154.8±48.2^{a}	3333.0±61.0^{b}	3502.0±13.5^{cd}	3396.1±46.1^{bc}	3453.7±61.6^{bc}	3625.8±70.1^{d}	3874.7±36.9^{e}	3952.6±56.6^{ef}	4051.7±94.1^{f}	3593.8±297.4
	WC	3245.2±79.2^{a}	3323.7±26.5^{a}	3598.6±79.4^{b}	3600.8±43.3^{b}	3699.8±49.0^{b}	3607.3±51.1^{b}	3885.9±83.9^{c}	3911.2±49.2^{c}	3933.8±73.7^{c}	3645.2±241.1
60 Days	**LB**	3033.9±81.3^{a}	3293.5±36.2^{b}	3467.1±108.2^{bc}	3313.9±13.1^{bc}	3529.0±132.8^{d}	3503.9±52.4^{cd}	3812.0±70.6^{e}	3856.2±48.6^{e}	3908.5±27.6^{e}	3524.2±287.1
	CB	3177.8±49.6^{a}	3411.9±59.9^{b}	3695.9±45.1^{cd}	3583.5±86.3^{bc}	3624.1±64.6^{c}	3889.7±111.9^{de}	3957.0±33.1^{ef}	4014.8±25.5^{ef}	4111.5±112.1^{f}	3718.4±298.7
	PPEB	3509.4±62.3^{a}	3710.2±72.5^{ab}	3616.8±81.1^{ab}	3658.4±19.6^{ab}	3816.8±77.7^{bc}	3969.3±90.2^{cd}	4051.9±61.8^{cd}	4099.7±81.1^{d}	4192.9±160.3^{d}	3847.3±241.8
	PC	2986.7±25.6^{a}	3229.4±45.8^{b}	3353.±762.8^{bc}	3268.8±34.4^{bc}	3391.1±45.2^{c}	3302.5±49.2^{bc}	3573.0±37.8^{d}	3847.3±23.2^{e}	3944.3±60.2^{e}	3433.0±295.7
	WC	3038.7±9.5^{a}	3203.5±109.9^{ab}	3399.5±103.6^{c}	3298.3±45.1^{bc}	3333.9±20.4^{bc}	3409.7±4.7^{c}	3641.6±84.1^{d}	3797.3±74.3^{d}	3750.1±47.1^{d}	3430.3±249.9
90 Days	**LB**	2998.7±30.4^{a}	3153.9±56.8^{b}	3423.7±47.1^{c}	3270.3±54.1^{b}	3500.1±52.9^{c}	3426.1±81.6^{c}	3748.4±28.6^{d}	3801.1±55.1^{d}	3860.6±51.7^{d}	3464.8±288.8
	CB	3165.5±102.5^{a}	3174.6±39.8^{a}	3682.4±50.5^{c}	3437.5±47.6^{b}	3635.4±36.7^{c}	3933.0±90.4^{de}	3896.2±27.3^{d}	4019.7±75.4^{de}	4092.8±64.5^{e}	3670.8±339.9
	PPEB	3383.2±42.7^{a}	3612.6±12.0^{bc}	3605.0±11.3^{bc}	3583.2±82.2^{b}	3765.9±104.2^{bcd}	3799.3±36.1^{cd}	3951.5±59.9^{de}	4005.7±126.3^{e}	4131.5±52.2^{e}	3759.8±236.4
	PC	2885.0±120.5^{a}	3226.0±45.5^{b}	3218.4±62.1^{b}	3264.9±44.6^{bc}	3363.8±27.6^{bc}	3362.3±78.2^{bc}	3515.3±160.4^{c}	3698.3±85.2^{d}	3774.5±126.6^{d}	3367.6±270.6
	WC	2585.3±24.4^{a}	2799.0±71.9^{ab}	2982.3±128.4^{b}	2960.3±124.6^{b}	2937.2±46.2^{b}	3011.0±48.5^{bc}	3220.4±35.9^{cd}	3310.9±110.6^{d}	3385.2±80.6^{d}	3021.3±251.7
120 Days	**LB**	2729.0±70.7^{a}	3018.0±74.2^{ab}	3240.8±90.7^{bcd}	3175.0±113.3^{bc}	3221.3±92.0^{bcd}	3267.4±142.2^{bcd}	3531.3±106.8^{de}	3684.1±216.9^{e}	3470.6±43.4^{cde}	3259.7±289.8
	CB	3066.2±109.3^{a}	3112.1±24.4^{a}	3449.6±97.9^{b}	3378.7±21.2^{b}	3571.5±71.2b^{cd}	3536.0±24.4^{bc}	3691.3±64.5^{cde}	3810.2±115.1^{e}	3760.0±73.1^{de}	3486.2±262.0
	PPEB	3196.0±69.1^{a}	3195.5±44.4^{a}	3505.3±120.2^{b}	3495.9±69.4^{b}	3649.0±48.2^{bc}	3855.9±63.7^{cd}	3928.0±105.3^{d}	3924.5±27.1^{d}	4003.0±76.1^{d}	3639.2±305.5
	PC	2540.0±124.3^{a}	2727.0±36.0^{a}	3112.3±36.1^{bc}	3065.1±65.9^{bc}	3014.8±35.0^{b}	3005.1±102.4^{b}	3270.3±23.4^{cd}	3393.7±57.5^{de}	3590.2±153.0^{e}	3079.8±315.6
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	2533.4±136.9^{a}	2705.9±198.3^{ab}	3060.5±62.0^{cd}	2983.1±203.6^{bcd}	2880.9±121.4^{bc}	3061.9±64.7^{cd}	3112.4±66.7^{cd}	3164.8±3.6^{cd}	3319.2±63.3^{d}	2980.2±252.4
	CB	2753.9±90.8^{a}	3060.6±181.4^{b}	3118.7±64.0^{b}	3202.6±35.6^{b}	3455.5±85.5^{c}	3499.1±95.5^{c}	3571.1±19.8^{c}	3604.3±7.0^{c}	3620.2±32.1^{c}	3320.7±298.7
	PPEB	3085.5±83.0a	3125.2±42.5^{ab}	3360.8±59.8^{bc}	3366.4±16.5^{bc}	3506.1±63.8^{cd}	3685.8±140.5^{de}	3740.4±139.1^{de}	3787.3±9.4^{e}	3906.3±75.5^{e}	3507.1±291.3
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

4.3.7 Total Flavonoid Content (mg (RE)/g):

It is evident from Table 4.3.9 that the TFC content of the treated carrot root decreased with the advancement of the storage period, irrespective of their treatments. The TFC content of treated roots was observed to be maximum during the 30-day storage period and thereafter declined. Maximum losses occurred when treated carrots were kept in wooden boxes for 90 days of storage, and minimum losses occurred under a perforated polyethylene bag where on 150 days of storage an average TFC was found 0.73, and the range among the treatments was 0.30–1.19 mg (RE)/g. However, the effects of packaging and treatment interactions were not significant ($p > 0.05$). The total flavonoid content of root was highest at harvest but decreased with storage periods.

4.3.8 Total phenolic content (mg (GE)/g):

It was significantly influenced by different types of packaging materials. Among the various types of packaging materials, the maximum total phenolic content occurred in treated carrot roots packed in a perforated polyethylene bag. In perforated polyethylene bags, average TPC content 3.98 mg (RE)/g started appearing after 30 days of storage, and the range between treatments was 3.7– 6.3 mg (RE)/g after 150 days. However, minimum average TPC content (1.49 mg (RE)/g) was noted in treated carrots packed in Leno bags. Among 90 days of storage, the minimum average TPC was observed in treated carrots packed in wooden crates, followed by plastic crates, which was significantly lower than that in the other packaging treatments. The total phenolic content TPC showed a trend toward decline until the end of the storage period. Perforated polyethylene bag packaging maintained the maximum TPC, whereas the leno bag had the minimum phenolic content during 150 days of storage. The interaction between the treatments and the packaging materials was observed not significantly different. The enzyme polyphenol oxidase (PPO), which catalyzes the oxidation of phenolic substances, is frequently activated when boron is scarce (Pfeffer *et al*., 1998). According to Tomas-Barberan *et al*., (1997), the slower rate of phenolic degradation indicates that boric acid is crucial in delaying the activity of the polyphenol oxidase enzyme because it causes a delay in the respiratory activity of the fruit. According to reports, the fruit's phenolic acid level decreased as it ripened (Li *et al*., 2023).

Table 4.3.9: Effect of treatments and packaging materials on total flavonoids (mg (RE)/g) content of carrot during storage

Storage periods	Packaging materials	Total flavonoids content									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	1.27±0.4^{bc}	1.15±0.1^{abc}	0.67±0.2^{ab}	1.48±0.2^{c}	1.09±0.1^{abc}	1.38±0.2^{bc}	0.67±0.5^{ab}	0.79±0.1^{abc}	0.44±0.3^{a}	0.99±0.4
	CB	1.47±0.3^{cd}	1.35±0.1^{bcd}	0.83±0.0^{ab}	1.63±0.2^{d}	1.18±0.1^{abcd}	1.59±0.1^{d}	0.84±0.4^{ab}	0.94±0.1^{abc}	0.73±0.1^{a}	1.17±0.4
	PPEB	1.50±0.3^{cd}	1.35±0.1^{bcd}	0.76±0.1^{ab}	1.59±0.2^{d}	1.20±0.1^{abcd}	1.55±0.2^{d}	0.83±0.4^{abc}	0.89±0.1^{abcd}	0.60±0.4^{a}	1.14±0.4
	PC	1.37±0.4^{bc}	1.34±0.2^{bc}	0.72±0.1^{ab}	1.60±0.3^{c}	1.18±0.2^{abc}	1.60±0.1^{c}	0.79±0.3^{ab}	0.82±0.1^{ab}	0.54±0.3^{a}	1.11±0.4
	WC	1.31±0.3^{bc}	1.32±0.2^{bc}	0.69±0.1^{ab}	1.59±0.3^{c}	1.16±0.2^{abc}	1.56±0.1^{c}	0.77±0.3^{ab}	0.86±0.0^{ab}	0.55±0.3^{a}	1.09±0.4
60 Days	LB	1.19±0.4^{bcd}	1.20±0.2^{bcd}	0.65±0.1^{ab}	1.53±0.3^{d}	1.02±0.1^{abcd}	1.40±0.1^{cd}	0.69±0.3^{ab}	0.73±0.1^{abc}	0.43±0.3^{a}	0.98±0.4
	CB	1.41±0.3^{cd}	1.34±0.1^{bcd}	0.86±0.1^{ab}	1.62±0.2^{d}	1.21±0.1^{bcd}	1.54±0.1^{d}	0.85±0.3^{ab}	0.92±0.1^{abc}	0.69±0.1^{a}	1.16±0.4
	PPEB	1.43±0.3^{bcd}	1.26±0.1^{bcd}	0.79±0.1^{ab}	1.62±0.2^{d}	1.18±0.1^{abcd}	1.52±0.1^{bc}	0.79±0.4^{ab}	0.87±0.1^{abc}	0.58±0.4^{a}	1.11±0.4
	PC	1.26±0.5^{b}	1.18±0.1^{ab}	0.61±0.1^{ab}	1.11±0.4^{ab}	0.94±0.1^{ab}	1.33±0.1^{b}	0.60±0.4^{ab}	0.67±0.1^{ab}	0.41±0.2^{a}	0.90±0.4
	WC	1.16±0.4^{a}	1.11±0.1^{a}	0.54±0.2^{a}	0.84±0.7^{a}	0.86±0.1^{a}	1.24±0.2^{a}	0.50±0.4^{a}	0.61±0.1^{a}	0.31±0.2^{a}	0.80±0.4
90 Days	LB	1.30±0.4^{ab}	1.19±0.1^{ab}	0.65±0.1^{ab}	0.95±0.8^{ab}	0.99±0.1^{ab}	1.41±0.1^{b}	0.61±0.4^{ab}	0.71±0.1^{ab}	0.37±0.3^{a}	0.91±0.4
	CB	1.35±0.3^{bc}	1.34±0.2^{bc}	0.83±0.0^{ab}	1.62±0.2^{c}	1.16±0.1^{bc}	1.58±0.1^{c}	0.84±0.4^{ab}	0.96±0.1^{ab}	0.58±0.2^{a}	1.14±0.4
	PPEB	1.34±0.3^{bc}	1.19±0.2^{abc}	0.83±0.1^{abc}	1.53±0.1^{c}	1.07±0.3^{abc}	1.37±0.3^{bc}	0.76±0.4^{ab}	0.84±0.1^{abc}	0.52±0.3^{a}	1.05±0.4
	PC	1.07±0.3^{bcde}	1.11±0.1^{cde}	0.57±0.0^{ab}	1.41±0.1^{e}	0.80±0.3^{abcd}	1.27±0.2^{de}	0.47±0.1^{a}	0.72±0.1^{abc}	0.35±0.2^{a}	0.86±0.4
	WC	0.78±0.3^{ab}	0.76±0.1^{ab}	0.32±0.1^{ab}	0.82±0.5^{ab}	0.65±0.1^{ab}	0.91±0.0^{b}	0.31±0.3^{ab}	0.34±0.0^{ab}	0.19±0.2^{a}	0.56±0.3
120 Days	LB	1.10±0.3^{cde}	1.07±0.1^{cde}	0.56±0.0^{ab}	1.33±0.1^{e}	0.78±0.2^{bcd}	1.23±0.2^{de}	0.45±0.2^{ab}	0.64±0.1^{abc}	0.30±0.2^{a}	0.83±0.4
	CB	1.24±0.3^{bc}	1.25±0.1^{bc}	0.73±0.0^{ab}	1.49±0.2^{c}	1.09±0.1^{abc}	1.55±0.2^{c}	0.70±0.4^{ab}	0.85±0.1^{ab}	0.56±0.2^{a}	1.05±0.4
	PPEB	1.17±0.4^{bc}	1.22±0.2^{bc}	0.67±0.1^{ab}	1.41±0.3^{c}	1.04±0.2^{abc}	1.42±0.1^{c}	0.61±0.4^{ab}	0.81±0.2^{abc}	0.42±0.3^{a}	0.98±0.4
	PC	0.73±0.2^{b}	0.52±0.1^{ab}	0.23±0.1^{a}	0.92±0.3^{b}	0.55±0.2^{ab}	0.80±0.2^{b}	0.24±0.1^{a}	0.19±0.1^{a}	0.24±0.1^{a}	0.49±0.3
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	0.72±0.3^{b}	0.51±0.1^{ab}	0.19±0.1^{a}	0.93±0.3^{b}	0.52±0.2^{ab}	0.81±0.1^{b}	0.19±0.2^{a}	0.19±0.1^{a}	0.10±0.1^{a}	0.46±0.3
	CB	0.99±0.4^{bc}	0.87±0.1^{abc}	0.38±0.1^{a}	1.16±0.2^{c}	0.75±0.2^{abc}	1.16±0.2^{c}	0.38±0.3^{a}	0.49±0.1^{ab}	0.36±0.1^{a}	0.73±0.4
	PPEB	0.97±0.3^{bc}	0.87±0.1^{abc}	0.44±0.1^{ab}	1.19±0.2^{c}	0.76±0.1^{abc}	1.19±0.1^{c}	0.38±0.4^{a}	0.51±0.1^{ab}	0.30±0.2^{a}	0.73±0.4
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Table 4.3.10: Effect of treatments and packaging materials on total phenolic (mg GE/g DW) content of carrot during storage

Storage periods	Packaging materials	Total phenolic content									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	4.3 ± 1.4^{ab}	4.5 ± 0.2^{ab}	2.7 ± 0.8^{a}	5.4 ± 0.4^{b}	3.7 ± 0.1^{b}	5.6 ± 0.4^{b}	3.0 ± 0.9^{a}	3.7 ± 0.2^{ab}	2.9 ± 0.5^{a}	3.96±1.2
	CB	4.2 ± 0.2^{abc}	4.9 ± 0.4^{bcd}	3.2 ± 0.4^{a}	5.5 ± 0.2^{cd}	4.1 ± 0.6^{abc}	6.0 ± 0.1^{d}	3.5 ± 1.1^{ab}	4.1 ± 0.7^{abc}	3.5 ± 0.4^{ab}	4.34±1.0
	PPEB	4.8 ± 0.9^{ab}	5.3 ± 0.3^{ab}	3.7 ± 0.1^{a}	5.9 ± 0.2^{b}	4.8 ± 0.7^{ab}	6.3 ± 0.4^{b}	3.7 ± 1.3^{a}	4.6 ± 0.5^{ab}	3.9 ± 0.3^{a}	4.77±1.0
	PC	3.9 ± 0.9^{abc}	4.4 ± 0.2^{bcd}	2.6 ± 0.4^{a}	5.0 ± 0.3^{cd}	$3.5\pm0.5a^{bc}$	5.2 ± 0.4^{d}	2.8 ± 1.1^{ab}	3.6 ± 0.5^{abcd}	2.8 ± 0.3^{ab}	3.76±1.0
	WC	3.7 ± 1.1^{abcd}	4.2 ± 0.1^{bcd}	2.3 ± 0.6^{a}	4.8 ± 0.3^{cd}	3.3 ± 0.5^{abc}	5.2 ± 0.2^{d}	2.5 ± 1.1^{ab}	3.3 ± 0.5^{abcd}	2.5 ± 0.4^{ab}	3.53±1.1
60 Days	**LB**	4.1 ± 1.4^{ab}	4.3 ± 0.2^{ab}	2.5 ± 0.9^{a}	5.2 ± 0.4^{b}	3.5 ± 0.1^{ab}	5.4 ± 0.4^{b}	2.8 ± 1.0^{a}	3.5 ± 0.2^{ab}	2.7 ± 0.5^{a}	3.79±1.1
	CB	3.6 ± 0.6^{ab}	4.7 ± 0.4^{bc}	2.5 ± 0.5^{a}	5.4 ± 0.1^{c}	3.5 ± 0.7^{ab}	5.4 ± 0.1^{c}	2.9 ± 1.2^{a}	3.6 ± 0.6^{ab}	2.9 ± 0.3^{a}	3.82±1.5
	PPEB	4.5 ± 0.8^{abc}	4.9 ± 0.6^{abc}	3.3 ± 0.2^{a}	5.3 ± 0.3^{bc}	4.4 ± 0.7^{abc}	5.5 ± 0.4^{c}	3.4 ± 1.4^{ab}	4.3 ± 0.5^{abc}	3.4 ± 0.3^{ab}	4.36±1.0
	PC	3.7 ± 1.0^{ab}	4.3 ± 0.9^{ab}	2.6 ± 1.1^{a}	5.1 ± 0.5^{b}	3.5 ± 0.3^{ab}	5.0 ± 0.4^{b}	2.9 ± 0.5^{a}	3.2 ± 0.3^{ab}	2.6 ± 0.9^{a}	3.64±1.1
	WC	2.8 ± 0.6^{ab}	3.7 ± 0.7^{ab}	2.1 ± 1.0^{a}	4.3 ± 0.5^{b}	3.1 ± 0.3^{ab}	4.5 ± 0.5^{b}	2.3 ± 0.6^{a}	2.9 ± 0.4^{ab}	2.2 ± 0.9^{a}	3.12±1.0
90 Days	**LB**	3.8 ± 1.4^{ab}	4.1 ± 0.3^{ab}	2.3 ± 1.0^{a}	5.0 ± 0.4^{b}	3.3 ± 0.1^{ab}	5.0 ± 0.5^{b}	2.5 ± 1.1^{a}	3.3 ± 0.2^{ab}	2.4 ± 0.6^{a}	3.51±1.2
	CB	3.2 ± 0.9^{ab}	4.4 ± 0.3^{ab}	2.6 ± 0.2^{a}	4.9 ± 0.4^{b}	3.1 ± 0.6^{ab}	4.8 ± 0.1^{ab}	2.8 ± 1.6^{ab}	3.4 ± 0.7^{ab}	2.7 ± 0.7^{a}	3.54±1.1
	PPEB	4.2 ± 1.2^{ab}	4.6 ± 0.3^{ab}	3.0 ± 0.2^{a}	5.1 ± 0.2^{b}	4.0 ± 0.6^{ab}	5.3 ± 0.4^{b}	3.0 ± 1.3^{a}	3.8 ± 0.5^{ab}	3.1 ± 0.3^{a}	4.00±1.0
	PC	3.1 ± 1.5^{ab}	3.5 ± 0.6^{ab}	1.7 ± 1.2^{a}	4.2 ± 0.8^{ab}	2.8 ± 0.4^{ab}	4.4 ± 0.8^{b}	2.0 ± 1.1^{ab}	2.7 ± 0.6^{ab}	1.8 ± 0.6^{ab}	2.91±1.2
	WC	2.3 ± 1.2^{a}	3.0 ± 0.5^{a}	1.4 ± 1.3^{a}	3.4 ± 0.8^{a}	2.6 ± 0.6^{a}	3.8 ± 0.8^{a}	1.8 ± 1.4^{a}	2.4 ± 0.6^{a}	1.4 ± 0.8^{a}	2.45±1.2
120 Days	**LB**	2.7 ± 1.2^{ab}	3.4 ± 0.4^{ab}	1.5 ± 0.9^{a}	4.2 ± 0.4^{b}	2.6 ± 0.1^{ab}	4.5 ± 0.5^{b}	1.8 ± 1.0^{a}	2.6 ± 0.2^{ab}	1.7 ± 0.6^{a}	2.76±1.2
	CB	3.0 ± 0.5^{abc}	3.6 ± 0.2^{bcd}	1.9 ± 0.5^{a}	4.3 ± 0.1^{cd}	2.9 ± 0.6^{abc}	4.5 ± 0.5^{d}	2.2 ± 1.1^{ab}	2.9 ± 0.4^{abc}	2.3 ± 0.1^{ab}	3.08±1.0
	PPEB	3.7 ± 0.9^{ab}	4.4 ± 0.5^{ab}	2.6 ± 0.4^{a}	4.8 ± 0.3^{b}	3.6 ± 0.5^{ab}	$5.0\pm0.^{b}$	2.7 ± 1.2^{a}	3.4 ± 0.6^{ab}	2.8 ± 0.3^{a}	3.68±1.0
	PC	2.0 ± 0.8^{ab}	2.1 ± 0.5^{ab}	0.9 ± 0.6^{a}	2.9 ± 0.8^{b}	1.2 ± 0.6^{ab}	2.9 ± 0.7^{b}	1.2 ± 0.7^{ab}	1.2 ± 0.4^{ab}	0.9 ± 0.8^{a}	1.70±1.0
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	1.6 ± 1.1^{abc}	1.9 ± 0.5^{abc}	0.6 ± 0.3^{a}	2.6 ± 0.4^{bc}	1.0 ± 0.1^{a}	2.8 ± 0.5^{c}	1.1 ± 0.3^{ab}	1.1 ± 0.2^{a}	0.7 ± 0.6^{a}	1.49±0.9
	CB	2.1 ± 1.3^{ab}	2.3 ± 0.9^{ab}	1.4 ± 0.1^{a}	2.9 ± 0.2^{ab}	1.6 ± 0.4^{a}	3.4 ± 0.1^{b}	$1.6\pm0.^{5a}$	1.7 ± 0.4^{ab}	1.2 ± 0.6^{a}	2.02± 0.9
	PPEB	2.7 ± 0.6^{abc}	3.5 ± 0.4^{bc}	2.1 ± 0.5^{ab}	4.1 ± 0.4^{c}	3.1 ± 0.5^{abc}	4.1 ± 0.6^{c}	1.9 ± 1.3^{ab}	2.7 ± 0.3^{abc}	1.7 ± 0.4^{a}	2.87±1.0
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

4.3.9 Total titratable acidity (%):

The total titratable acidity level of the carrot root decreased during storage. At the end of storage, the minimum average acid content was recorded in treated roots packed in wooden crates (0.18%), followed by plastic crates (0.20%). However, a significantly higher average titratable acidity (0.26%) was observed in treated roots stored in perforated polyethylene bags for up to 150 days. The decrease in acidity during storage could be attributed to the use of organic acids as respiratory substrates during storage (Kaur *et al*., 2013) and the conversion of acids into sugars. Reduced oxygen availability to the roots may be the cause of the higher acidity content in the perforated polyethylene-packed roots. Excessive acidity is caused by the non-oxidation of organic acids, which are involved in respiratory functions. Compared with roots packed in leno bags, the treated roots packaged in perforated polyethylene bags showed increased acidity. The comparatively moderate drop in the acid content of roots under improved perforated polyethylene packing may have contributed to the slower rate of ethylene production.

Table 4.3.11: Effect of treatments and packaging materials on total titratable acidity % content of carrot during storage

Storage periods	Packaging materials	Total titratable acidity %									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	0.34±0.0^{abc}	0.34±0.0^{abc}	0.33±0.0^{a}b	0.33±0.0^{ab}	0.36±0.0^{c}	0.36±0.0^{bc}	0.36±0.0^{abc}	0.32±0.0^{a}	0.34±0.0^{abc}	0.34±0.0
	CB	0.32±0.0^{a}	0.33±0.0^{a}	0.34±0.0^{a}	0.33±0.0^{a}	0.34±0.0^{a}	0.35±0.0^{a}	0.35±0.0^{a}	0.33±0.0^{a}	0.34±0.0^{a}	0.34±0.0.0
	PPEB	0.32±0.0^{a}	0.32±0.0^{a}	0.33±0.0^{a}	0.34±0.0^{a}	0.35±0.0^{a}	0.35±0.0^{a}	0.36±0.0^{a}	0.34±0.0^{a}	0.36±0.0^{a}	0.40±0.0.0
	PC	0.29±0.0^{a}	0.28±0.0^{a}	0.29±0.0^{a}	0.29±0.0^{a}	0.30±0.0^{a}	0.31±0.0^{a}	0.31±0.0^{a}	0.30±0.0^{a}	0.31±0.0^{a}	0.30±0.0
	WC	0.29±0.0^{a}	0.30±0.0^{a}	0.30±0.0a	0.30±0.0^{a}	0.30±0.0^{a}	0.30±0.0^{a}	0.30±0.0^{a}	0.31±0.0^{a}	0.30±0.0^{a}	0.30±0.0
60 Days	**LB**	0.33±0.0^{a}	0.32±0.0^{a}	0.32±0.0^{a}	0.31±0.0^{a}	0.32±0.0^{a}	0.34±0.0^{a}	0.32±0.0^{a}	0.31±0.0^{a}	0.32±0.0^{a}	0.32±0.0
	CB	0.30±0.0^{a}	0.31±0.0^{a}	0.31±0.0^{a}	0.32±0.0^{a}	0.33±0.0^{a}	0.32±0.0^{a}	0.31±0.0^{a}	0.30±0.0^{a}	0.32±0.0^{a}	0.31±0.0
	PPEB	0.30±0.0^{a}	0.30±0.0^{a}	0.31±0.0^{a}	0.32±0.0^{a}	0.32±0.0^{a}	0.33±0.0^{a}	0.34±0.0^{a}	0.33±0.0^{a}	0.34±0.0^{a}	0.32±0.0
	PC	0.28±0.0^{a}	0.27±0.0^{a}	0.28±0.0^{a}	0.27±0.0^{a}	0.27±0.0^{a}	0.29±0.0^{a}	0.30±0.0^{a}	0.30±0.0^{a}	0.30±0.0^{a}	0.28±0.0
	WC	0.26±0.0^{a}	0.27±0.0^{a}	0.26±0.0^{a}	0.26±0.0^{a}	0.26±0.0^{a}	0.26±0.0^{a}	0.26±0.0^{a}	0.27±0.0^{a}	0.26±0.0^{a}	0.26±0.0
90 Days	**LB**	0.31±0.0^{a}	0.30±0.0^{a}	0.29±0.0^{a}	0.29±0.0^{a}	0.30±0.0^{a}	0.31±0.0^{a}	0.30±0.0^{a}	0.29±0.0^{a}	0.29±0.0^{a}	0.30±0.0
	CB	0.28±0.0^{a}	0.29±0.0^{a}	0.30±0.^{0a}	0.30±0.0^{a}	0-.31±0.0^{a}	0.29±0.0^{a}	0.28±0.^{0a}	0.29±0.0^{a}	0.29±0.0^{a}	0.29±0.0
	PPEB	0.30±0.0^{ab}	0.29±0.0^{a}	0.30±0.0^{ab}	0.29±0.0^{ab}	0.31±0.0^{ab}	0.33±0.0^{ab}	0.34±0.0^{b}	0.33±0.0^{ab}	0.31±0.0^{ab}	0.31±0.0
	PC	0.26±0.0^{a}	0.25±0.1^{a}	0.26±0.0^{a}	0.26±0.0^{a}	0.27±0.0^{a}	0.29±0.0^{a}	0.30±0.0^{a}	0.28±0.0^{a}	0.28±0.0^{a}	0.27±0.0
	WC	0.23±0.0^{a}	0.25±0.0^{a}	0.25±0.0^{a}	0.25±0.0^{a}	0.24±0.0^{a}	0.25±0.0^{a}	0.27±0.0^{a}	0.25±0.0^{a}	0.26±0.0^{a}	0.25±0.0
120 Days	**LB**	0.27±0.0^{a}	0.26±0.0^{a}	0.28±0.0^{a}	0.27±0.0^{a}	0.25±0.0^{a}	0.28±0.0^{a}	0.27±0.0^{a}	0.28±0.0^{a}	0.26±0.0^{a}	0.27±0.0
	CB	0.27±0.0^{a}	0.27±0.0^{a}	0.28±0.0^{a}	0.29±0.0^{a}	0.28±0.0^{a}	0.27±0.0^{a}	0.27±0.0^{a}	0.29±0.0^{a}	0.28±0.0^{a}	0.28±0.0
	PPEB	0.27±0.0^{a}	0.29±0.0^{ab}	0.29±0.0^{ab}	0.27±0.0^{ab}	0.30±0.0^{ab}	0.31±0.0^{b}	0.32±0.0^{b}	0.30±0.0^{ab}	0.28±0.0^{ab}	0.29±0.0
	PC	0.23±0.0^{a}	0.23±0.0^{a}	0.25±0.0^{a}	0.24±0.0^{a}	0.25±0.0^{a}	0.24±0.0^{a}	0.25±0.0^{a}	0.24±0.0^{a}	0.26±0.0^{a}	0.24±0.0
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	0.24±0.0^{a}	0.24±0.0^{a}	0.22±0.0^{a}	0.24±0.0^{a}	0.22±0.0^{a}	0.26±0.0^{a}	0.25±0.0^{a}	0.22±0.0^{a}	0.23±0.0^{a}	0.24±0.0
	CB	0.24±0.0^{a}	0.25±0.0^{a}	0.25±0.0^{a}	0.26±0.0^{a}	0.26±0.0^{a}	0.25±0.0^{a}	0.26±0.0^{a}	0.26±0.0^{a}	0.25±0.0^{a}	0.25±0.0
	PPEB	0.25±0.0^{a}	0.26±0.0^{a}	0.28±0.0^{a}	0.26±0.0^{aa}	0.27±0.0^{a}	0.29±0.0^{a}	0.29±0.0^{a}	0.28±0.0^{a}	0.27±0.0^{a}	0.27±0.0
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

4.3.10 Micronutrients (Cu, Fe, Mn, Na, Zn) content (mg/100g):

Copper in treated carrots experienced a linear decline as the storage period advanced. It was noticed that perforated polyethylene packed root showed higher copper than other packaging materials throughout the storage period and recorded average copper content 0.39 mg/100g followed by cotton bag packed root (0.35 mg/100g). The copper content in perforated polyethylene bag and cotton bag packed roots, the range was observed among the treatments 0.37– 0.43 mg/100g and 0.31– 0.37 mg/100g, respectively, after 150 days of storage as compared to leno bag where copper was found to be the lowest and the range among the treatments was 0.29 and 0.36 mg/100g. The minimum average copper content (0.31 mg/100g) was observed in wooden packed roots after 90 days of storage, followed closely by plastic crate packed roots (0.33 mg/100g) after 120 days of storage. The iron content of the treated carrots decreased linearly as the storage period advanced (Table 4.3.13). It was noticed that leno bag-packed treated roots showed higher iron content than the other packaging materials throughout the storage period and recorded average iron content 9.01 mg/100g followed by cotton bag root (8.57 mg/100g). The iron content in leno bag, the ranged was recorded among the treatments 7.62–10.50 mg/100g after 150 days of storage as compared to perforated polyethylene bag where iron content was found to be the lowest and the ranged among the treatments was 6.62 – 9.49 mg/100g. Manganese of the treated carrots experienced a linear decline as the storage period advanced (Table 4.3.14). It was noticed that leno bag-packed carrot root showed higher Mn than the other packaging materials throughout the storage period and recorded average of Mn content 1.34 mg/100g followed by cotton bag root (1.32 mg/100g). The Mn content in leno bag packed roots, the ranged was noticed that among the treatments1.06–1.77 mg/100g, from 150 days of storage as compared to perforated polyethylene bag where average Mn content 1.29 mg/100g was found to be the lowest and the ranged among the treatments was 1.24 and 1.33 mg/100g.

The sodium content in treated carrots gradually declined as the storage duration increased (Table 4.3.15). Perforated polyethylene bags packed treated carrot root observed higher sodium levels compared to other packaging materials during the storage period and recorded average sodium content 286.9 mg/100g followed by cotton bag (283.6 mg/100g).

Table 4.3.12: Effect of treatments and packaging materials on copper (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Copper									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	0.44±0.1^{a}	0.44±0.1^{a}	0.43±0.1^{a}	0.45±0.1^{a}	0.35±0.0^{a}	0.45±0.0^{a}	0.42±0.0^{a}	0.47±0.0^{a}	0.47±0.0^{a}	0.44±0.1
	CB	0.45±0.0^{a}	0.45±0.1^{a}	0.41±0.0^{a}	0.46±0.0^{a}	0.37±0.0^{a}	0.42±0.0^{a}	0.42±0.0^{a}	0.47±0.0^{a}	0.48±0.0^{a}	0.44±0.0
	PPEB	0.45±0.0^{ab}	0.47±0.0^{ab}	0.40±0.0^{ab}	0.46±0.1^{ab}	0.38±0.0^{a}	0.42±0.1^{ab}	0.42±0.0^{ab}	0.47±0.0^{ab}	0.50±0.0^{a}	0.44±0.0
	PC	0.51±0.0^{b}	0.44±0.0^{ab}	0.49±0.0^{b}	0.50±0.0^{b}	0.40±0.0^{a}	0.44±0.0^{ab}	0.47±0.0^{ab}	0.43±0.0^{ab}	0.47±0.0^{ab}	0.46±0.0
	WC	0.31±0.0^{ab}	0.34±0.0^{ab}	0.32±0.0^{ab}	0.29±0.0^{a}	0.35±0.0^{ab}	0.35±0.0^{ab}	0.39±0.0^{b}	0.33±0.0^{ab}	0.34±0.0^{ab}	0.33±0.0
60 Days	LB	0.46±0.1^{a}	0.43±0.1^{a}	0.45±0.1^{a}	0.46±0.1^{a}	0.36±0.0^{a}	0.43±0.1^{a}	0.41±0.0^{a}	0.45±0.0^{a}	0.48±0.0^{a}	0.44±0.1
	CB	0.50±0.0^{ab}	0.53±0.0^{b}	0.50±0.1^{ab}	0.51±0.0^{b}	0.39±0.0^{a}	0.45±0.1^{ab}	0.48±0.0^{ab}	0.48±0.0^{ab}	0.49±0.0^{ab}	0.48±0.0
	PPEB	0.49±0.0^{a}	0.46±0.0^{a}	0.50±0.1^{a}	0.50±0.0^{a}	0.38±0.0^{a}	0.44±0.0^{a}	0.50±0.1^{a}	0.42±0.0^{a}	0.48±0.1^{a}	0.46±0.1
	PC	0.34±0.0^{abc}	0.36±0.0^{bc}	0.30±0.0^{a}	0.39±0.0^{c}	0.34±0.0^{abc}	0.33±0.0^{ab}	0.33±0.0^{abc}	0.33±0.0^{abc}	0.38±0.0^{bc}	0.34±0.0
	WC	0.37±0.0^{a}	0.37±0.0^{a}	0.35±0.0^{a}	0.37±0.0^{a}	0.32±0.0^{a}	0.38±0.0^{a}	0.37±0.0^{a}	0.38±0.0^{a}	0.37±0.0^{a}	0.36±0.0
90 Days	LB	0.32±0.0^{a}	0.38±0.0^{a}	0.32±0.0^{a}	0.33±0.0^{a}	0.30±0.0^{a}	0.33±0.0^{a}	0.32±0.0^{a}	0.37±0.1^{a}	0.37±0.0^{a}	0.34±0.0
	CB	0.43±0.0^{abcd}	0.51±0.0^{d}	0.46±0.0^{bcd}	0.41±0.0^{abc}	0.36±0.0^{a}	0.40±0.0^{abc}	0.38±0.0^{ab}	0.48±0.0^{cd}	0.44±0.0^{bcd}	0.43±0.0
	PPEB	0.45±0.0^{a}	0.49±0.0^{a}	0.48±0.0^{a}	0.45±0.0^{a}	0.42±0.0^{a}	0.45±0.0^{a}	0.43±0.0^{a}	0.49±0.1^{a}	0.45±0.0^{a}	0.46±0.0
	PC	0.33±0.0^{ab}	0.36±0.0^{abcd}	0.37±0.0^{bcd}	0.38±0.0^{cd}	0.32±0.0^{a}	0.39±0.0^{de}	0.34±0.0^{abc}	0.44±0.0^{e}	0.41±0.0^{de}	0.37±0.0
	WC	0.29±0.0^{a}	0.32±0.0^{a}	0.33±0.0^{a}	0.34±0.0^{a}	0.28±0.0^{a}	0.34±0.0^{a}	0.31±0.0^{a}	0.32±0.0^{a}	0.29±0.0^{a}	0.31±0.0
120 Days	LB	0.36±0.0^{a}	0.40±0.1^{a}	0.38±0.0^{a}	0.37±0.0^{a}	0.33±0.0^{a}	0.38±0.1^{a}	0.35±0.0^{a}	0.44±0.0^{a}	0.39±0.0^{a}	0.38±0.0
	CB	0.40±0.0^{a}	0.45±0.0^{a}	0.43±0.0^{a}	0.43±0.0^{a}	0.39±0.0^{a}	0.44±0.0^{a}	0.41±0.0^{a}	0.46±0.0^{a}	0.43±0.0^{a}	0.43±0.0
	PPEB	0.40±0.0^{ab}	0.46±0.0^{b}	0.44±0.0^{ab}	0.40±0.0^{ab}	0.37±0.0^{a}	0.38±0.0^{ab}	0.39±0.0^{ab}	0.46±0.0^{b}	0.40±0.0^{ab}	0.41±0.0
	PC	0.33±0.0^{abc}	0.29±0.0^{a}	0.31±0.0^{ab}	0.36±0.0^{bcd}	0.28±0.0^{a}	0.36±0.0^{cd}	0.35±0.0^{bcd}	0.39±0.0^{d}	0.37±0.0^{cd}	0.34±0.0
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	0.33±0.0^{a}	0.35±0.1^{a}	0.32±0.0^{a}	0.32±0.^{0a}	0.29±0.0^{a}	0.33±0.1^{a}	0.35±0.0^{a}	0.36±0.1^{a}	0.35±0.1^{a}	0.33±0.0
	CB	0.34±0.0^{a}	0.36±0.0^{a}	0.35±0.0^{a}	0.34±0.0^{a}	0.31±0.0^{a}	0.37±0.0^{a}	0.33±0.0^{a}	0.37±0.0^{a}	0.37±0.0^{a}	0.35±0.0
	PPEB	0.38±0.0^{a}	0.42±0.0^{a}	0.41±0.0^{a}	0.38±0.0^{a}	0.37±0.0^{a}	0.38±0.0^{a}	0.39±0.^{0a}	0.43±0.0^{a}	0.38±0.0^{a}	0.39±0.0
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Table 4.3.13: Effect of treatments and packaging materials on iron (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Iron									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	8.56±0.6^{a}	10.07±0.4^{ab}	11.01±0.5^{b}	11.75±0.7^{b}	11.14±0.4^{b}	11.72±0.8^{b}	11.05±1.0^{b}	11.70±1.2^{b}	10.74±0.8^{b}	10.86±1.1
	CB	8.16±0.3^{a}	8.96±0.6^{a}	8.94±0.4^{a}	9.37±0.8^{a}	9.60±0.2^{a}	9.42±0.5^{a}	9.47±0.7^{a}	9.44±0.4^{a}	9.37±0.4^{a}	9.19±0.6
	PPEB	8.51±0.4^{a}	9.09±0.6^{a}	9.40±0.4^{a}	9.57±0.7^{a}	9.96±0.3^{a}	9.80±0.7^{a}	9.68±0.6^{a}	9.40±0.4^{a}	9.41±0.3^{a}	9.42±0.6
	PC	7.57±0.7^{a}	7.99±0.6^{ab}	9.82±0.4^{bc}	9.54±1.2^{abc}	9.11±0.6^{abc}	8.69±0.5^{abc}	9.54±0.7^{bc}	10.66±0.4^{c}	8.22±0.6^{ab}	9.02±1.1
	WC	7.87±0.9^{a}	8.37±0.1^{ab}	9.95±1.1^{bc}	8.82±0.8^{abc}	9.90±0.4^{abc}	9.88±0.8^{abc}	10.70±1.0^{c}	10.37±0.5^{bc}	8.61±0.2^{ab}	9.38±1.1
60 Days	LB	7.82±0.3^{a}	8.67±0.7^{ab}	11.20±0.6^{cd}	9.67±0.5^{abc}	10.66±1.1^{bcd}	9.21±0.9^{abc}	10.76±0.3^{bcd}	12.34±1.2^{d}	8.79±0.9^{ab}	9.90±1.5
	CB	7.30±0.3^{a}	8.42±0.2^{ab}	10.34±0.2^{d}	9.64±0.4^{bcd}	10.18±0.5^{cd}	8.96±0.4^{bc}	10.31±0.8^{d}	10.18±0.2^{cd}	8.44±0.4^{ab}	9.31±1.1
	PPEB	7.50±0.3^{a}	8.78±0.3^{abc}	10.26±0.6^{cd}	9.88±1.0^{bcd}	10.42±0.3^{d}	9.46±0.6^{bcd}	9.71±0.9^{bcd}	9.68±0.2^{bcd}	8.54±0.4^{ab}	9.36±1.5
	PC	7.28±0.6^{a}	8.27±0.2^{abc}	10.12±0.6^{d}	8.96±0.5^{bc}	9.43±0.3^{cd}	8.70±0.4^{bc}	9.41±0.5^{cd}	10.13±0.2^{d}	7.93±0.6^{ab}	8.92±1.0
	WC	7.81±0.6^{a}	8.74±0.6^{abc}	10.57±0.8^{bc}	8.80±0.5^{abc}	9.29±0.4^{abc}	8.37±1.3^{ab}	9.35±1.1^{abc}	10.86±0.6^{c}	7.87±0.9^{a}	9.07±1.2
90 Days	LB	8.17±0.2^{a}	9.08±0.2^{bc}	10.45±0.4^{fg}	9.74±0.2^{de}	10.29±0.1^{ef}	9.43±0.1^{cd}	10.10±0.1^{ef}	10.94±0.1^{g}	8.71±0.3^{ab}	9.66±0.9
	CB	7.08±0.3^{a}	7.91±0.4^{ab}	10.24±0.3^{e}	9.31±0.4^{cd}	9.94±0.3^{de}	8.49±0.2^{bc}	10.15±0.3^{de}	9.84±0.2^{de}	8.30±0.3^{b}	9.03±1.1
	PPEB	7.04±0.4^{a}	8.19±0.5^{b}	10.48±0.4^{cd}	9.59±0.3^{c}	10.03±0.1^{cd}	8.66±0.2^{b}	9.92±0.3^{cd}	10.52±0.1^{d}	8.34±0.2^{b}	9.20±1.2
	PC	6.91±0.8^{a}	7.45±0.5^{a}	8.22±0.5^{ab}	8.21±0.3^{ab}	9.12±0.3^{b}	7.59±0.3^{a}	9.28±0.2^{b}	9.38±0.8^{b}	7.16±0.2^{a}	8.15±1.0
	WC	7.04±0.7^{a}	7.74±0.6^{ab}	10.24±0.5^{cd}	8.55±1.3^{abc}	9.22±0.9^{abcd}	8.42±0.6^{abc}	9.61±1.1^{bcd}	10.93±0.9^{d}	8.05±0.3^{abc}	8.87±1.4
120 Days	LB	7.24±1.0^{a}	8.97±0.4^{abc}	10.21±0.9^{c}	9.61±0.8^{bc}	10.03±0.6^{c}	8.63±0.9^{abc}	9.40±0.4^{bc}	10.39±0.5^{c}	7.72±0.4^{ab}	9.13±1.2
	CB	7.14±0.3^{a}	8.34±0.3^{bc}	9.76±0.4^{ef}	9.05±0.4^{cde}	9.76±0.2^{ef}	8.77±0.2^{bcd}	9.57±0.3^{de}	10.43±0.3^{f}	7.98±0.2^{ab}	8.98±1.0
	PPEB	7.03±0.1^{a}	8.14±0.2^{bc}	9.54±0.2^{ef}	8.61±0.2^{cd}	9.75±0.4^{ef}	8.55±0.2^{cd}	8.98±0.2^{de}	10.14±0.5^{f}	7.48±0.3^{ab}	8.69±1.0
	PC	6.54±0.3^{a}	7.43±0.5^{ab}	8.37±0.^{3bcde}	7.97±0.4^{bcd}	9.22±0.4^{de}	7.71±0.3^{abc}	9.41±0.9^{e}	8.95±0.4^{cde}	7.17±0.2^{ab}	8.08±1.0
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	7.62±0.7^{a}	7.89±1.2^{ab}	9.51±0.5^{abcd}	8.36±0.8^{abc}	10.35±0.2^{cd}	9.10±0.6^{abcd}	9.75±0.5^{bcd}	10.50±1.1^{d}	8.03±0.7^{ab}	9.01±1.2
	CB	7.21±0.8^{a}	7.89±0.7^{abc}	9.60±0.4^{cd}	8.61±0.7^{abcd}	9.14±0.3^{bcd}	8.20±0.9^{abcd}	9.00±0.7^{bcd}	9.81±0.2^{d}	7.69±0.2^{ab}	8.57±1.0
	PPEB	6.62±1.1^{a}	7.60±1.0^{abc}	9.24±0.8^{bc}	8.03±0.9^{abc}	8.87±0.8^{abc}	7.79±0.7^{abc}	7.96±0.6^{abc}	9.49±0.6^{c}	7.05±0.7^{ab}	8.07±1.1
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

The sodium content in perforated polyethylene bag, the range was recorded among the treatments 267.27–295.85 mg/100g, from 150 days of storage as compared to leno bag where average sodium 278.7 mg/100g was found to be the lowest and the range among the treatments was 255.44 to 319.30 mg/100g. During the storage periods, minimum loss of zinc was observed in perforated polyethylene bag packed roots. Root zinc generally followed a declining trend commensurate with advancement in the storage period (Table 4.3.16). The treated roots packed in cotton bags maintained the highest average zinc concentration 6.42 mg/100g, which is statically at par with the leno bag (6.36 mg/100g) and perforated polyethylene bag (6.31 mg/100g). The zinc of roots in cotton bags declined slower and steadily, and the range among the treatments was 6.97 mg/100g and 6.42 mg/100g during 150 days of storage interval, whereas in the case of plastic crates, the decline in zinc was abrupt and sharp, and the range was observed among the treatments 4.52 to 7.38 mg/100g during 120 days of storage. Additionally, Chung *et al*., (2004) discovered that by interfering with nitrate reductase's internal electron transport, a low temperature might significantly lower the enzyme's activity in green vegetable leaves.

A similar conclusion that nitrite results from the microbiological decrease of nitrate in foods (such vegetables) when maintained at room temperature was discovered in the literature previously mentioned (Phillips, 1968). These stated that the elemental properties of minerals were stable and unaffected by the outside environment. According to research by Bouzari *et al*., (2015) and other authors, the thermal treatments used in traditional food processing had no effect on minerals. According to Dresow *et al*., (2013), the genotype of the plant, weather, crop management practices, and soil characteristics all influence the amount of mineral components, including potassium, phosphorus, and magnesium in tuber crops. Throughout the storage period, the minerals showed a mild change that was not significant; comparable findings have been reported (Jood *et al*., 1992). Mineral losses were minimal both during storage before consumption and after the veggies were harvested, according to Zhang *et al*., (2017). Carrot cultivation using zinc and boron does not prevent the loss of microelement concentrations in the roots during storage, as evidenced by the lack of substantial interaction between the analyzed components (Zn and B applications).

Table 4.3.14: Effect of treatments and packaging materials on manganese (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Manganese									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	1.88 ± 0.3^{a}	1.95 ± 0.2^{a}	1.64 ± 0.1^{a}	1.84 ± 0.2^{a}	1.64 ± 0.1^{a}	1.97 ± 0.2^{a}	1.45 ± 0.1^{a}	1.80 ± 0.3^{a}	1.74 ± 0.1^{a}	1.77±0.2
	CB	1.51 ± 0.0^{ab}	1.42 ± 0.1^{a}	1.73 ± 0.1^{d}	1.73 ± 0.1^{bc}	1.52 ± 0.1^{abc}	1.65 ± 0.1^{bcd}	1.71 ± 0.1^{bcd}	1.71 ± 0.0^{bcd}	1.58 ± 0.1^{abcd}	1.62±0.1
	PPEB	1.48 ± 0.0^{a}	1.47 ± 0.1^{a}	1.55 ± 0.0^{a}	1.56 ± 0.1^{a}	1.51 ± 0.1^{a}	1.62 ± 0.0^{a}	1.58 ± 0.0^{a}	1.51 ± 0.1^{a}	1.53 ± 0.1^{a}	1.53±0.1
	PC	1.83 ± 0.1^{bc}	1.75 ± 0.0^{bc}	1.60 ± 0.1^{ab}	1.98 ± 0.0^{c}	1.76 ± 0.0^{bc}	1.91 ± 0.1^{c}	1.49 ± 0.1^{a}	1.85 ± 0.1^{bc}	1.61 ± 0.1^{ab}	1.75±0.2
	WC	1.42 ± 0.1^{a}	1.52 ± 0.1^{a}	1.46 ± 0.0^{a}	1.49 ± 0.1^{a}	1.48 ± 0.1^{a}	1.46 ± 0.0^{a}	1.39 ± 0.1^{a}	1.40 ± 0.1^{a}	1.52 ± 0.0^{a}	1.46±0.2
60 Days	**LB**	2.10 ± 0.3^{a}	1.84 ± 0.5^{a}	1.52 ± 0.4^{a}	1.94 ± 0.3^{a}	2.05 ± 0.3^{a}	1.99 ± 0.3^{a}	1.38 ± 0.5^{a}	1.68 ± 0.5^{a}	1.71 ± 0.4^{a}	1.80±0.4
	CB	1.64 ± 0.1^{bc}	1.44 ± 0.1^{a}	1.75 ± 0.0^{c}	1.52 ± 0.0^{ab}	1.60 ± 0.1^{abc}	1.76 ± 0.1^{c}	1.71 ± 0.0^{c}	1.59 ± 0.1^{abc}	1.70 ± 0.1^{c}	1.63±0.1
	PPEB	1.51 ± 0.1^{a}	1.43 ± 0.0^{a}	1.50 ± 0.1^{a}	1.43 ± 0.1^{a}	1.48 ± 0.1^{a}	1.58 ± 0.1^{a}	1.56 ± 0.1^{a}	1.43 ± 0.0^{a}	1.52 ± 0.1^{a}	1.49±0.1
	PC	1.73 ± 0.1^{d}	1.65 ± 0.0^{cd}	1.46 ± 0.1^{ab}	1.47 ± 0.0^{ab}	1.46 ± 0.0^{ab}	1.60 ± 0.1^{bcd}	1.43 ± 0.1^{a}	1.35 ± 0.0^{a}	1.50 ± 0.1^{abc}	1.52±0.1
	WC	1.34 ± 0.0^{a}	1.38 ± 0.1^{a}	1.31 ± 0.1^{a}	1.37 ± 0.1^{a}	1.36 ± 0.1^{a}	1.38 ± 0.0^{a}	1.37 ± 0.1^{a}	1.33 ± 0.0^{a}	1.39 ± 0.0^{a}	1.36±0.1
90 Days	**LB**	1.74 ± 0.3^{bc}	1.86 ± 0.0^{c}	1.34 ± 0.0^{a}	1.48 ± 0.0^{ab}	1.49 ± 0.0^{ab}	1.64 ± 0.1^{abc}	1.39 ± 0.1^{a}	1.32 ± 0.1^{a}	1.63 ± 0.0^{abc}	1.54±0.2
	CB	1.54 ± 0.1^{a}	1.61 ± 0.1^{a}	1.67 ± 0.1^{a}	1.52 ± 0.2^{a}	1.54 ± 0.1^{a}	1.74 ± 0.1^{a}	1.59 ± 0.2^{a}	1.59 ± 0.1^{a}	1.66 ± 0.1^{a}	1.61±0.1
	PPEB	1.49 ± 0.1^{a}	1.47 ± 0.1^{a}	1.58 ± 0.1^{a}	1.49 ± 0.1^{a}	1.46 ± 0.1^{a}	1.60 ± 0.1^{a}	1.52 ± 0.1^{a}	1.54 ± 0.1^{a}	1.58 ± 0.1^{a}	1.53±0.1
	PC	1.74 ± 0.3^{a}	1.68 ± 0.0^{a}	$1.44\pm0.^{0a}$	1.50 ± 0.1^{a}	1.47 ± 0.1^{a}	1.62 ± 0.2^{a}	1.42 ± 0.1^{a}	1.57 ± 0.0^{a}	1.52 ± 0.1^{a}	1.55±0.1
	WC	1.24 ± 0.1^{a}	1.20 ± 0.0^{a}	1.18 ± 0.1^{a}	1.28 ± 0.1^{a}	1.24 ± 0.1^{a}	1.24 ± 0.0^{a}	1.27 ± 0.0^{a}	1.19 ± 0.1^{a}	1.34 ± 0.0^{a}	1.24±0.1
120 Days	**LB**	1.49 ± 0.3^{ab}	1.72 ± 0.1^{b}	1.29 ± 0.1^{a}	1.30 ± 0.1^{a}	1.37 ± 0.0^{ab}	1.49 ± 0.1^{ab}	1.35 ± 0.1^{ab}	1.28 ± 0.2^{a}	1.51 ± 0.1^{ab}	1.42±0.2
	CB	1.46 ± 0.0^{a}	1.48 ± 0.2^{a}	1.47 ± 0.1^{a}	1.39 ± 0.1^{a}	1.40 ± 0.0^{a}	1.49 ± 0.1^{a}	1.57 ± 0.1^{a}	1.45 ± 0.1^{a}	1.47 ± 0.0^{a}	1.46±0.1
	PPEB	1.39 ± 0.0^{a}	1.34 ± 0.1^{a}	1.35 ± 0.1^{a}	1.38 ± 0.1^{a}	1.36 ± 0.0^{a}	1.36 ± 0.0^{a}	1.47 ± 0.0^{a}	1.41 ± 0.1^{a}	1.40 ± 0.0^{a}	1.39±0.1
	PC	1.22 ± 0.1^{a}	1.40 ± 0.0^{ab}	1.24 ± 0.0^{ab}	1.31 ± 0.0^{ab}	1.28 ± 0.0^{ab}	1.41 ± 0.1^{b}	1.30 ± 0.1^{ab}	1.29 ± 0.0^{ab}	1.36 ± 0.1^{ab}	1.31±0.1
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	1.26 ± 0.1^{a}	1.77 ± 0.4^{a}	1.27 ± 0.1^{a}	1.33 ± 0.3^{a}	1.16 ± 0.1^{a}	1.44 ± 0.1^{a}	1.32 ± 0.5^{a}	1.06 ± 0.2^{a}	1.41 ± 0.2^{a}	1.34±0.3
	CB	1.14 ± 0.1^{a}	1.47 ± 0.4^{a}	1.25 ± 0.1^{a}	1.38 ± 0.1^{a}	1.28 ± 0.0^{a}	1.36 ± 0.3^{a}	1.28 ± 0.1^{a}	1.14 ± 0.3^{a}	1.54 ± 0.2^{a}	1.32±0.2
	PPEB	1.27 ± 0.1^{a}	1.28 ± 0.1^{a}	1.30 ± 0.1^{a}	1.31 ± 0.0^{a}	1.29 ± 0.0^{a}	1.29 ± 0.0^{a}	1.33 ± 0.0^{a}	1.24 ± 0.0^{a}	1.30 ± 0.0^{a}	1.29±0.1
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Table 4.3.15: Effect of treatments and packaging materials on sodium (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Sodium									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	349.79±15.7^{ab}	380.03±4.7^{b}	337.61±9.9^{a}	361.24±9.7^{ab}	352.40±7.1^{ab}	379.73±16.3^{b}	359.24±7.2^{ab}	343.88±18.1^{a}	350.67±10.3^{ab}	357.2±17.2
	CB	296.65±13.9^{a}	310.07±9.7^{ab}	309.13±14.9^{ab}	336.93±10.0^{ab}	346.45±16.5^{b}	342.41±14.^{8b}	329.99±8.3^{ab}	316.61±19.8^{ab}	333.89±20.5^{ab}	324.7±20.6
	PPEB	301.80±4.7^{a}	321.72±4.3^{abc}	317.98±7.2^{ab}	329.03±11.5^{bc}	344.15±9.9^{c}	344.54±8.8^{c}	320.48±9.0^{ab}	330.05±8.3^{bc}	336.96±7.2bc	327.4±14.8
	PC	304.50±3.5^{bc}	322.81±1.1^{cd}	281.62±9.8^{a}	326.62±6.9^{d}	296.55±5.0^{ab}	327.69±4.4^{d}	324.12±13.0^{cd}	301.03±4.4^{ab}	308.33±7.7^{bcd}	310.4±16.5
	WC	307.05±12.7a^{bc}	296.32±4.6^{ab}	272.65±20.5^{a}	301.72±15.6^{abc}	299.31±6.2^{abc}	309.53±15.3^{ab} c	334.40±7.^{1c}	296.29±12.8^{ab}	317.30±16.0^{bc}	303.8±19.6
60 Days	**LB**	306.27±16.1^{abc}	346.17±4.7^{c}	294.12±17.1^{a}	322.07±15.6^{abc}	313.35±1.3^{abc}	340.79±25.7^{bc}	319.54±9.7^{abc}	302.46±11.3^{ab}	311.97±19.4^{abc}	317.4±20.7
	CB	294.91±9.1^{a}	298.46±27.6^{a}	293.52±24.0^{a}	310.52±5.2^{a}	305.30±9.5^{aa}	303.56±10.4^{a}	296.92±18.8^{a}	305.27±12.1^{a}	296.29±23.5^{a}	300.5±15.5
	PPEB	298.65±11.5^{a}	284.37±67.8^{a}	308.65±19.7^{a}	318.88±6.5^{a}	316.86±6.6^{a}	320.28±23.5^{a}	305.31±7.6^{a}	321.39±5.0^{a}	300.61±13.1^{a}	308.3±24.6
	PC	284.63±2.9^{a}	320.29±10.4^{a}	288.98±18.0^{a}	294.26±25.6^{a}	294.31±12.1^{a}	305.63±7.3^{a}	307.31±14.2^{a}	286.31±9.5^{a}	307.86±12.4^{a}	298.8±16.4
	WC	273.26±16.8^{a}	295.87±18.9^{a}	269.41±21.5^{a}	287.49±0.5^{a}	296.86±16.1^{a}	300.51±34.5^{a}	292.58±5.5^{a}	276.27±4.8^{a}	284.82±11.6^{a}	286.3±18.1
90 Days	**LB**	301.71±4.6^{bcd}	341.69±3.8^{f}	284.27±4.2^{a}	311.51±2.3^{cde}	304.98±7.7^{bcd}	324.99±7.2^{e}	312.96±3.6^{de}	289.96±7.6^{ab}	296.76±5.5^{abc}	307.6±17.7
	CB	285.53±8.9^{a}	294.31±15.3^{a}	293.39±12.5^{a}	303.62±4.7^{a}	301.44±10.9^{a}	306.73±12.5^{a}	298.40±9.8^{a}	305.65±15.1^{a}	287.98±12.4^{a}	297.5±12.2
	PPEB	286.62±8.8^{a}	297.58±20.2^{a}	301.87±10.2^{a}	305.06±9.6^{a}	307.08±8.2^{a}	309.90±8.0^{a}	308.39±9.6^{a}	313.34±12.1^{a}	298.15±6.1^{a}	303.1±12.1
	PC	287.32±8.7^{bc}	300.35±3.7^{cd}	279.94±4.0^{ab}	295.20±5.1^{bcd}	292.18±7.9^{bcd}	304.53±2.4^{d}	294.12±2.8^{bcd}	268.28±7.8^{a}	286.78±5.1^{bc}	289.9±11.5
	WC	267.32±7.0^{ab}	282.97±5.8^{ab}	264.60±3.7^{ab}	280.87±5.5^{ab}	272.86±22.6^{ab}	289.71±3.9^{b}	261.47±12.9^{ab}	262.31±9.9a^{b}	254.89±12.5^{a}	270.8±14.4
120 Days	**LB**	290.99±6.7^{abc}	326.58±15.3^{c}	274.20±3.4^{a}	296.29±18.4^{abc}	283.50±16.6^{ab}	319.83±6.1^{bc}	303.02±8.7^{abc}	279.23±10.7^{a}	280.26±18.8^{a}	294.9±20.7
	CB	290.79±21.8^{a}	305.13±12.8^{a}	285.27±11.5^{a}	296.13±4.3^{a}	296.01±9.4^{a}	295.37±11.7^{a}	298.76±12.9^{a}	295.08±12.2^{a}	281.68±21.8^{a}	293.8±13.6
	PPEB	288.98±4.5^{a}	303.42±13.4a	290.37±4.5^{a}	297.91±4.5^{a}	286.89±9.8^{a}	300.55±7.1^{a}	304.27±9.6^{a}	303.37±14.6^{a}	289.40±7.7^{a}	296.1±10.25
	PC	270.05±10.3^{bcde}	267.53±14.4^{abcde}	255.59±11.1^{ab}	282.21±7.8^{cde}	264.44±4.7^{abcd}	292.33±8.4^{e}	288.77±9.3^{de}	241.38±6.7^{a}	260.44±6.1^{abc}	269.2±17.5
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	264.37±17.9^{a}	319.30±14.4^{b}	262.23±13.0^{a}	287.47±18.7^{ab}	265.45±5.7^{a}	290.24±32.7^{ab}	292.57±17.6^{ab}	255.44±16.0^{a}	271.39±12.3^{ab}	278.7±24.5
	CB	277.41±23.1^{a}	293.13±2.4^{a}	268.83±17.8^{a}	283.65±10.3^{a}	277.32±11.2^{a}	289.06±4.8^{a}	288.36±12.9^{a}	289.71±4.5^{a}	284.90±21.4^{a}	283.6±13.8
	PPEB	267.27±12.1^{a}	292.85±7.7^{a}	277.92±23.7^{a}	294.00±2.9^{a}	282.63±6.0^{a}	294.74±11.0^{a}	288.54±20.9^{a}	295.85±11.6^{a}	288.06±13.8^{a}	286.9±14.6
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Table 4.3.16: Effect of treatments and packaging materials on zinc (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Zinc									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	5.80±0.2^{a}	6.83±0.4^{abc}	5.58±1.0^{a}	7.82±0.3^{bc}	9.86±0.7^{d}	8.66±1.0^{cd}	6.01±0.5^{ab}	7.22±0.7^{abc}	8.36±0.6^{cd}	7.35±1.5
	CB	5.55±0.3^{a}	5.89±0.3^{ab}	5.63±0.7^{ab}	8.16±0.6^{cd}	7.05±0.5^{bc}	9.01±0.4^{d}	6.53±0.4^{ab}	6.65±0.2^{ab}	8.31±0.7^{cd}	6.97±1.3
	PPEB	5.42±0.3^{a}	5.99±0.7^{abc}	5.73±0.6^{ab}	8.27±0.5^{def}	7.35±0.5^{cde}	8.77±0.6^{ef}	6.66±0.3^{abc}	7.08±0.6^{bcd}	8.94±0.2^{f}	7.13±1.3
	PC	5.04±0.5^{a}	7.38±1.0^{ab}	7.67±1.1^{b}	8.24±0.5^{b}	8.82±0.7^{b}	10.71±1.2^{c}	7.42±0.7^{ab}	7.81±0.9^{b}	9.60±0.7^{bc}	8.08±1.7
	WC	5.80±0.2^{a}	6.49±0.5^{abc}	5.76±0.2^{a}	6.74±0.7^{abc}	8.01±0.5^{c}	8.11±0.6^{c}	6.20±0.9^{ab}	7.63±0.7^{bc}	7.78±0.5^{bc}	6.95±1.0
60 Days	**LB**	5.60±0.6^{a}	7.36±1.6^{ab}	6.50±1.4^{ab}	8.61±1.2^{ab}	9.55±0.2^{b}	8.24±1.5^{ab}	6.59±1.5^{ab}	7.80±0.7^{ab}	8.84±0.6^{ab}	7.68±1.5
	CB	5.33±0.5^{a}	5.99±0.6^{ab}	5.77±0.4^{ab}	8.07±0.1^{c}	7.41±0.3^{c}	7.73±0.2^{c}	6.72±0.3^{abc}	6.80±0.6^{bc}	8.01±0.9^{c}	6.87±1.0
	PPEB	5.36±0.1^{a}	6.06±0.2^{a}	6.14±0.2^{ab}	8.08±0.4^{de}	7.41±0.4^{cd}	7.96±0.3^{d}	6.91±0.3^{bc}	6.98±0.3^{c}	8.86±0.1^{e}	7.08±1.1
	PC	6.01±0.3^{a}	7.61±0.6^{ab}	7.13±0.8^{ab}	7.32±0.5^{ab}	6.94±0.7^{ab}	8.92±0.5^{b}	6.63±0.9^{a}	7.25±1.1^{ab}	7.08±0.6^{ab}	7.29±1.0
	WC	5.90±0.3^{a}	6.74±0.6^{ab}	5.96±0.4^{a}	7.25±0.2^{ab}	7.63±0.5^{ab}	7.87±0.7^{b}	6.34±0.6^{ab}	7.60±0.5^{ab}	7.38±1.3^{ab}	6.96±0.9
90 Days	**LB**	4.86±1.3^{a}	6.86±0.9^{ab}	6.76±1.4^{ab}	7.28±0.7^{ab}	7.61±1.2^{ab}	9.49±1.0^{b}	6.82±1.1^{ab}	7.90±0.7^{ab}	8.26±1.4^{b}	7.32±1.5
	CB	5.34±0.4^{a}	6.25±0.3^{ab}	6.08±0.4^{ab}	7.78±0.3^{de}	7.53±0.2^{cde}	7.96±0.4^{e}	6.60±0.2^{bc}	6.78±0.4^{bcd}	8.27±0.5^{e}	6.96±1.0
	PPEB	4.96±0.4^{a}	6.33±0.5^{bc}	6.12±0.4^{b}	7.51±0.3^{de}	7.36±0.5^{de}	8.28±0.3^{fe}	7.00±0.1^{bcd}	7.13±0.3^{cd}	8.61±0.1^{f}	7.03±1.1
	PC	6.15±0.4^{a}	7.45±0.6^{b}	6.93±0.5^{ab}	7.15±0.1^{ab}	7.59±0.3^{b}	8.64±0.3^{c}	6.24±0.3^{a}	7.14±0.2^{ab}	7.60±0.2^{bc}	7.21±0.8
	WC	5.63±0.6^{a}	7.08±1.6^{a}	6.46±0.8^{a}	6.87±1.9^{a}	6.90±1.0^{a}	8.53±1.2^{a}	6.92±1.2^{a}	7.60±0.7^{a}	7.15±0.8^{a}	7.01±1.2
120 Days	**LB**	4.94±0.4^{a}	6.54±0.6^{abc}	5.85±0.1^{a}	6.52±0.6^{abc}	7.51±0.6^{bcd}	8.53±0.8^{d}	6.01±0.8^{ab}	7.77±0.1^{cd}	7.83±0.7^{cd}	6.83±1.2
	CB	5.24±0.2^{a}	6.27±0.3^{abc}	5.64±0.3^{ab}	7.30±0.2^{cde}	6.78±0.5^{cde}	7.56±0.5^{de}	6.51±0.7^{bcd}	6.48±0.3^{bcd}	7.91±0.3^{e}	6.63±0.9
	PPEB	4.97±0.4^{a}	6.53±0.2^{bc}	6.12±0.3^{b}	7.33±0.4^{cd}	7.47±0.4^{d}	8.35±0.2^{e}	7.06±0.3^{cd}	6.84±0.1^{bcd}	8.56±0.1^{e}	7.03±1.1
	PC	5.56±0.7^{a}	6.37±0.3^{ab}	6.04±0.2^{ab}	7.33±0.9^{bc}	6.60±0.2^{abc}	8.24±0.2^{c}	5.89±0.9^{ab}	7.11±0.3^{abc}	6.26±0.9^{ab}	6.60±0.9
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	4.39±0.0^{a}	5.99±0. 1^{b}	5.71±0.8^{ab}	6.35±0.3^{b}	7.02±0.1^{b}	7.89±0.9^{c}	5.67±0.1^{ab}	7.09±0.2^{bc}	7.16±0.9^{bc}	6.36±1.1
	CB	5.42±0.7^{a}	6.26±0.6^{ab}	5.47±0.4^{a}	6.97±0.3^{b}	6.56±0.4^{ab}	6.97±0.4^{a}	6.28±0.3^{ab}	6.49±0.4^{ab}	7.32±0.3^{b}	6.42±0.7
	PPEB	4.52±0.1^{a}	5.74±0.5^{bc}	5.12±0.1^{ab}	6.80±0.2^{de}	7.22±0.3^{e}	7.10±0.3^{de}	6.24±0.3^{cd}	6.70±0.4^{cde}	7.38±0.5^{e}	6.31±1.0
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

4.3.11 Macronutrients (K & Mg) content (mg/100g):

The potassium content in treated carrots gradually declined as the storage duration increased (Table 4.3.17). It was noticed that leno bag-packed treated roots showed maximum average potassium over other packaging materials throughout the storage period and recorded average potassium 3042.8 mg/100g followed by perforated polyethylene bag roots (2988.1 mg/100g). The potassium content in leno bag packed roots, ranged was observed among the treatments 2772.6–3305.3 mg/100g, after 150 days of storage as compared to cotton bag where average potassium 2926.0 mg/100g was found to be the minimum and range among the treatments was 2757.9 to 3240.1 mg/100g.

Magnesium of the treated carrots experienced a linear decline as the storage period advanced (Table 4.3.18). It was noticed that leno bag-packed treated carrot root showed higher average Mg content than other packaging materials throughout the storage period and recorded average magnesium 288.3 mg/100g, followed by perforated polyethylene bag (266.1 mg/100g) and cotton bag root (262.1) mg/100g. The magnesium content in leno bag packed roots, range was observed among the treatments 250.47–339.55 mg/100g, after 150 days of storage as compared to cotton bag where magnesium was found to be the lowest and the range among the treatments was 244.39 and 278.33 mg/100g. Each variation of the Zn and B application showed comparable changes in the macro element concentrations in the carrot storage roots following storage compared with the levels discovered following harvesting. According to Szczepanek *et al*., (2015), following storage, the concentrations of P, Ca, and N remained constant, whereas those of Mg, Na, and K declined. Nicolle *et al*., (2004), potassium is the most significant mineral in carrots. When properly fertilized, this element improves root quality and increases postharvest storability (Negrea *et al*., 2012). Upon storing the carrot roots, a marginally significant drop in the amounts of Mg, and K was observed in comparison with their post-harvest content.

Table 4.3.17: Effect of treatments and packaging materials on potassium (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Potassium									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	3193.0±47.1^{a}	3642.7±100.6^{c}	3442.4±41.0^{bc}	3612.7±78.3^{c}	3490.3±103.6^{bc}	3996.3±26.3^{d}	3304.7±41.0^{ab}	3344.1±103.4^{ab}	3457.1±82.7^{bc}	3498.1±234.2
	CB	3070.2±13.7^{a}	3561.7±95.7^{bc}	3332.0±322.3^{abc}	3679.2±141.4^{bc}	3384.5±93.4^{abc}	3720.3±177.5^{c}	3273.1±44.4^{ab}	3120.1±60.9^{a}	3384.0±101.4^{abc}	3391.6±249.7
	PPEB	3167.7±64.1^{a}	3606.4±83.6^{ef}	3427.4±81.5^{cde}	3589.9±37.7^{de}	3441.7±24.3^{cde}	3787.1±27.6^{f}	3367.6±56.1^{cd}	3214.9±101.8^{ab}	3414.3±52.3^{cd}	3446.4±193.8
	PC	3087.1±20.8^{a}	3408.0±38.8^{c}	3412.4±102.8^{c}	3242.7±26.5^{abc}	3094.8±34.1^{a}	3359.1±67.0^{bc}	3175.7±31.5^{ab}	3184.1±58.8^{ab}	3136.8±119.2^{a}	3233.4±135.5
	WC	3058.5±160.1^{a}	3361.7±56.3^{a}	3348.5±258.4^{a}	3053.9±110.2^{a}	3208.7±454.4^{a}	3437.7±321.6^{a}	3335.8±295.0^{a}	3070.5±245.7^{a}	3374.4±264.2^{a}	3250.0±265.8
60 Days	**LB**	2906.1±103.6^{a}	3400.0±146.4^{c}	3404.3±111.6^{c}	3052.2±57.6^{ab}	3129.7±55.1^{abc}	3221.0±100.7^{bc}	2989.6±106.8^{ab}	3212.0±102.8^{bc}	3176.8±108.7^{abc}	3165.7±183.8
	CB	2964.8±100.2^{a}	3272.8±141.9^{a}	3302.1±213.7^{a}	3090.7±64.8^{a}	3013.1±146.1^{a}	3214.3±128.5^{a}	3093.3±26.0^{a}	2966.5±170.8^{a}	3182.4±35.8^{a}	3122.2±162.6
	PPEB	3043.8±31.3^{ab}	3423.8±34.2^{e}	3421.6±68.5^{e}	3196.9±42.6^{cd}	3023.3±50.3^{a}	3321.2±23.8^{de}	3149.1±14.9^{abc}	3192.0±90.1^{de}	3169.6±58.3^{bc}	3215.7±146.7
	PC	2977.3±36.8^{ab}	3251.3±53.5^{de}	3316.3±53.5^{e}	3136.5±35.2c^{d}	2966.3±48.2^{a}	3213.9±95.5^{de}	3110.6±27.3^{bcd}	3044.6±29.8^{abc}	2981.1±30.9^{ab}	3110.9±130.7
	WC	2881.2±146.0^{a}	3348.7±126.6^{bc}	3440.5±89.4^{c}	3018.6±138.9^{ab}	3205.7±190.4^{abc}	3244.8±50.3^{abc}	3008.8±209.5^{ab}	3185.0±84.0^{abc}	3168.7±165.1^{abc}	3166.9±205.4
90 Days	**LB**	2908.4±72.6^{a}	3415.8±176.2^{c}	3361.6±132.2^{bc}	3093.6±151.8^{abc}	3050.0±98.5a^{b}	3317.0±77.1^{bc}	3020.2±147.2^{ab}	3199.2±87.9^{abc}	3099.3±112.7^{abc}	3162.8±193.6
	CB	2954.5±130.3^{a}	3218.7±196.6a^{b}	3187.1±190.3^{ab}	3099.7±31.3^{ab}	2917.7±189.0^{a}	3370.3±81.2^{b}	3006.3±107.1^{ab}	3101.3±85.0^{ab}	3072.8±152.5^{ab}	3103.2±178.6
	PPEB	3023.4±50.4^{a}	3280.0±58.8^{bc}	3354.9±147.8^{c}	3133.1±120.7^{abc}	3050.3±89.7^{abc}	3370.94110.1^{c}	3124.1±32.3^{abc}	3128.1±27.4^{abc}	3199.0±71.9^{abc}	3184.9±141.2
	PC	2884.0±71.4^{a}	3231.4±88.3d^{e}	3327.9±58.4^{e}	3091.3±56.3^{bcd}	3070.0±41.1^{bcd}	3193.3±72.2^{de}	2956.6±9.^{8ab}	3131.6±51.5c^{d}	2999.5±18.0^{abc}	3098.4±198.3
	WC	2769.5±126.4^{a}	3265.6±134.8^{c}	3262.2±69.0^{c}	2969.0±100.1^{abc}	2916.1±78.0^{ab}	3043.5±120.8^{abc}	2815.7±75.5^{a}	3154.3±173.7^{bc}	2956.9±129.1^{abc}	3017.0±215.8
120 Days	**LB**	2833.4±267.4^{a}	3297.6±132.8^{ab}	3407.8±29.5^{b}	3205.7±106.5^{ab}	3124.6±137.1^{ab}	3171.7±248.4^{ab}	2973.6±164.5^{ab}	3029.1±206.9^{ab}	3118.6±17.7^{ab}	3129.1±215.8
	CB	2820.61±91.8^{a}	3131.0±86.1^{ab}	3373.1±124.8^{b}	3125.9±25.8^{ab}	2960.2±209.0^{a}	3142.4±97.4^{ab}	2976.0±117.2^{a}	3066.6±184.3^{ab}	2967.7±26.8^{a}	3062.6±181.7
	PPEB	2938.25±78.2^{ab}	3109.1±84.3^{abc}	3507.6±126.5d	3130.5±101.2^{abc}	3104.2±98.1^{abc}	3173.6±63.5^{bc}	3057.8±62.9^{abc}	3223.4±103.8^{c}	2886.3±85.5^{a}	3125.7±187.8
	PC	2856.77±139.8^{ab}	3146.5±153.2^{bc}	3206.9±133.9^{c}	2952.7±41.1^{abc}	2893.8±53.2^{abc}	3048.6±120.6^{abc}	2766.0±160.1^{a}	3091.7±71.7^{bc}	2983.1±54.1a^{bc}	2994.0±166.3
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	2722.6±73.3^{a}	3305.5±111.7^{c}	3254.0±107.3^{c}	2999.8±114.7^{abc}	2991.2±169.3^{abc}	3188.5±95.2^{bc}	2838.4±105.2^{ab}	3030.1±203.2^{abc}	3055.2±71.7^{abc}	3042.8±208.2
	CB	2757.9±165.4^{a}	2757.8±120.8^{a}	3240.1±254.7^{b}	2954.3±135.8^{ab}	2904.9±23.2^{ab}	2956.3±168.1^{ab}	2794.4±74.0^{a}	3027.0±67.9^{ab}	2940.6±82.8^{ab}	2926.0±185.8
	PPEB	2863.7±79.2^{a}	2848.8±181.6^{a}	3352.8±81.0^{b}	2941.8±164.8^{a}	2933.4±117.9^{a}	2951.4±87.5^{a}	2884.8±48.5^{a}	3092.3±156.4^{ab}	3023.5±110.1^{ab}	2988.1±181.7
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, $n = 3$. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Table 4.3.18: Effect of treatments and packaging materials on magnesium (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Magnesium									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	**LB**	326.91±35.0^{a}	420.63±8.5^{b}	379.23±7.0^{ab}	412.27±16.9^{b}	386.65±35.9^{ab}	406.11±25.7^{b}	360.20±28.7^{ab}	375.98±31.5^{ab}	323.14±9.8^{a}	376.8±39.38
	CB	275.03±31.6^{a}	343.60±31.2^{ab}	307.48±15.2^{ab}	370.46±42.2^{b}	364.47±21.2^{b}	350.58±0.7^{ab}	330.37±18.5^{ab}	363.69±35.8^{b}	329.75±35.0^{ab}	337.3±37.93
	PPEB	273.48±58.7^{a}	294.17±3.2^{a}	312.16±46.7^{a}	307.72±61.5^{a}	298.11±43.9^{a}	313.22±57.4^{a}	341.15±14.9^{a}	324.94±27.1^{a}	351.05±36.9^{a}	312.9±42.76
	PC	299.03±6.8^{a}	397.36±19.9^{bc}	341.83±29.3^{ab}	415.25±16.1^{b}	414.10±30.2^{b}	378.06±16.2^{bc}	393.90±20.1^{bc}	369.66±21.3^{bc}	380.52±19.1^{bc}	376.6±39.55
	WC	301.14±29.7^{a}	354.89±27.3^{a}	346.19±17.3^{abc}	344.05±31.3^{a}	326.03±46.2^{a}	323.73±30.7^{a}	328.14±41.6^{a}	307.70±43.2^{a}	306.99±21.2^{a}	326.5±33.24
60 Days	**LB**	286.76±31.7^{a}	331.35±12.9^{abc}	342.88±34.6^{abc}	398.09±4.0^{c}	400.00±20.9^{abc}	366.70±47.5^{ab}	318.14±35.8^{abc}	336.22±24.6^{abc}	328.84±19.8^{abc}	345.4±42.8
	CB	276.51±27.3^{a}	310.38±36.8^{a}	324.72±27.7^{a}	357.17±26.2^{a}	361.55±31.1^{a}	351.78±32.6^{a}	303.05±31.3^{a}	331.77±36.8^{a}	307.02±29.5^{a}	324.9±37.8
	PPEB	297.67±33.1^{a}	295.69±31.8^{a}	309.10±32.4^{a}	310.72±8.7^{a}	309.99±6.0^{a}	309.20±21.0^{a}	326.09±12.7^{a}	301.38±10.1^{a}	303.12±15.3^{a}	307.0±20.0
	PC	282.68±5.9^{a}	293.86±41.9^{a}	312.73±30.6^{a}	348.01±12.4^{a}	348.61±16.5^{a}	313.01±19.9^{a}	313.96±9.6^{a}	313.97±33.8^{a}	318.45±20.8^{a}	316.1±28.8
	WC	264.58±31.5^{a}	291.38±41.0^{a}	316.83±43.6^{a}	320.57±31.2^{a}	338.27±23.3^{a}	276.28±30.2^{a}	279.29±29.6^{a}	291.25±17.4^{a}	309.76±19.8^{a}	298.7±34.6
90 Days	**LB**	252.12±8.3^{a}	270.87±7.7^{ab}	291.25±29.6^{abc}	325.37±29.5^{bc}	347.16±21.7^{c}	278.15±27.5^{ab}	271.74±9.4^{ab}	283.56±23.3^{ab}	323.05±20.1^{bc}	293.7±34.9
	CB	279.48±24.6^{a}	327.45±16.7^{a}	307.75±37.9^{a}	342.11±20.4^{a}	341.30±36.0^{a}	340.91±34.6^{a}	300.99±39.5^{a}	318.53±26.6^{a}	318.33±21.1^{a}	319.6±32.0
	PPEB	252.51±5.1^{a}	269.19±18.5^{ab}	288.23±24.5^{ab}	289.78±17.9^{ab}	301.31±20.9^{ab}	291.87±22.6^{ab}	307.59±17.7^{b}	286.41±14.2^{ab}	295.13±16.7^{ab}	286.9±22.2
	PC	252.49±13.3^{a}	282.73±19.3^{ab}	302.30±35.0^{ab}	317.00±24.2^{b}	339.23±23.5^{b}	286.76±20.4a^{b}	286.67±6.2^{ab}	288.43±18.2^{ab}	320.86±7.8^{b}	297.4±29.9
	WC	230.95±26.2^{a}	278.90±26.9^{ab}	300.55±24.5^{ab}	296.73±18.1^{ab}	307.84±26.9^{b}	273.70±24.6^{ab}	286.79±22.5^{ab}	293.93±20.2^{ab}	276.46±30.5^{ab}	282.9±29.9
120 Days	**LB**	255.79±16.7^{a}	270.10±15.3^{a}	318.78±43.9^{abc}	345.84±9.6^{bc}	368.40±8.2^{c}	293.34±33.8^{ab}	282.05±21.2^{ab}	283.76±29.9^{ab}	314.79±25.5^{abc}	303.7±41.0
	CB	260.17±30.0^{a}	318.32±45.0^{a}	297.04±15.1^{a}	297.14±19.9^{a}	292.19±16.8^{a}	277.79±25.4^{a}	267.99±34.1^{a}	298.02±22.5^{a}	291.74±19.3^{a}	288.9±28.1
	PPEB	253.33±9.2^{a}	269.83±41.2^{a}	279.83±16.6^{a}	285.26±33.5^{a}	297.70±28.6^{a}	274.02±28.5^{a}	303.37±29.3^{a}	301.17±22.7^{a}	289.24±25.1^{a}	283.7±27.8
	PC	245.92±32.5^{a}	276.42±31.1^{ab}	311.67±20.1^{abc}	353.33±16.5^{c}	330.34±25.9^{bc}	284.47±18.3^{abc}	299.03±28.6^{abc}	283.24±29.3^{abc}	278.26±21.4^{ab}	295.9±37.4
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	**LB**	250.47±7.6^{a}	269.47±21.9^{ab}	284.08±10.4^{abc}	339.55±8.4^{c}	322.32±28.4^{bc}	297.23±35.5^{abc}	278.09±23.6^{abc}	264.35±22.2^{bc}	289.42±22.9^{abc}	288.3±32.7
	CB	244.39±17.4^{a}	271.86±28.1^{a}	263.38±23.2^{a}	258.79±28.2^{a}	252.08±7.1^{a}	256.59±22.6^{a}	275.11±24.8^{a}	258.08±20.4^{a}	278.33±18.1^{a}	262.1±21.2
	PPEB	236.22±25.3^{a}	277.75±22.8^{a}	269.33±4.3^{a}	266.11±31.2^{a}	253.15±8.9^{a}	268.41±26.9^{a}	276.59±22.4^{a}	260.71±16.2^{a}	286.51±29.2^{a}	266.123.6
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

4.3.12 Anion (nitrate, phosphate, sulfate) content (mg/100g):

A gradual decline in nitrate content was noticed in leno bag-packed roots compared with perforated polyethylene bags, where the decline was sharp under the same storage (Table 4.3.19). It was noticed that perforated polyethylene bag packed treated roots showed higher nitrate over the other packaging materials throughout the storage period and recorded average nitrate content 270.21 mg/100g and the range was observed the treatments 227.18–308.23 mg/100g after 150 days of storage. In the leno bag, the roots experienced a faster loss of nitrate during storage, and the range among the treatments was 186.91 to 234.34 mg/100g, with an average root nitrate of 213.13 mg/100g. The phosphate content was noticed in different packaging bags packed with treated carrots and is presented in Table 4.3.20. It was noticed that perforated polyethylene bag packed treated roots showed higher phosphate than other packaging materials throughout the storage period and recorded average phosphate content 707.2 mg/100g, and the range between treatments was 648.16 –759.63 mg/100g after 150 days of storage. In cotton bags, the roots experienced the lowest phosphate content during storage, and the range among the treatments was 580.43 to 698.17 mg/100g with an average root phosphate of 629.6 mg/100g. The sulfate content of the treated carrot roots decreased linearly as the storage period advanced (Table 4.3.21). It was noticed that perforated polyethylene packed treated roots showed maximum sulfate than other packaging materials throughout the storage period and recorded average sulfate content 465.47 mg/100g followed by leno bag roots (427.54 mg/100g). The sulfate content in perforated polyethylene bag packed roots, range among the treatments was 411.60 –507.68 mg/100g, after 150 days of storage as compared to cotton bag where average sulfate 365.66 mg/100g was found to be minimum and the range among the treatments was 316.0 to 415.88 mg/100g.

Table 4.3.19: Effect of treatments and packaging materials on nitrate (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Nitrate									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	239.85±2.5^{ab}	210.43±18.8^{a}	254.62±26.9^{abc}	312.07±39.1^{c}	308.38±24.1^{c}	317.04±9.5^{c}	295.75±28.1^{bc}	243.89±18.4^{ab}	240.95±8.6^{ab}	269.22±42.0
	CB	257.55±5.7^{a}	265.82±6.8^{b}	304.18±1.6^{c}	303.08±7.5^{bc}	308.88±8.2^{c}	318.93±4.7^{c}	310.47±3.3^{c}	314.93±4.8^{c}	286.74±5.7^{b}	296.73±21.6
	PPEB	243.98±5.1^{a}	254.41±4.8^{ab}	291.72±4.7^{cd}	274.62±3.3^{c}	314.22±3.4^{f}	298.46±5.4^{e}	304.53±3.2^{ef}	280.10±7.6^{cd}	268.02±4.1^{bc}	281.12±22.7
	PC	269.87±16.9^{a}	271.49±12.3^{a}	285.14±17.9^{a}	295.00±22.3^{a}	299.91±5.9^{a}	305.60±7.1^{a}	295.09±7.5^{a}	293.94±5.1^{a}	290.54±6.5^{a}	289.62±15.8
	WC	253.16±3.1^{a}	267.55±6.3^{ab}	291.59±3.2^{de}	322.65±1.4^{f}	308.11±7.3^{ef}	314.76±1.9^{f}	320.62±9.6^{f}	285.77±8.3^{cd}	270.69±5.0^{bc}	292.77±24.8
60 Days	LB	225.68±14.5^{ab}	199.71±13.6^{a}	279.41±23.9^{bc}	304.57±31.8^{c}	301.36±23.9^{c}	275.46±15.5^{bc}	275.49±3.8^{bc}	218.98±8.0^{a}	229.27±20.9^{ab}	256.66±40.3
	CB	253.18±10.6^{a}	261.35±5.6^{ab}	293.11±5.9^{cd}	298.12±4.9^{d}	298.35±5.4^{d}	303.67±2.7^{d}	300.28±1.6^{d}	299.57±10.7^{d}	277.70±5.2^{bc}	287.26±18.7
	PPEB	234.72±0.8^{a}	243.26±0.9^{ab}	267.24±3.4^{cd}	264.11±9.2^{bc}	301.26±9.6^{e}	287.60±4.0^{de}	303.78±18.7^{e}	267.89±2.9^{cd}	269.48±6.5^{cd}	271.04±23.6
	PC	251.87±5.1^{a}	263.98±2.3^{ab}	281.44±7.9^{cd}	291.03±2.3^{d}	285.41±1.4^{d}	280.23±3.6^{cd}	271.04±4.7^{bc}	263.00±9.0^{ab}	262.25±1.1^{ab}	272.25±13.1
	WC	245.78±3.3^{a}	253.74±7.6^{ab}	289.02±5.2^{de}	317.08±7.3^{f}	303.42±4.6^{ef}	304.59±3.5^{f}	318.81±8.2^{f}	275.23±2.9^{cd}	264.92±2.2^{bc}	285.84±26.5
90 Days	LB	206.46±23.8^{ab}	177.94±7.8^{a}	238.90±18.5^{b}	294.47±3.6^{c}	285.30±14.0^{c}	279.64±35.3^{c}	252.42±24.2^{bc}	211.78±19.5^{ab}	256.80±9.2^{bc}	244.86±41.5
	CB	257.68±3.0^{a}	264.72±7.7^{ab}	285.26±5.8^{bcd}	293.59±13.2^{cd}	289.12±5.9^{cd}	301.24±6.0^{cd}	303.47±4.3^{d}	301.95±5.6^{d}	280.92±8.3^{bc}	286.44±16.8
	PPEB	222.84±5.1^{a}	238.54±5.1^{ab}	270.38±4.8^{bc}	268.86±13.2^{bc}	291.24±16.3^{c}	274.15±7.2^{c}	298.21±22.0^{c}	271.95±2.9^{bc}	268.53±14.2^{bc}	267.19±24.6
	PC	239.91±4.4^{a}	253.66±5.6^{b}	295.74±2.0^{d}	291.68±3.7^{d}	277.19±2.7^{c}	266.53±2.8^{c}	252.42±4.1^{b}	253.26±3.3^{b}	250.69±7.5^{ab}	264.5619.1
	WC	224.52±7.7^{a}	243.97±2.7^{ab}	277.49±18.4^{bcd}	289.38±18.4^{cd}	278.64±13.0^{bcd}	286.23±16.0^{cd}	305.45±20.7^{d}	261.27±10.5^{abc}	250.61±14.9^{abc}	268.6227.4
120 Days	LB	197.82±16.5^{a}	205.25±1.5^{a}	197.73±2.7^{a}	268.01±3.5^{c}	253.54±7.2^{bc}	269.73±4.5^{c}	262.31±8.4^{c}	212.13±12.7^{a}	237.90±5.3^{b}	233.82±30.3
	CB	246.60±1.6^{a}	255.50±3.0^{ab}	268.96±4.6^{bc}	275.78±4.4^{cd}	283.55±2.3^{cde}	303.93±8.1^{f}	288.43±0.7^{def}	293.12±13.8^{ef}	272.44±1.4^{cd}	276.48±18.1
	PPEB	207.13±5.1^{a}	220.14±3.9^{b}	246.28±1.9^{cd}	251.10±2.4^{cd}	292.42±4.2^{e}	257.57±5.3^{d}	289.25±5.5^{e}	238.90±3.5^{c}	238.67±5.7^{c}	249.05±27.4
	PC	229.06±2.6^{a}	239.50±1.3^{ab}	293.89±7.3^{e}	290.07±3.8^{e}	256.53±8.3^{cd}	262.70±6.6^{d}	238.46±4.7^{ab}	249.69±6.9^{bcd}	243.34±2.2^{abc}	255.92±22.2
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	206.62±8.9^{abc}	194.81±19.8^{ab}	186.91±14.5^{a}	232.32±6.9^{c}	219.86±2.8^{bc}	234.34±5.5^{c}	219.13±2.6^{bc}	208.43±12.0^{abc}	215.78±11.9^{abc}	213.13±17.6
	CB	227.18±3.3^{a}	235.27±0.8^{a}	260.53±5.7^{b}	273.94±7.1^{bc}	273.90±2.8^{bc}	308.23±15.5^{d}	292.59±6.6^{cd}	291.81±5.4^{cd}	268.44±2.9^{b}	270.21±26.1
	PPEB	205.45±9.5^{a}	218.51±15.7^{ab}	246.57±17.0^{bcd}	262.76±6.6^{cde}	281.81±17.7^{de}	241.57±17.0^{abcd}	297.75±20.2^{e}	230.07±7.6^{abc}	236.89±9.9^{abc}	246.82±30.8
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, $n = 3$. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Table 4.3.20: Effect of treatments and packaging materials on phosphate (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Phosphate									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	701.69±5.1^{bcd}	682.71±1.8^{ab}	708.05±9.8^{d}	685.00±8.0^{abc}	699.61±4.5^{abcd}	679.31±11.3^{a}	703.91±4.5^{cd}	679.60±8.4^{a}	694.04±6.3^{abcd}	692.7±12.3
	CB	708.36±42.1^{a}	766.71±21.1^{a}	687.49±50.0^{a}	770.91±85.8^{a}	761.87±47.4^{a}	698.69±17.2^{a}	805.72±30.9^{a}	704.77±28.3^{a}	757.96±31.0^{a}	740.3±53.8
	PPEB	716.83±3.2^{cd}	684.39±5.4^{a}	699.52±3.8^{ab}	732.12±8.9^{e}	770.60±6.1f^{g}	721.87±5.4^{de}	784.96±4.4^{g}	703.81±5.3^{bc}	766.32±2.1^{f}	731.2±34.1
	PC	701.64±19.4^{a}	731.33±13.6^{ab}	715.74±24.2^{ab}	716.78±15.7^{ab}	759.02±16.4^{b}	744.43±22.3^{ab}	710.36±19.2^{ab}	693.20±21.0^{a}	741.61±11.6^{ab}	723.8±25.9
	WC	708.70±10.0^{a}	693.95±10.2^{a}	699.41±37.4^{a}	728.60±58.3^{a}	713.65±43.7^{a}	695.37±2.5^{a}	702.57±10.9^{a}	715.71±36.5^{a}	718.33±10.8^{a}	708.5±27.9
60 Days	LB	703.79±7.1^{d}	676.88±5.9^{ab}	712.02±5.3^{d}	667.77±6.6^{a}	698.33±3.2^{cd}	688.76±3.4^{bc}	701.06±1.4^{cd}	702.00±6.5^{cd}	702.30±1.5^{cd}	694.8±14.3
	CB	711.41±22.4^{a}	714.48±34.6^{a}	673.41±26.1^{a}	706.87±3.0^{a}	701.10±44.0^{a}	656.22±18.0^{a}	713.53±101.0^{a}	663.23±38.7^{a}	711.10±54.8^{a}	694.6±44.7
	PPEB	706.02±8.3^{b}	679.46±3.6^{a}	689.46±4.2^{ab}	745.63±8.9^{cd}	767.87±4.8^{de}	727.80±5.1^{c}	795.42±13.6^{f}	699.65±5.3^{ab}	765.51±4.9^{de}	730.8±39.1
	PC	693.42±37.7^{ab}	677.55±14.8^{ab}	714.91±27.3^{b}	631.48±39.2^{a}	634.23±35.5^{a}	678.93±7.9^{ab}	667.55±16.2^{ab}	699.35±32.8^{ab}	717.19±18.1^{b}	679.4±37.8
	WC	706.52±17.9^{a}	683.98±13.5^{a}	683.74±29.7^{a}	685.22±37.6^{a}	690.66±26.7^{a}	673.05±25.2^{a}	701.30±9.9^{a}	683.66±21.7^{a}	711.57±42.6^{a}	691.1±25.5
90 Days	LB	693.24±5.9^{bc}	691.18±5.0^{b}	685.60±4.6^{b}	712.95±1.3^{d}	696.18±5.7^{bc}	654.62±4.7^{a}	705.77±6.1^{cd}	657.11±5.7^{a}	682.06±4.1^{b}	686.5±19.5
	CB	697.43±48.8^{a}	677.50±57.2^{a}	695.85±83.0^{a}	700.59±81.2^{a}	713.69±14.1^{a}	684.73±38.8^{a}	739.72±47.5^{a}	710.37±23.9^{a}	689.99±32.8^{a}	701.1±47.1
	PPEB	699.89±1.8^{a}	683.06±28.8^{a}	709.79±7.3^{ab}	678.61±33.1^{a}	761.92±2.7^{b}	732.97±6.3^{ab}	761.57±41.3^{b}	714.19±3.4^{ab}	715.40±6.5^{ab}	717.5±33.56
	PC	700.45±14.4^{ab}	669.50±39.4^{ab}	709.91±19.6^{b}	634.11±41.2^{a}	671.59±9.4^{ab}	692.44±6.6^{ab}	687.66±12.0^{ab}	699.08±18.1^{ab}	716.76±26.9^{b}	686.8±31.4
	WC	688.96±33.4^{a}	634.28±31.1^{a}	663.19±70.5^{a}	658.49±52.7^{a}	733.94±32.1^{a}	696.35±14.4^{a}	666.08±48.3^{a}	666.71±54.4^{a}	677.49±28.8^{a}	676.2±45.3
120 Days	LB	673.11±25.5^{a}	667.73±19.1^{a}	668.95±7.5^{a}	676.37±22.7^{a}	666.56±5.8^{a}	666.69±9.5^{a}	671.34±37.0^{a}	648.89±56.4^{a}	677.21±20.9^{a}	668.5±24.1
	CB	674.96±29.0^{a}	699.29±9.7^{ab}	708.76±41.8^{ab}	755.88±8.6^{bc}	762.80±6.2^{bc}	737.19±16.6^{abc}	785.02±29.1^{c}	743.01±7.4^{bc}	749.55±24.5^{bc}	735.2±38.1
	PPEB	688.23±14.3^{ab}	629.26±11.7^{a}	678.02±34.8^{ab}	756.62±3.7^{c}	761.30±2.8^{c}	726.62±33.3^{bc}	726.22±5.1^{bc}	708.70±5.9^{bc}	723.77±38.3^{bc}	711.0±43.4
	PC	657.64±42.0^{ab}	697.68±10.7^{ab}	620.30±27.8^{a}	674.41±25.1^{ab}	700.77±19.7^{ab}	713.92±9.5^{b}	647.84±50.0^{ab}	647.71±38.3^{ab}	696.54±37.5^{ab}	673.0±40.2
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	621.49±44.4^{ab}	651.32±37.7^{ab}	652.86±28.3^{ab}	663.31±30.5^{ab}	663.97±23.2^{ab}	644.72±29.5^{ab}	683.50±44.1^{b}	583.95±32.4^{a}	656.02±36.4^{ab}	646.8±40.0
	CB	621.87±4.5^{abc}	599.33±18.0^{ab}	580.43±2.2^{a}	597.51±36.9^{ab}	670.43±1.7^{cd}	600.50±33.5^{ab}	698.17±2.9^{d}	650.01±31.9^{bcd}	648.16±14.7^{bcd}	629.641.8
	PPEB	693.08±2.0^{abc}	660.07±34.0^{ab}	648.16±6.2^{a}	729.86±51.5^{bcd}	759.63±2.8^{cd}	725.21±26.4^{abcd}	779.83±40.9^{d}	702.49±5.4^{abcd}	666.90±22.5^{ab}	707.2±49.1
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test ($P = 0.05$). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Table 4.3.21: Effect of treatments and packaging materials on sulfate (mg/100g DW) content of carrot during storage

Storage periods	Packaging materials	Sulfate									
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
30 Days	LB	475.59±44.5^{ab}	501.06±37.3^{abc}	533.28±86.5^{abc}	612.79±29.5^{c}	534.82±36.6^{abc}	575.55±42.6^{bc}	439.63±12.6^{a}	478.05±30.9^{ab}	595.90±37.0^{bc}	527.41±67.5
	CB	502.86±24.5^{b}	488.16±15.5^{b}	321.30±5.7^{a}	575.74±14.5^{c}	563.91±8.5^{c}	576.49±18.9^{c}	495.27±6.9^{b}	506.32±31.3^{b}	602.37±4.1^{c}	514.71±81.8
	PPEB	471.89±12.0^{bc}	440.18±0.6^{ab}	418.24±9.8^{a}	536.65±8.7^{de}	537.97±7.9^{e}	497.31±13.6^{cd}	527.49±12.8^{de}	467.44±23.3^{bc}	623.97±21.3^{f}	502.35±60.9
	PC	429.42±50.1^{ab}	404.4.5±7.2^{a}	410.07±70.5^{ab}	498.75±8.4^{b}	447.72±7.1^{ab}	420.22±26.4^{ab}	493.60±15.4^{ab}	457.31±29.8^{ab}	490.22±7.7^{ab}	450.20±44.7
	WC	362.84±8.1^{a}	371.87±8.2^{a}	398.03±12.4^{b}	454.40±7.2^{c}	486.42±9.0^{d}	495.86±10.0^{de}	512.78±6.4^{ef}	482.08±3.9^{d}	521.49±9.2^{f}	453.97±59.1
60 Days	LB	487.69±60.6^{ab}	451.02±23.7^{a}	421.60±20.4^{a}	521.15±30.8^{ab}	577.86±54.4^{b}	452.97±4.5^{a}	421.11±8.1^{a}	529.01±30.8^{ab}	506.40±66.1^{ab}	485.42±60.68
	CB	424.21±76.2^{a}	486.56±27.3^{a}	403.06±49.7^{a}	405.24±44.^{0a}	522.55±26.8^{a}	476.46±152.1^{a}	456.72±11.4^{a}	456.44±8.0^{a}	536.14±30.0^{a}	463.04±69.7
	PPEB	458.84±10.6^{ab}	414.18±5.3^{a}	407.72±5.1^{a}	532.74±13.3^{b}	544.67±15.3^{b}	484.46±17.6^{ab}	549.24±7.4^{b}	433.74±48.8^{ab}	537.60±106.8^{b}	484.80±65.2
	PC	388.54±22.0^{a}	410.28±37.8^{ab}	388.72±72.2^{a}	466.82±40.0^{ab}	448.97±6.9^{ab}	450.26±74.6^{ab}	519.11±15.3^{b}	466.73±47.1^{ab}	525.48±13.6^{b}	451.66±60.22
	WC	316.29±15.6^{a}	337.67±15.2^{a}	342.31±2.7^{a}	417.03±3.7^{b}	446.75±10.1^{bc}	451.77±0.7^{c}	449.48±17.0^{c}	437.17±13.0^{bc}	459.71±9.3^{c}	406.47±55.97
90 Days	LB	461.76±15.5^{ab}	412.00±39.3^{a}	405.33±10.4^{a}	522.80±42.7^{b}	500.86±52.1^{ab}	445.47±23.0^{ab}	421.96±23.0^{a}	536.92±54.6^{b}	440.47±19.8^{ab}	460.84±54.9
	CB	433.66±48.2^{ab}	439.40±10.4^{ab}	432.02±6.7^{ab}	450.60±80.0^{ab}	453.40±11.0^{ab}	495.79±42.3^{b}	458.70±3.7^{ab}	383.18±12.2^{a}	453.37±14.5^{ab}	444.46±40.9
	PPEB	436.08±6.4^{ab}	397.76±10.^{6a}	381.14±11.0^{a}	520.08±13.4^{cd}	516.79±22.7^{cd}	472.79±13.8^{bc}	532.69±14.1^{cd}	476.62±9.3^{bc}	569.06±62.1^{d}	478.11±64.2
	PC	371.50±7.6^{a}	381.57±5.4^{ab}	484.21±16.6^{de}	397.04±9.3^{ab}	448.69±3.7^{c}	382.54±3.0^{ab}	457.75±10.2^{cd}	402.17±9.8^{b}	500.79±12.3^{e}	425.14±47.2
	WC	324.93±3.6^{ab}	305.99±5.0^{a}	311.67±6.7^{a}	365.26±7.1^{b}	420.89±16.7^{c}	436.37±33.5^{c}	437.35±15.2^{c}	418.75±8.4^{c}	436.15±3.3^{c}	384.15±56.1
120 Days	LB	430.22±68.8^{a}	401.51±27.4^{a}	409.33±24.1^{a}	430.72±39.3^{a}	565.53±42.4^{b}	432.35±12.6^{a}	487.88±32.8^{ab}	484.35±46.8^{ab}	448.14±41.5^{a}	454.45±59.4
	CB	336.02±34.9^{a}	362.44±43.6^{a}	391.83±21.3^{a}	427.82±87.1^{a}	386.66±38.7^{a}	396.76±67.2^{a}	364.77±41.7^{a}	355.02±40.9^{a}	368.03±30.8^{a}	376.60±48.3
	PPEB	394.03±39.0^{a}	403.00±30.1^{a}	405.39±11.5^{ab}	441.66±24.3^{abc}	532.45±32.7^{d}	482.76±13.9^{bcd}	534.09±34.5^{d}	430.80±32.3^{abc}	496.75±10.1^{cd}	457.88±57.7
	PC	339.50±31.1^{a}	383.48±26.2^{ab}	424.48±50.2a^{bc}	385.94±3.4a^{b}	396.85±32.0^{ab}	387.65±44.5^{ab}	467.91±16.4^{bc}	434.54±25.8^{bc}	486.75±7.0^{c}	411.90±50.8
	WC	×	×	×	×	×	×	×	×	×	×
150 Days	LB	413.56±38.0^{a}	395.50±51.1^{a}	412.48±59.0^{a}	416.51±44.6^{a}	481.20±74.8^{a}	397.87±24.3^{a}	433.76±28.3^{a}	473.59±29.8^{a}	423.41±71.0^{a}	427.54±50.9
	CB	316.00±86.2^{a}	322.56±38.7^{a}	324.87±33.4^{a}	408.12±91.0^{a}	389.59±39.8^{a}	343.08±80.0^{a}	379.00±53.9^{a}	415.88±66.2^{a}	391.84±49.6^{a}	365.66±64.7
	PPEB	436.02±24.1^{ab}	465.50±3.5^{ab}	411.60±29.5^{a}	460.25±3.8^{ab}	461.69±35.4^{ab}	491.21±25.6^{ab}	507.68±49.3^{b}	450.67±45.1^{ab}	504.64±26.7^{b}	465.47±39.8
	PC	×	×	×	×	×	×	×	×	×	×
	WC	×	×	×	×	×	×	×	×	×	×

Different letters within each column indicate significant differences according to Tukey's test (P = 0.05). All data are expressed as mean ± standard deviation, n = 3. T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

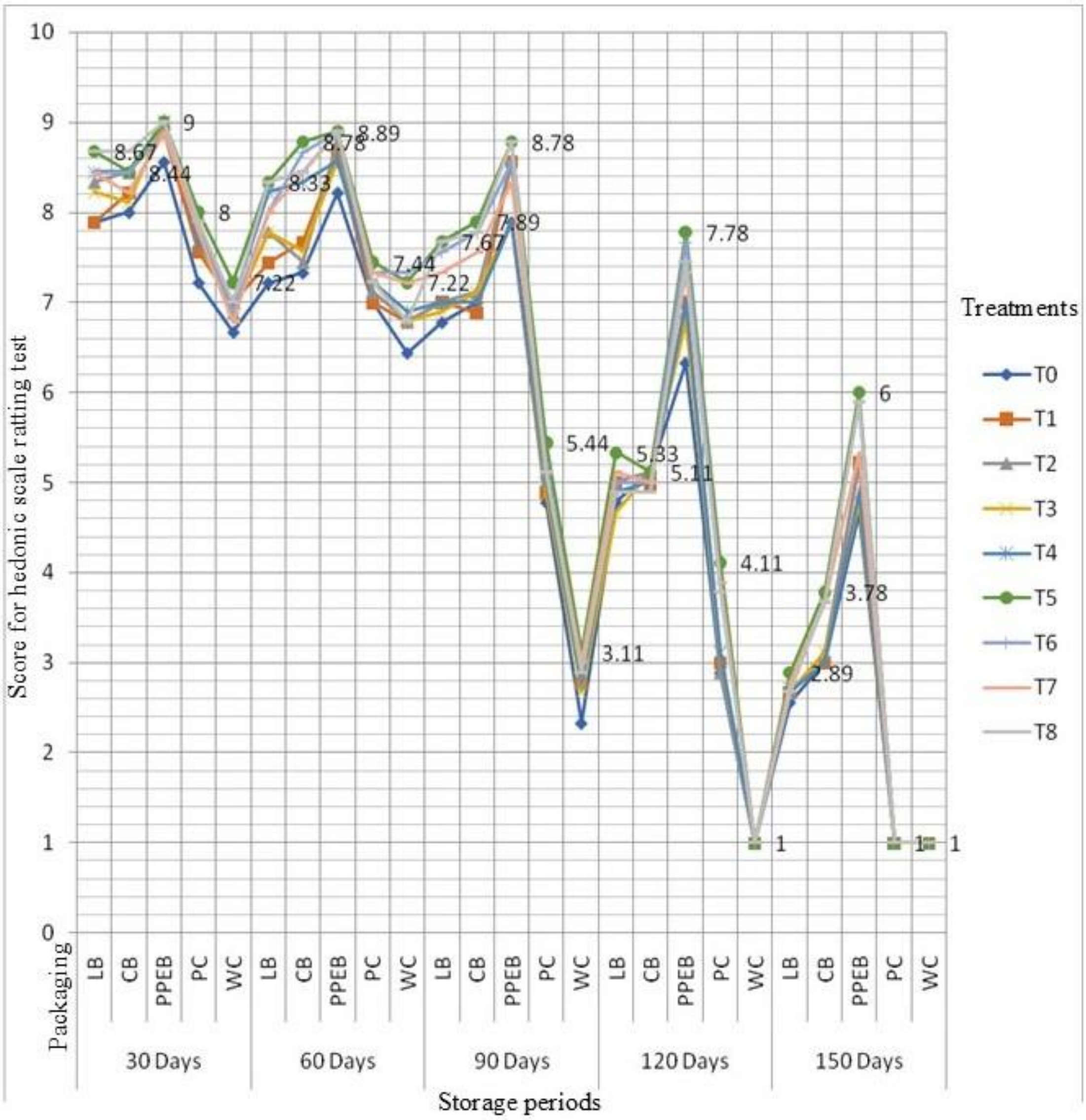

ToR1
ToR2
ToR3

Figure 4.4. Types of packaging materials used during storage trail

4.3.13. Changes in Overall acceptability of the carrot using different packaging materials during different storage period

It was evident from the figure 4.5 that after 30 days of storage, all treatments exhibited good organoleptic scores, with carrots packed in PPEB scoring the highest (9.0), which was liked extremely. Treatments T_2, T_3, T_4, T_5, and T_8 followed closely. Packaging material WC showed the poor organoleptic score. After 60 days, organoleptic scores ranged from 6.44 to 8.89, with PPBE showing the highest score (8.89) in T_5, T_6, T_7, and T_8. The lowest score (6.44) was recorded with WC in T_1. While samples examined after 90 days, organoleptic scores ranged between 6.89 to 8.78, with T_5 and T_8 in PPEB scoring the highest.

WC in T_1 performed poorly. After 120 days of study, scores ranged from 1.00 to 7.78, with T_5 in PPEB scoring the highest (7.78). PC recorded the lowest score (1.00), which was disliked extremely. At end of experimentation after 150 days, most samples were unacceptable, except those in PPEB, which scored between 4.67 and 6.00, with T_5 scoring 6.00.



T_0- Control, T_1- Boron @ 0.1%, T_2- Boron @ 0.2%, T_3- $ZnSO_4$ @ 0.5%, T_4- $ZnSO_4$ @ 1.0%, T_5- Boron @ 0.1% + $ZnSO_4$ @ 0.5%, T_6- Boron @ 0.2% + $ZnSO_4$ @ 1.0%, T_7- Boron @ 0.1% + $ZnSO_4$ @ 1.0%, T_8- Boron @ 0.2% + $ZnSO_4$ @ 0.5, LB- Leno Bag, CB- Cotton Bag, PPEB- Perforated polyethylene Bag, PC- Plastic Crate, WC- Wooden Crate

Figure 4.5. Impact of storage period and packaging material on overall acceptability of carrots

Figure 4.6. Organoleptic test of carrot at trans Himalayan region

CHAPTER-V

SUMMARY AND CONCLUSION

The present experiment, titled "Effect of Preharvest Application of Micronutrients (zinc & boron) on Performance of Carrot (*Daucus carota* L.) and Its Shelf Life Under Different Storage Conditions in Cold Desert Trans-Himalayan Ladakh Region" was conducted at the Agriculture Research Unit, Division of Vegetable Science, DIHAR-DRDO during 2020-2021 and 2021-2022. The key findings are as follows:

Summary

Objective 1.

- The maximum number of leaves per plants (13.16) was recorded in the foliar application of $ZnSO_4$ @ 1.0% (T_4) while minimum number of leaves per plants was observed in control T_0. The maximum leaf length (29.61 cm) was recorded in foliar application of $ZnSO_4$ 0.5% (T_3), Whereas, lowest leaf length (20.33 cm) was recorded in control T_0. The leaf breadth of carrot during experiment pooled data of the both years was observed non-significantly differences.
- The highest root length (17.25 cm) was recorded with foliar application of $ZnSO_4$ 1.0% (T_4), While the lowest value of root length (12.92 cm) was recorded with control T_0. However, foliar application of Boron 0.1% + ZnSO4 0.5% (T_5) showed that highest root diameter (34.59 mm).
- Average root weight was found statically significant. The highest average root weight (94.95 g) was recorded with foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5) Whereas, the lowest average root weight (61.66 g) was recorded in control (T_0). The maximum yield (316.50 q/ha) was recorded with the foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5%. The lowest average yield (205.53 q/ha) was recorded in control (T_0).
- It is evident form the data that all the treatments significantly increased chlorophyll content (9.29 CCI) was found in leaf when the plant treated with foliar application of Boron @ 0.2% + $ZnSO_4$ @ 1.0% (T_6). The minimum value (6.59 CCI) was observed in control (T_0).

- The maximum TSS (9.15° B) of carrot was observed under treatment T_2-Boron @ 0.2%, while the minimum TSS (8.42° B) of carrot was observed under treatment T_5.
- The highest nitrate content (351.08 mg/100g) of carrot root was found in foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5). However, the maximum phosphate (956.90 mg/100g) of carrot root was found in foliar application of Boron @ 0.2% + $ZnSO_4$ @ 1.0% (T_6). Among the treatments, maximum values of sulfate (661.23 mg/100g) were observed in treatment T_3.The minimum sulfate content was found in T_2 (476.21 mg/100g). The uptake of Zn and Mn into roots was increased by the addition of $ZnSO_4$ and boron to the uptake solution.
- The highest glucose (17.90 g/100 g) and fructose content (7.86 g/100 g) were observed by foliar application of Boron @ 0.1% (T_1). While the lowest glucose and fructose content was found in the control. Maximum sucrose content was recorded in the foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5). The pooled data showed the highest total sugar (43.51 g/100g) in the foliar application of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5). The highest value of total phenol concentration (6.59±0.34 mg GAE/100 g DW) was recorded under foliar application of $ZnSO_4$ @ 1.0 % (T_3).
- The foliar application of zinc and boron with various concentrations had no significant impact on the ascorbic acid content of carrot roots. Whereas, the maximum value of carotenes (4298.78 µg/100 g FW) was found in the foliar application of $ZnSO_4$ @ 0.5 % (T3). A minimum value of carotenes (3533.04 µg/100 g FW) was also found in the foliar application of Boron @ 0.2 %. The highest TFC (1.75±0.22 mg RE/100g DW) was recorded in the foliar application of $ZnSO_4$ @ 0.5 % (T_3).
- The manganese concentration ranges between 1.30 to 1.84 mg/100 g DW, with the lowest value found with the $ZnSO_4$ @ 0.5 % (T_3), while the Boron @ 0.1 % +$ZnSO_4$ @ 0.5 % (T_5) foliar dose produced the highest value (1.84 mg/100 g DW). The application of Boron @ 0.2 %+ $ZnSO_4$ @ 0.5 % produced highest zinc concentrations 11.17 mg/100 g DW. The copper concentration was highest (0.62 mg/100 g DW) in control compared to all the

treatments. Minimum copper concentration (0.41 mg/100 g DW) was observed with foliar application of $ZnSO_4$ @ 1.0 % and Boron 0.2 % + $ZnSO_4$ @ 1.0 %.

Objective-2

- The results revealed that storage conditions significantly ($p \leq 0.05$) affected many key quality attributes, namely, weight loss, glucose, and total sugars increased with storage time, while ascorbic acid, titratable acidity, and carotene contents decreased.
- Total phenolic and flavonoid contents exhibited a nearly parabolic trend throughout the storage period.
- Among the various storage conditions, underground passive storage proved to be the most effective in preserving the vital quality attributes of carrots over 150 days.
- After 30 and 60 days of storage, 6.2% and 6.46% weight loss were observed, respectively. Whereas minimum weight loss (5%) was recorded in the month of January. It increased upto 9.6% in the month of February and sudden weight loss (16.66%) was recorded in month of March. It assures that passive underground store has maintained suitable environment for the storage of carrots upto February (120 Days) but during march sudden increase in temperature caused extreme weight loss%.
- In contrast, carrots stored at room temperature suffered significant weight loss, ranging from 38.03% to 52.67% across all treatments.
- Throughout the storage period, the average ascorbic acid content of the treated carrot roots stored in trench storage remained higher at 4.75 mg/100g followed by underground passive storage 4.47mg/100g.
- Substantial carbohydrate losses may occur due to respiratory activity during extended storage at relatively high temperatures. The glucose, fructose and sucrose content in all treated carrot roots showed no significant difference throughout the storage period.
- While the mineral content of the roots was minimally affected, it may be influenced during prolonged storage. Notably, treated carrot roots stored in

underground passive storage maintained a higher average manganese content of 1.34 mg/100g.

Objective-3

- Treated carrot roots were packaged in (a) perforated polyethylene bag, (b) cotton bag, (c) leno bag, (d) plastic crate, (e) wooden crate were used for experiment.
- Samples were stored either underground passive storage at ambient temperature for 150 days from the time of harvesting. The quality parameters such as weight loss, TSS, ascorbic acid, titratable acidity, carotene, total phenolic compounds, total flavonoids, sugars, anions, and minerals were evaluated periodically during storage.
- It was noticed that the perforated polyethylene bag packed root maintained the lowest average weight loss (10.25 %), total sugar (39.53 g/100g), TSS (13.7° B), and maximum ascorbic acid (5.27 mg/100g), carotene (3507.05 µg/100 g FW), TPC (3.98 mg GE/100g) during 150 days of storage.
- After 150 days of storage, it was observed that treated roots packed in perforated polyethylene bags had greater nitrate levels than the other packaging materials. The average nitrate was measured at 270.21 mg/100g, with a range of 227.18–308.23 mg/100g among the treatments. It was noticed that perforated polyethylene bag packed treated roots showed higher phosphate than other packaging materials throughout the storage period and recorded average phosphate content (707.2 mg/100g).
- Leno bag-packed-treated roots had the highest average potassium and manganese content across all packaging materials over the storage period, with average K and Mn content of 3042.8 mg/100g and 1.34 mg/100g.
- The maximum average sodium content (286.9 mg/100g) in perforated polyethylene bag packed roots, the range between treatments was 267.27–295.85 mg/100g, from 150 days of storage as compared to leno bag where average sodium (278.7 mg/100g) was found to be the lowest and the range between treatments was 255.44 and 319.30 mg/100g.

- Perforated polyethylene bag was an excellent package in maintaining changes in the characteristics of carrots during the storage process.

Conclusion

The results indicate that foliar application of boron and zinc significantly enhances various quality attributes of carrots, including root diameter, weight, yield, and sugar content. Notably, the combination of Boron @ 0.1% + $ZnSO_4$ @ 0.5% (T_5) significantly improved root diameter, average root weight, yield, sucrose content, total sugar, sweetness index, and total sweetness index compared to the control. Zinc application, particularly $ZnSO_4$ @ 0.5% (T_3), increased carotene and flavonoid contents, while $ZnSO_4$ @ 1.0% (T_4) maximized total phenol concentration.

The study also evaluated storage conditions and concluded that underground passive storage was the best option for carrot storage in the trans-Himalayan region. Carrots stored at room temperature decayed within 20 days, while those in trenches were only accessible after uncovering, requiring immediate use to prevent moisture buildup and damage. In contrast, carrots in underground passive storage remained physically and biochemically stable until February, with some changes observed in March.

The different packaging conditions played a crucial role, with perforated polyethylene bags (PPEB) exhibiting the best overall performance in maintaining weight loss, sugar content, and nutrient levels. The carrots packed with PPEB in treatment showed the desirable overall acceptability even after 150 days of the experimentation period. The results demonstrate that careful management of micronutrient applications, storage conditions, and packaging can significantly improve carrot quality and shelf life in challenging environments.

Suggestion and future prospects

Foliar application of micronutrients, especially the combination of Boron @ 0.1% and $ZnSO_4$ @ 0.5% (T_5), should be incorporated into regular crop management practices by farmers of the trans-Himalayan and similar challenging environments as this treatment was found best in increasing root size, weight, yield, sweetness and nutritional content.

For post-harvest management, farmers should prioritize underground passive storage methods, which have proven effective in extending the shelf life of carrots up to February without significant quality deterioration. This low-cost, energy-efficient storage technique helps minimize losses, particularly in remote areas lacking cold storage facilities. Additionally, using perforated polyethylene bags (PPEB) for packaging is recommended to maintain carrot freshness, reduce moisture loss, and preserve nutritional quality during storage and transportation.

By implementing these scientifically backed practices, farmers can reduce post-harvest losses, ensure a consistent supply of high-quality produce to the market, and tap into premium market segments. This approach not only increases income and profitability but also contributes to better food security and resource efficiency in fragile agro-ecological zones. Extension services and local agricultural departments should support farmers in training and access to micronutrient inputs, storage materials, and packaging to enable widespread adoption of these practices.

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APPENDIX

Objective 1.

Appendix 1. Effect of foliar application of micronutrients on growth, yield and biochemicals of carrot grown at trans Himalayan region

				Sum of Squares	df	Mean Square	F	Sig.
No. of Leaves/plant	Between Groups	(Combined)		25.482	8	3.185	2.207	.078
		Linear Term	Contrast	6.294	1	6.294	4.362	.051
			Deviation	19.188	7	2.741	1.900	.129
	Within Groups			25.973	18	1.443		
	Total			51.456	26			
Leaf Length	Between Groups	(Combined)		216.087	8	27.011	8.424	.000
		Linear Term	Contrast	16.435	1	16.435	5.126	.036
			Deviation	199.653	7	28.522	8.895	.000
	Within Groups			57.714	18	3.206		
	Total			273.801	26			
Leaf width	Between Groups	(Combined)		13.690	8	1.711	1.892	.124
		Linear Term	Contrast	1.262	1	1.262	1.395	.253
			Deviation	12.428	7	1.775	1.963	.118
	Within Groups			16.277	18	.904		
	Total			29.967	26			
Root Length	Between Groups	(Combined)		49.417	8	6.177	7.232	.000
		Linear Term	Contrast	10.878	1	10.878	12.735	.002
			Deviation	38.539	7	5.506	6.445	.001
	Within Groups			15.375	18	.854		
	Total			64.792	26			
Root Dia.	Between Groups	(Combined)		239.036	8	29.880	14.510	.000
		Linear Term	Contrast	30.826	1	30.826	14.969	.001
			Deviation	208.210	7	29.744	14.444	.000
	Within Groups			37.067	18	2.059		
	Total			276.103	26			
Avg. root Wt.	Between Groups	(Combined)		2376.671	8	297.084	7.293	.000
		Linear Term	Contrast	659.067	1	659.067	16.178	.001
			Deviation	1717.604	7	245.372	6.023	.001
	Within Groups			733.270	18	40.737		
	Total			3109.940	26			
Yield	Between Groups	(Combined)		26406.631	8	3300.829	7.476	.000
		Linear Term	Contrast	7319.010	1	7319.010	16.576	.001
			Deviation	19087.621	7	2726.803	6.176	.001
	Within Groups			7947.532	18	441.530		
	Total			34354.164	26			
Chlo.	Between Groups	(Combined)		20.335	8	2.542	100.336	.000
		Linear Term	Contrast	18.394	1	18.394	726.064	.000
			Deviation	1.941	7	.277	10.946	.000
	Within Groups			.456	18	.025		

			Sum of Squares	df	Mean Square	F	Sig.
		Total	20.791	26			
Acidity	Between Groups	(Combined)	.026	8	.003	144.375	.000
		Linear Term Contrast	.000	1	.000	.025	.876
		Linear Term Deviation	.026	7	.004	164.996	.000
	Within Groups		.000	18	.000		
	Total		.026	26			
TSS	Between Groups	(Combined)	1.624	8	.203	3.614	.011
		Linear Term Contrast	.042	1	.042	.748	.398
		Linear Term Deviation	1.582	7	.226	4.024	.008
	Within Groups		1.011	18	.056		
	Total		2.634	26			

Appendix 2. Effect of foliar application of micronutrients on sugar and anion of carrot grown at trans Himalayan region

			Sum of Squares	df	Mean Square	F	Sig.
Glucose	Between Groups	(Combined)	27.773	8	3.472	52.198	.000
		Linear Term Contrast	.113	1	.113	1.699	.209
		Linear Term Deviation	27.660	7	3.951	59.413	.000
	Within Groups		1.197	18	.067		
	Total		28.970	26			
Sucrose	Between Groups	(Combined)	101.537	8	12.692	44.948	.000
		Linear Term Contrast	38.688	1	38.688	137.013	.000
		Linear Term Deviation	62.848	7	8.978	31.796	.000
	Within Groups		5.083	18	.282		
	Total		106.619	26			
fructose	Between Groups	(Combined)	12.196	8	1.525	16.134	.000
		Linear Term Contrast	.745	1	.745	7.884	.012
		Linear Term Deviation	11.451	7	1.636	17.313	.000
	Within Groups		1.701	18	.094		
	Total		13.897	26			
Phosphate	Between Groups	(Combined)	39904.466	8	4988.058	27.322	.000
		Linear Term Contrast	1414.786	1	1414.786	7.750	.012
		Linear Term Deviation	38489.680	7	5498.526	30.118	.000
	Within Groups		3286.139	18	182.563		
	Total		43190.605	26			
Sulphate	Between Groups	(Combined)	110720.600	8	13840.075	129.973	.000
		Linear Term Contrast	16246.140	1	16246.140	152.568	.000
		Linear Term Deviation	94474.460	7	13496.351	126.745	.000
	Within Groups		1916.721	18	106.484		
	Total		112637.321	26			

Appendix 3. Effect of foliar application of micronutrients on Cu, Fe, Mn, Na and Zn of carrot grown at trans Himalayan region

				Sum of Squares	df	Mean Square	F	Sig.
Cu	Between Groups	(Combined)		.105	8	.013	2.482	.052
		Linear Term	Contrast	.022	1	.022	4.071	.059
			Deviation	.084	7	.012	2.255	.078
	Within Groups			.096	18	.005		
	Total			.201	26			
Fe	Between Groups	(Combined)		6.442	8	.805	1.538	.213
		Linear Term	Contrast	2.088	1	2.088	3.989	.061
			Deviation	4.354	7	.622	1.188	.358
	Within Groups			9.423	18	.524		
	Total			15.865	26			
Mn	Between Groups	(Combined)		.937	8	.117	3.489	.013
		Linear Term	Contrast	.033	1	.033	.974	.337
			Deviation	.904	7	.129	3.849	.010
	Within Groups			.604	18	.034		
	Total			1.541	26			
Na	Between Groups	(Combined)		22309.123	8	2788.640	4.878	.003
		Linear Term	Contrast	40.301	1	40.301	.071	.794
			Deviation	22268.822	7	3181.260	5.565	.002
	Within Groups			10289.356	18	571.631		
	Total			32598.479	26			
Zn	Between Groups	(Combined)		118.975	8	14.872	90.857	.000
		Linear Term	Contrast	64.174	1	64.174	392.056	.000
			Deviation	54.801	7	7.829	47.828	.000
	Within Groups			2.946	18	.164		
	Total			121.922	26			

Appendix 4. Effect of foliar application of micronutrients on cost of cultivation of carrot grown at trans Himalayan region:

A. Common cost

S.No.	Particular	Quantity	Rate (Rs.)	Carrot Total (Rs.)
1. Field preparation				
a.	Pre- irrigation	10 hour	100/ hour	1000
b.	Labour for irrigation	5 labour	450/labour	2250
c.	Ploughing by disc plough	1 time	7500/ha.	7500
d.	Ploughing by cultivator	2 time	6000/ha.	12000
e.	Planking	2 time	100/ha.	1000
2. Layout and Seed sowing				
a.	Carrot Seed	4 kg	1500/kg	6000
b.	Labour for sowing of seed	20 labour	450/labour	9000
c.	Labour for layout	20 labour	450/labour	9000

d	FYM	200q/ha	100/q	20000
3. Cultural practices				
a.	Labour for three weeding	80 labour	450/labour	36000
b.	Irrigation by tube well	100 hour	100/ hour	10000
c.	Labour for irrigation	10 labour	450/labour	4500
d.	Labour for micronutrient spray	6 labour	450/labour	2700
5. Harvesting				
a.	Labour for Harvesting	60 labour	450/labour	27000
b.	Transportation (by tractor)	6 times	1000/times	6000
6	Sub total	-	-	**144950**
7	Interest on cultivation cost @ 4 %	-	-	5798
8	Total	-	-	150748
9	Marginal risk @ 10 %	2 months	10%	150748
10	Land rent	5 months	5000/Months	25000
11	Total cost of cultivation	-	-	**175748**

B. Variable cost of cultivation

Treatment	Particulars	Input	Rate (Rs)	Total cost of treatments	Total cost of cultivation
T_0	Control	---	--	0.0	175748
T_1	Boron @ 0.1%	400g	450/Kg	180	175928
T_2	Boron @ 0.2%	800g	450/Kg	360	176108
T_3	$ZnSO_4$ @ 0.5%	2kg	400/Kg	800	176548
T_4	$ZnSO_4$ @ 1.0%	4kg	400/Kg	1600	177348
T_5	Boron @ 0.1% + $ZnSO_4$ @ 5%	400g+2kg	450kg+400kg	980	176728
T_6	Boron @ 0.2%+ $ZnSO_4$ @ 1.0%	800g+4 kg	450kg+400kg	1960	177708
T_7	Boron @ 0.1%+ $ZnSO_4$ @ 1.0%	400g+4kg	450kg+400kg	1780	177528
T_8	Boron @ 0.2%+ $ZnSO_4$ @ 0.5%	800g+2kg	450kg+400kg	1160	176908

C. Economics of different treatments of carrot grown at trans Himalayan region

Treatments	Yield (q/ha)	Rate (Rs/q)	Gross return (Rs/ha)	Total cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C Ratio
T_0	205.53	3500	719355	175748	543607	3.09
T_1	250.36	3500	876260	175928	700332	3.98
T_2	255.49	3500	894215	176108	718107	4.08
T_3	262.21	3500	917735	176548	741187	4.20
T_4	299.74	3500	1049090	177348	871742	4.92
T_5	316.5	3500	1107750	176728	931022	5.27
T_6	242.95	3500	850325	177708	672617	3.78
T_7	289.65	3500	1013775	177528	836247	4.71
T_8	264.41	3500	925435	176908	748527	4.23

Objective 2.

		Sum of Squares	df	Mean Square	F	Sig.
WEIGHT LOSS Room Storage	Between Groups	288.852	8	36.107	.757	.643
	Within Groups	858.195	18	47.677		
	Total	1147.047	26			
WEIGHT LOSS Underground Passive Storage	Between Groups	681.468	8	85.184	6.491	.000
	Within Groups	236.218	18	13.123		
	Total	917.686	26			
WEIGHT LOSS Trench Storage	Between Groups	104.460	8	13.057	7.808	.000
	Within Groups	30.102	18	1.672		
	Total	134.562	26			
ACIDITY Room Storage	Between Groups	.001	8	.000	.338	.939
	Within Groups	.008	18	.000		
	Total	.009	26			
ACIDITY Underground Passive Storage	Between Groups	.005	8	.001	1.786	.146
	Within Groups	.006	18	.000		
	Total	.011	26			
ACIDITY Trench Storage	Between Groups	.005	8	.001	1.227	.339
	Within Groups	.009	18	.000		
	Total	.013	26			
ASCORBIC ACID Room Storage	Between Groups	2.899	8	.362	.778	.627
	Within Groups	8.384	18	.466		
	Total	11.283	26			
ASCORBIC ACID Underground Passive Storage	Between Groups	11.520	8	1.440	1.255	.325
	Within Groups	20.645	18	1.147		
	Total	32.165	26			
ASCORBIC ACID Trench Storage	Between Groups	10.099	8	1.262	4.060	.006
	Within Groups	5.597	18	.311		
	Total	15.696	26			
CAROTENE Room Storage	Between Groups	383848.903	8	47981.113	4.840	.003
	Within Groups	178446.321	18	9913.685		
	Total	562295.224	26			
CAROTENE Underground Passive Storage	Between Groups	1392835.567	8	174104.446	11.898	.000
	Within Groups	263401.451	18	14633.414		
	Total	1656237.018	26			
CAROTENE Trench Storage	Between Groups	2032044.985	8	254005.623	18.975	.000
	Within Groups	240959.918	18	13386.662		
	Total	2273004.903	26			
ANTIOXIDANT Room Storage	Between Groups	54.048	8	6.756	8.266	.000
	Within Groups	14.711	18	.817		
	Total	68.759	26			
ANTIOXIDANT Underground Passive Storage	Between Groups	20.532	8	2.566	4.349	.005
	Within Groups	10.621	18	.590		
	Total	31.153	26			
ANTIOXIDANT Trench Storage	Between Groups	85.993	8	10.749	3.291	.017
	Within Groups	58.784	18	3.266		

	Total	144.777	26			
TPC Room Storage	Between Groups	2.190	8	.274	.890	.544
	Within Groups	5.536	18	.308		
	Total	7.726	26			
TPC Underground Passive Storage	Between Groups	15.278	8	1.910	7.324	.000
	Within Groups	4.693	18	.261		
	Total	19.971	26			
TPC Trench Storage	Between Groups	14.074	8	1.759	4.837	.003
	Within Groups	6.547	18	.364		
	Total	20.620	26			
TFC Room Storage	Between Groups	.982	8	.123	4.459	.004
	Within Groups	.495	18	.028		
	Total	1.477	26			
TFC Underground Passive Storage	Between Groups	2.312	8	.289	9.404	.000
	Within Groups	.553	18	.031		
	Total	2.865	26			
TFC Trench Storage	Between Groups	2.867	8	.358	9.087	.000
	Within Groups	.710	18	.039		
	Total	3.577	26			

				Sum of Squares	df	Mean Square	F	Sig.
GLUCOSE Room Storage	Between Groups	(Combined)		22.967	8	2.871	10.451	.000
		Linear Term	Contrast	6.948	1	6.948	25.292	.000
			Deviation	16.019	7	2.288	8.331	.000
	Within Groups			4.945	18	.275		
	Total			27.912	26			
GLUCOSE Underground Passive Storage	Between Groups	(Combined)		49.105	8	6.138	3.905	.008
		Linear Term	Contrast	15.573	1	15.573	9.908	.006
			Deviation	33.533	7	4.790	3.048	.027
	Within Groups			28.292	18	1.572		
	Total			77.397	26			
GLUCOSE Trench Storage	Between Groups	(Combined)		11.231	8	1.404	2.108	.090
		Linear Term	Contrast	2.054	1	2.054	3.084	.096
			Deviation	9.177	7	1.311	1.969	.117
	Within Groups			11.986	18	.666		
	Total			23.217	26			
FRUCTOSE Room Storage	Between Groups	(Combined)		4.236	8	.530	.719	.673
		Linear Term	Contrast	1.279	1	1.279	1.738	.204
			Deviation	2.957	7	.422	.574	.768
	Within Groups			13.253	18	.736		
	Total			17.489	26			
FRUCTOSE Underground Passive Storage	Between Groups	(Combined)		31.416	8	3.927	11.128	.000
		Linear Term	Contrast	.078	1	.078	.220	.644
			Deviation	31.338	7	4.477	12.686	.000

				Sum of Squares	df	Mean Square	F	Sig.
	Within Groups			6.352	18	.353		
	Total			37.768	26			
FRUCTOSE Trench Storage	Between Groups	(Combined)		3.144	8	.393	5.631	.001
		Linear Term	Contrast	1.007	1	1.007	14.429	.001
			Deviation	2.137	7	.305	4.374	.005
	Within Groups			1.256	18	.070		
	Total			4.401	26			
SUCROSE Room Storage	Between Groups	(Combined)		9.866	8	1.233	.309	.953
		Linear Term	Contrast	2.177	1	2.177	.545	.470
			Deviation	7.689	7	1.098	.275	.956
	Within Groups			71.918	18	3.995		
	Total			81.784	26			
SUCROSE Underground Passive Storage	Between Groups	(Combined)		7.752	8	.969	2.231	.075
		Linear Term	Contrast	.529	1	.529	1.219	.284
			Deviation	7.222	7	1.032	2.375	.066
	Within Groups			7.819	18	.434		
	Total			15.570	26			
SUCROSE Trench Storage	Between Groups	(Combined)		5.851	8	.731	1.052	.436
		Linear Term	Contrast	.035	1	.035	.051	.825
			Deviation	5.816	7	.831	1.195	.354
	Within Groups			12.515	18	.695		
	Total			18.366	26			
TOTAL SUGAR Room Storage	Between Groups	(Combined)		27.102	8	3.388	1.875	.128
		Linear Term	Contrast	15.639	1	15.639	8.655	.009
			Deviation	11.464	7	1.638	.906	.523
	Within Groups			32.525	18	1.807		
	Total			59.627	26			
TOTAL SUGAR Underground Passive Storage	Between Groups	(Combined)		149.463	8	18.683	8.699	.000
		Linear Term	Contrast	12.232	1	12.232	5.695	.028
			Deviation	137.231	7	19.604	9.128	.000
	Within Groups			38.660	18	2.148		
	Total			188.124	26			
TOTAL SUGAR Trench Storage	Between Groups	(Combined)		21.651	8	2.706	1.669	.174
		Linear Term	Contrast	6.886	1	6.886	4.246	.054
			Deviation	14.764	7	2.109	1.301	.305
	Within Groups			29.191	18	1.622		
	Total			50.841	26			
TSS Room Storage	Between Groups	(Combined)		5.732	8	.716	3.255	.018
		Linear Term	Contrast	4.057	1	4.057	18.430	.000
			Deviation	1.675	7	.239	1.087	.411
	Within Groups			3.962	18	.220		
	Total			9.694	26			
TSS Underground Passive Storage	Between Groups	(Combined)		7.265	8	.908	25.464	.000
		Linear Term	Contrast	.381	1	.381	10.684	.004
			Deviation	6.884	7	.983	27.575	.000
	Within Groups			.642	18	.036		
	Total			7.907	26			
TSS Trench Storage	Between Groups	(Combined)		1.042	8	.130	2.019	.103
		Linear Term	Contrast	.432	1	.432	6.701	.019
			Deviation	.610	7	.087	1.351	.284

	Within Groups			1.161	18	.064		
	Total			2.203	26			

Mn Room Storage	Between Groups	(Combined)		.049	8	.006	2.778	.034
		Linear Term	Contrast	.014	1	.014	6.421	.021
			Deviation	.035	7	.005	2.258	.078
	Within Groups			.040	18	.002		
	Total			.089	26			
Mn Underground Passive Storage	Between Groups	(Combined)		.969	8	.121	1.857	.131
		Linear Term	Contrast	.090	1	.090	1.383	.255
			Deviation	.879	7	.126	1.925	.125
	Within Groups			1.175	18	.065		
	Total			2.144	26			
Mn Trench Storage	Between Groups	(Combined)		.014	8	.002	.411	.900
		Linear Term	Contrast	.000	1	.000	.092	.765
			Deviation	.014	7	.002	.456	.853
	Within Groups			.079	18	.004		
	Total			.093	26			
Na Room Storage	Between Groups	(Combined)		2158.668	8	269.834	2.964	.026
		Linear Term	Contrast	591.546	1	591.546	6.498	.020
			Deviation	1567.122	7	223.875	2.459	.059
	Within Groups			1638.710	18	91.039		
	Total			3797.378	26			
Na Underground Passive Storage	Between Groups	(Combined)		9893.230	8	1236.654	3.881	.008
		Linear Term	Contrast	500.233	1	500.233	1.570	.226
			Deviation	9392.996	7	1341.857	4.211	.006
	Within Groups			5735.165	18	318.620		
	Total			15628.394	26			
Na Trench Storage	Between Groups	(Combined)		2724.390	8	340.549	1.847	.133
		Linear Term	Contrast	1051.492	1	1051.492	5.704	.028
			Deviation	1672.898	7	238.985	1.296	.307
	Within Groups			3318.392	18	184.355		
	Total			6042.782	26			
Zn Room Storage	Between Groups	(Combined)		51.050	8	6.381	176.223	.000
		Linear Term	Contrast	25.215	1	25.215	696.336	.000
			Deviation	25.835	7	3.691	101.921	.000
	Within Groups			.652	18	.036		
	Total			51.702	26			
Zn Underground Passive Storage	Between Groups	(Combined)		26.608	8	3.326	12.131	.000
		Linear Term	Contrast	12.556	1	12.556	45.794	.000
			Deviation	14.052	7	2.007	7.322	.000
	Within Groups			4.935	18	.274		
	Total			31.543	26			
Zn Trench Storage	Between Groups	(Combined)		23.519	8	2.940	19.174	.000
		Linear Term	Contrast	13.883	1	13.883	90.550	.000
			Deviation	9.636	7	1.377	8.978	.000
	Within Groups			2.760	18	.153		
	Total			26.279	26			
Fe Room Storage	Between Groups	(Combined)		11.734	8	1.467	1.204	.351
		Linear	Contrast	.771	1	.771	.633	.437

		Linear Term	Deviation	10.963	7	1.566	1.285	.312
	Within Groups			21.931	18	1.218		
	Total			33.665	26			
Fe Underground Passive Storage	Between Groups	(Combined)		28.215	8	3.527	6.364	.001
		Linear Term	Contrast	5.714	1	5.714	10.311	.005
			Deviation	22.501	7	3.214	5.801	.001
	Within Groups			9.975	18	.554		
	Total			38.189	26			
Fe Trench Storage	Between Groups	(Combined)		16.606	8	2.076	3.050	.024
		Linear Term	Contrast	.662	1	.662	.974	.337
			Deviation	15.943	7	2.278	3.347	.018
	Within Groups			12.249	18	.681		
	Total			28.855	26			
Cu Room Storage	Between Groups	(Combined)		.007	8	.001	3.359	.016
		Linear Term	Contrast	.003	1	.003	10.652	.004
			Deviation	.004	7	.001	2.317	.072
	Within Groups			.005	18	.000		
	Total			.011	26			
Cu Underground Passive Storage	Between Groups	(Combined)		.011	8	.001	.502	.839
		Linear Term	Contrast	.002	1	.002	.637	.435
			Deviation	.009	7	.001	.482	.835
	Within Groups			.049	18	.003		
	Total			.060	26			
Cu Trench Storage	Between Groups	(Combined)		.019	8	.002	3.307	.017
		Linear Term	Contrast	.000	1	.000	.156	.698
			Deviation	.018	7	.003	3.757	.011
	Within Groups			.013	18	.001		
	Total			.031	26			
NITRATE Room Storage	Between Groups	(Combined)		10544.167	8	1318.021	19.000	.000
		Linear Term	Contrast	394.805	1	394.805	5.691	.028
			Deviation	10149.362	7	1449.909	20.901	.000
	Within Groups			1248.637	18	69.369		
	Total			11792.804	26			
NITRATE Underground Passive Storage	Between Groups	(Combined)		5981.771	8	747.721	6.351	.001
		Linear Term	Contrast	1036.272	1	1036.272	8.802	.008
			Deviation	4945.499	7	706.500	6.001	.001
	Within Groups			2119.161	18	117.731		
	Total			8100.932	26			
NITRATE Trench Storage	Between Groups	(Combined)		9737.758	8	1217.220	33.203	.000
		Linear Term	Contrast	1191.711	1	1191.711	32.507	.000
			Deviation	8546.047	7	1220.864	33.302	.000
	Within Groups			659.888	18	36.660		
	Total			10397.646	26			
PHOSPHATE Room Storage	Between Groups	(Combined)		4083.506	8	510.438	1.837	.135
		Linear Term	Contrast	69.664	1	69.664	.251	.623
			Deviation	4013.842	7	573.406	2.064	.102
	Within Groups			5001.457	18	277.859		
	Total			9084.963	26			
PHOSPHATE Underground Passive	Between Groups	(Combined)		19954.524	8	2494.316	2.071	.095
		Linear Term	Contrast	22.684	1	22.684	.019	.892
			Deviation	19931.840	7	2847.406	2.364	.067

Storage	Within Groups		21679.395	18	1204.411		
	Total		41633.919	26			
PHOSPHATE Trench Storage	Between Groups	(Combined)	14088.492	8	1761.062	2.240	.074
		Linear Term Contrast	2224.292	1	2224.292	2.829	.110
		Linear Term Deviation	11864.200	7	1694.886	2.156	.090
	Within Groups		14151.842	18	786.213		
	Total		28240.334	26			
SULPHATE Room Storage	Between Groups	(Combined)	45061.896	8	5632.737	50.712	.000
		Linear Term Contrast	34345.472	1	34345.472	309.216	.000
		Linear Term Deviation	10716.424	7	1530.918	13.783	.000
	Within Groups		1999.307	18	111.073		
	Total		47061.203	26			
SULPHATE Underground Passive Storage	Between Groups	(Combined)	22518.581	8	2814.823	1.128	.391
		Linear Term Contrast	4427.990	1	4427.990	1.775	.199
		Linear Term Deviation	18090.591	7	2584.370	1.036	.441
	Within Groups		44903.635	18	2494.646		
	Total		67422.217	26			
SULPHATE Trench Storage	Between Groups	(Combined)	84944.342	8	10618.043	5.950	.001
		Linear Term Contrast	77083.908	1	77083.908	43.192	.000
		Linear Term Deviation	7860.433	7	1122.919	.629	.726
	Within Groups		32123.946	18	1784.664		
	Total		117068.287	26			

Objective 3.
Titratable Acidity ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		.006	8	.001	4.606	.003
		Linear Term	Contrast	.000	1	.000	.222	.643
			Deviation	.006	7	.001	5.232	.002
	Within Groups			.003	18	.000		
	Total			.009	26			
30Cotton bag	Between Groups	(Combined)		.003	8	.000	1.286	.310
		Linear Term	Contrast	.001	1	.001	2.666	.120
			Deviation	.002	7	.000	1.089	.410
	Within Groups			.006	18	.000		
	Total			.009	26			
30Poly Bag	Between Groups	(Combined)		.499	8	.062	.919	.524
		Linear Term	Contrast	.120	1	.120	1.774	.199
			Deviation	.378	7	.054	.797	.600
	Within Groups			1.221	18	.068		
	Total			1.719	26			
30Plastic crate	Between Groups	(Combined)		.003	8	.000	.469	.862
		Linear Term	Contrast	.002	1	.002	2.468	.134
			Deviation	.001	7	.000	.183	.985
	Within Groups			.015	18	.001		
	Total			.018	26			
30wooden crate	Between Groups	(Combined)		.000	8	.000	.150	.995
		Linear Term	Contrast	.000	1	.000	.246	.626
			Deviation	.000	7	.000	.136	.994
	Within Groups			.004	18	.000		
	Total			.005	26			
60Leno bag	Between Groups	(Combined)		.003	8	.000	1.712	.163
		Linear Term	Contrast	.000	1	.000	.001	.976
			Deviation	.003	7	.000	1.956	.119
	Within Groups			.003	18	.000		
	Total			.006	26			
60Cotton bag	Between Groups	(Combined)		.002	8	.000	.917	.525
		Linear Term	Contrast	.000	1	.000	.412	.529
			Deviation	.001	7	.000	.989	.469
	Within Groups			.004	18	.000		
	Total			.005	26			
60Poly Bag	Between Groups	(Combined)		.006	8	.001	1.954	.113
		Linear Term	Contrast	.006	1	.006	14.323	.001
			Deviation	.001	7	.000	.187	.985
	Within Groups			.007	18	.000		
	Total			.014	26			
60Plastic crate	Between Groups	(Combined)		.004	8	.001	1.182	.362
		Linear Term	Contrast	.003	1	.003	6.722	.018
			Deviation	.001	7	.000	.391	.895
	Within Groups			.008	18	.000		
	Total			.013	26			
60wooden	Between	(Combined)		.001	8	.000	.532	.817

crate	Groups	Linear Term	Contrast	.000	1	.000	.214	.649
			Deviation	.001	7	.000	.578	.765
	Within Groups			.004	18	.000		
	Total			.005	26			
90Leno bag	Between Groups	(Combined)		.001	8	.000	.981	.482
		Linear Term	Contrast	.000	1	.000	.289	.598
			Deviation	.001	7	.000	1.080	.416
	Within Groups			.003	18	.000		
	Total			.004	26			
90Cotton bag	Between Groups	(Combined)		.002	8	.000	.628	.744
		Linear Term	Contrast	.000	1	.000	.076	.785
			Deviation	.002	7	.000	.707	.667
	Within Groups			.006	18	.000		
	Total			.008	26			
90Poly Bag	Between Groups	(Combined)		.010	8	.001	3.584	.012
		Linear Term	Contrast	.005	1	.005	13.241	.002
			Deviation	.006	7	.001	2.204	.084
	Within Groups			.007	18	.000		
	Total			.017	26			
90Plastic crate	Between Groups	(Combined)		.006	8	.001	1.454	.242
		Linear Term	Contrast	.004	1	.004	8.875	.008
			Deviation	.001	7	.000	.394	.894
	Within Groups			.009	18	.001		
	Total			.015	26			
90wooden crate	Between Groups	(Combined)		.002	8	.000	.671	.710
		Linear Term	Contrast	.001	1	.001	2.426	.137
			Deviation	.001	7	.000	.421	.877
	Within Groups			.008	18	.000		
	Total			.010	26			
120Leno bag	Between Groups	(Combined)		.003	8	.000	1.079	.420
		Linear Term	Contrast	.000	1	.000	.150	.703
			Deviation	.003	7	.000	1.211	.346
	Within Groups			.006	18	.000		
	Total			.009	26			
120Cotton bag	Between Groups	(Combined)		.001	8	.000	.464	.866
		Linear Term	Contrast	.000	1	.000	.945	.344
			Deviation	.001	7	.000	.395	.893
	Within Groups			.006	18	.000		
	Total			.007	26			
120Poly Bag	Between Groups	(Combined)		.007	8	.001	3.805	.009
		Linear Term	Contrast	.003	1	.003	10.991	.004
			Deviation	.004	7	.001	2.779	.038
	Within Groups			.004	18	.000		
	Total			.011	26			
120Plastic crate	Between Groups	(Combined)		.002	8	.000	.521	.825
		Linear Term	Contrast	.001	1	.001	2.119	.163
			Deviation	.001	7	.000	.293	.948
	Within Groups			.008	18	.000		
	Total			.009	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear	Contrast	.000	1	.000	.	

			Sum of Squares	df	Mean Square	F	Sig.
		Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150Leno bag	Between Groups	(Combined)	.004	8	.001	1.799	.143
		Linear Term Contrast	.000	1	.000	.330	.573
		Deviation	.004	7	.001	2.009	.110
	Within Groups		.006	18	.000		
	Total		.010	26			
150Cotton bag	Between Groups	(Combined)	.001	8	.000	.665	.715
		Linear Term Contrast	.000	1	.000	.867	.364
		Deviation	.001	7	.000	.636	.720
	Within Groups		.003	18	.000		
	Total		.004	26			
150Poly Bag	Between Groups	(Combined)	.004	8	.001	1.227	.339
		Linear Term Contrast	.002	1	.002	3.842	.066
		Deviation	.003	7	.000	.853	.560
	Within Groups		.008	18	.000		
	Total		.012	26			
150Plastic crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			

Antioxidant activity ANOVA

			Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)	132.635	8	16.579	24.749	.000
		Linear Term Contrast	47.854	1	47.854	71.435	.000
		Deviation	84.781	7	12.112	18.080	.000
	Within Groups		12.058	18	.670		
	Total		144.693	26			
30Cotton bag	Between Groups	(Combined)	143.385	8	17.923	12.814	.000
		Linear Term Contrast	52.986	1	52.986	37.883	.000
		Deviation	90.399	7	12.914	9.233	.000
	Within Groups		25.176	18	1.399		
	Total		168.561	26			
30Poly Bag	Between Groups	(Combined)	171.120	8	21.390	6.169	.001
		Linear Term Contrast	93.860	1	93.860	27.069	.000
		Deviation	77.260	7	11.037	3.183	.022
	Within Groups		62.414	18	3.467		
	Total		233.534	26			
30Plastic crate	Between Groups	(Combined)	198.051	8	24.756	54.161	.000
		Linear Term Contrast	106.969	1	106.969	234.021	.000
		Deviation	91.082	7	13.012	28.466	.000

	Within Groups		8.228	18	.457		
	Total		206.278	26			
30wooden crate	Between Groups	(Combined)	68.601	8	8.575	22.208	.000
		Linear Term Contrast	2.578	1	2.578	6.676	.019
		Deviation	66.023	7	9.432	24.427	.000
	Within Groups		6.950	18	.386		
	Total		75.551	26			
60Leno bag	Between Groups	(Combined)	166.935	8	20.867	26.431	.000
		Linear Term Contrast	81.568	1	81.568	103.318	.000
		Deviation	85.368	7	12.195	15.447	.000
	Within Groups		14.211	18	.789		
	Total		181.146	26			
60Cotton bag	Between Groups	(Combined)	215.489	8	26.936	18.025	.000
		Linear Term Contrast	105.861	1	105.861	70.841	.000
		Deviation	109.628	7	15.661	10.480	.000
	Within Groups		26.898	18	1.494		
	Total		242.387	26			
60Poly Bag	Between Groups	(Combined)	124.118	8	15.515	13.372	.000
		Linear Term Contrast	70.876	1	70.876	61.089	.000
		Deviation	53.241	7	7.606	6.556	.001
	Within Groups		20.884	18	1.160		
	Total		145.002	26			
60Plastic crate	Between Groups	(Combined)	29.774	8	3.722	11.045	.000
		Linear Term Contrast	2.271	1	2.271	6.741	.018
		Deviation	27.502	7	3.929	11.660	.000
	Within Groups		6.065	18	.337		
	Total		35.839	26			
60wooden crate	Between Groups	(Combined)	77.738	8	9.717	23.493	.000
		Linear Term Contrast	5.682	1	5.682	13.737	.002
		Deviation	72.056	7	10.294	24.887	.000
	Within Groups		7.445	18	.414		
	Total		85.183	26			
90Leno bag	Between Groups	(Combined)	41.752	8	5.219	9.216	.000
		Linear Term Contrast	.000	1	.000	.000	.998
		Deviation	41.752	7	5.965	10.533	.000
	Within Groups		10.193	18	.566		
	Total		51.945	26			
90Cotton bag	Between Groups	(Combined)	39.924	8	4.990	2.600	.044
		Linear Term Contrast	.391	1	.391	.204	.657
		Deviation	39.533	7	5.648	2.943	.031
	Within Groups		34.543	18	1.919		
	Total		74.467	26			
90Poly Bag	Between Groups	(Combined)	168.248	8	21.031	9.369	.000
		Linear Term Contrast	107.725	1	107.725	47.989	.000
		Deviation	60.523	7	8.646	3.852	.010
	Within Groups		40.407	18	2.245		
	Total		208.655	26			
90Plastic crate	Between Groups	(Combined)	69.445	8	8.681	22.253	.000
		Linear Term Contrast	4.957	1	4.957	12.707	.002
		Deviation	64.488	7	9.213	23.616	.000
	Within Groups		7.022	18	.390		

		Total		76.466	26			
90wooden crate	Between Groups	(Combined)		58.590	8	7.324	14.114	.000
		Linear Term	Contrast	1.865	1	1.865	3.593	.074
			Deviation	56.726	7	8.104	15.617	.000
	Within Groups			9.340	18	.519		
	Total			67.931	26			
120Leno bag	Between Groups	(Combined)		58.390	8	7.299	7.820	.000
		Linear Term	Contrast	3.147	1	3.147	3.372	.083
			Deviation	55.243	7	7.892	8.455	.000
	Within Groups			16.801	18	.933		
	Total			75.191	26			
120Cotton bag	Between Groups	(Combined)		79.503	8	9.938	7.520	.000
		Linear Term	Contrast	5.611	1	5.611	4.246	.054
			Deviation	73.892	7	10.556	7.988	.000
	Within Groups			23.786	18	1.321		
	Total			103.289	26			
120Poly Bag	Between Groups	(Combined)		52.141	8	6.518	2.666	.040
		Linear Term	Contrast	21.535	1	21.535	8.809	.008
			Deviation	30.606	7	4.372	1.789	.151
	Within Groups			44.002	18	2.445		
	Total			96.143	26			
120Plastic crate	Between Groups	(Combined)		33.981	8	4.248	6.510	.000
		Linear Term	Contrast	6.689	1	6.689	10.253	.005
			Deviation	27.292	7	3.899	5.976	.001
	Within Groups			11.744	18	.652		
	Total			45.725	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		20.532	8	2.566	4.349	.005
		Linear Term	Contrast	4.443	1	4.443	7.530	.013
			Deviation	16.089	7	2.298	3.895	.009
	Within Groups			10.621	18	.590		
	Total			31.153	26			
150Cotton bag	Between Groups	(Combined)		20.319	8	2.540	2.003	.105
		Linear Term	Contrast	6.994	1	6.994	5.514	.030
			Deviation	13.326	7	1.904	1.501	.229
	Within Groups			22.828	18	1.268		
	Total			43.147	26			
150Poly Bag	Between Groups	(Combined)		95.803	8	11.975	5.556	.001
		Linear Term	Contrast	44.154	1	44.154	20.484	.000
			Deviation	51.649	7	7.378	3.423	.017
	Within Groups			38.800	18	2.156		
	Total			134.603	26			
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

				Sum of Squares	df	Mean Square	F	Sig.
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

Ascorbic acid ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		11.300	8	1.413	1.736	.158
		Linear Term	Contrast	9.439	1	9.439	11.600	.003
			Deviation	1.861	7	.266	.327	.932
	Within Groups			14.648	18	.814		
	Total			25.948	26			
30Cotton bag	Between Groups	(Combined)		7.826	8	.978	1.718	.162
		Linear Term	Contrast	7.061	1	7.061	12.396	.002
			Deviation	.766	7	.109	.192	.983
	Within Groups			10.252	18	.570		
	Total			18.079	26			
30Poly Bag	Between Groups	(Combined)		18.854	8	2.357	15.962	.000
		Linear Term	Contrast	16.248	1	16.248	110.048	.000
			Deviation	2.606	7	.372	2.522	.054
	Within Groups			2.658	18	.148		
	Total			21.512	26			
30Plastic crate	Between Groups	(Combined)		4.088	8	.511	.864	.563
		Linear Term	Contrast	1.893	1	1.893	3.200	.090
			Deviation	2.194	7	.313	.530	.801
	Within Groups			10.648	18	.592		
	Total			14.735	26			
30wooden crate	Between Groups	(Combined)		3.796	8	.475	.946	.505
		Linear Term	Contrast	.602	1	.602	1.201	.288
			Deviation	3.194	7	.456	.910	.521
	Within Groups			9.026	18	.501		
	Total			12.823	26			
60Leno bag	Between Groups	(Combined)		9.976	8	1.247	1.833	.136
		Linear Term	Contrast	6.659	1	6.659	9.790	.006
			Deviation	3.317	7	.474	.697	.674
	Within Groups			12.242	18	.680		
	Total			22.218	26			
60Cotton bag	Between Groups	(Combined)		13.373	8	1.672	2.694	.038
		Linear Term	Contrast	12.335	1	12.335	19.879	.000
			Deviation	1.038	7	.148	.239	.970
	Within Groups			11.169	18	.621		
	Total			24.542	26			
60Poly Bag	Between Groups	(Combined)		13.126	8	1.641	6.538	.000
		Linear Term	Contrast	9.674	1	9.674	38.550	.000
			Deviation	3.452	7	.493	1.965	.118
	Within Groups			4.517	18	.251		
	Total			17.643	26			
60Plastic	Between	(Combined)		6.128	8	.766	2.444	.055

crate	Groups	Linear Term	Contrast	5.003	1	5.003	15.967	.001
			Deviation	1.124	7	.161	.513	.813
	Within Groups			5.640	18	.313		
	Total			11.768	26			
60wooden crate	Between Groups	(Combined)		2.172	8	.271	.271	.967
		Linear Term	Contrast	1.867	1	1.867	1.864	.189
			Deviation	.305	7	.044	.044	1.000
	Within Groups			18.024	18	1.001		
	Total			20.196	26			
90Leno bag	Between Groups	(Combined)		9.617	8	1.202	1.068	.426
		Linear Term	Contrast	7.519	1	7.519	6.681	.019
			Deviation	2.097	7	.300	.266	.959
	Within Groups			20.258	18	1.125		
	Total			29.874	26			
90Cotton bag	Between Groups	(Combined)		15.007	8	1.876	2.734	.036
		Linear Term	Contrast	12.731	1	12.731	18.556	.000
			Deviation	2.276	7	.325	.474	.841
	Within Groups			12.350	18	.686		
	Total			27.356	26			
90Poly Bag	Between Groups	(Combined)		15.690	8	1.961	7.040	.000
		Linear Term	Contrast	11.740	1	11.740	42.142	.000
			Deviation	3.950	7	.564	2.025	.108
	Within Groups			5.015	18	.279		
	Total			20.705	26			
90Plastic crate	Between Groups	(Combined)		5.698	8	.712	1.014	.460
		Linear Term	Contrast	4.782	1	4.782	6.809	.018
			Deviation	.916	7	.131	.186	.985
	Within Groups			12.642	18	.702		
	Total			18.340	26			
90wooden crate	Between Groups	(Combined)		3.910	8	.489	1.079	.420
		Linear Term	Contrast	2.865	1	2.865	6.322	.022
			Deviation	1.045	7	.149	.329	.930
	Within Groups			8.158	18	.453		
	Total			12.068	26			
120Leno bag	Between Groups	(Combined)		14.118	8	1.765	2.375	.061
		Linear Term	Contrast	12.450	1	12.450	16.757	.001
			Deviation	1.667	7	.238	.321	.935
	Within Groups			13.374	18	.743		
	Total			27.492	26			
120Cotton bag	Between Groups	(Combined)		19.271	8	2.409	3.185	.020
		Linear Term	Contrast	13.111	1	13.111	17.335	.001
			Deviation	6.160	7	.880	1.163	.370
	Within Groups			13.614	18	.756		
	Total			32.885	26			
120Poly Bag	Between Groups	(Combined)		10.956	8	1.370	4.815	.003
		Linear Term	Contrast	7.934	1	7.934	27.895	.000
			Deviation	3.022	7	.432	1.518	.224
	Within Groups			5.120	18	.284		
	Total			16.076	26			
120Plastic crate	Between Groups	(Combined)		5.169	8	.646	1.603	.193
		Linear	Contrast	3.026	1	3.026	7.507	.013

		Linear Term Deviation	2.143	7	.306	.759	.628
	Within Groups		7.256	18	.403		
	Total		12.425	26			
120wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150Leno bag	Between Groups	(Combined)	11.520	8	1.440	1.255	.325
		Linear Term Contrast	6.054	1	6.054	5.278	.034
		Linear Term Deviation	5.466	7	.781	.681	.687
	Within Groups		20.645	18	1.147		
	Total		32.165	26			
150Cotton bag	Between Groups	(Combined)	9.482	8	1.185	2.931	.028
		Linear Term Contrast	4.465	1	4.465	11.043	.004
		Linear Term Deviation	5.017	7	.717	1.773	.155
	Within Groups		7.278	18	.404		
	Total		16.760	26			
150Poly Bag	Between Groups	(Combined)	10.898	8	1.362	4.140	.006
		Linear Term Contrast	8.694	1	8.694	26.421	.000
		Linear Term Deviation	2.204	7	.315	.957	.490
	Within Groups		5.923	18	.329		
	Total		16.822	26			
150Plastic crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			

Total flavonoids content ANOVA

			Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)	3.153	8	.394	5.522	.001
		Linear Term Contrast	1.010	1	1.010	14.144	.001
		Linear Term Deviation	2.144	7	.306	4.290	.006
	Within Groups		1.285	18	.071		
	Total		4.438	26			
30Cotton bag	Between Groups	(Combined)	2.968	8	.371	8.677	.000
		Linear Term Contrast	.879	1	.879	20.562	.000
		Linear Term Deviation	2.089	7	.298	6.980	.000
	Within Groups		.770	18	.043		
	Total		3.738	26			
30Poly Bag	Between Groups	(Combined)	3.420	8	.427	7.047	.000
		Linear Term Contrast	1.189	1	1.189	19.604	.000
		Linear Term Deviation	2.231	7	.319	5.254	.002

	Within Groups		1.092	18	.061		
	Total		4.512	26			
30Plastic crate	Between Groups	(Combined)	3.803	8	.475	7.893	.000
		Linear Term Contrast	1.119	1	1.119	18.572	.000
		Linear Term Deviation	2.685	7	.384	6.368	.001
	Within Groups		1.084	18	.060		
	Total		4.888	26			
30wooden crate	Between Groups	(Combined)	3.561	8	.445	7.941	.000
		Linear Term Contrast	.923	1	.923	16.467	.001
		Linear Term Deviation	2.638	7	.377	6.723	.001
	Within Groups		1.009	18	.056		
	Total		4.570	26			
60Leno bag	Between Groups	(Combined)	3.391	8	.424	7.440	.000
		Linear Term Contrast	1.026	1	1.026	18.008	.000
		Linear Term Deviation	2.365	7	.338	5.931	.001
	Within Groups		1.026	18	.057		
	Total		4.417	26			
60Cotton bag	Between Groups	(Combined)	2.766	8	.346	10.658	.000
		Linear Term Contrast	.905	1	.905	27.883	.000
		Linear Term Deviation	1.861	7	.266	8.197	.000
	Within Groups		.584	18	.032		
	Total		3.350	26			
60Poly Bag	Between Groups	(Combined)	3.288	8	.411	7.737	.000
		Linear Term Contrast	1.087	1	1.087	20.470	.000
		Linear Term Deviation	2.201	7	.314	5.918	.001
	Within Groups		.956	18	.053		
	Total		4.244	26			
60Plastic crate	Between Groups	(Combined)	2.718	8	.340	4.313	.005
		Linear Term Contrast	1.130	1	1.130	14.342	.001
		Linear Term Deviation	1.588	7	.227	2.881	.033
	Within Groups		1.418	18	.079		
	Total		4.136	26			
60wooden crate	Between Groups	(Combined)	2.594	8	.324	2.890	.029
		Linear Term Contrast	1.063	1	1.063	9.472	.006
		Linear Term Deviation	1.531	7	.219	1.950	.120
	Within Groups		2.019	18	.112		
	Total		4.613	26			
90Leno bag	Between Groups	(Combined)	2.929	8	.366	2.983	.026
		Linear Term Contrast	1.133	1	1.133	9.231	.007
		Linear Term Deviation	1.796	7	.257	2.091	.098
	Within Groups		2.209	18	.123		
	Total		5.138	26			
90Cotton bag	Between Groups	(Combined)	3.142	8	.393	9.665	.000
		Linear Term Contrast	.896	1	.896	22.050	.000
		Linear Term Deviation	2.246	7	.321	7.896	.000
	Within Groups		.731	18	.041		
	Total		3.874	26			
90Poly Bag	Between Groups	(Combined)	2.678	8	.335	5.225	.002
		Linear Term Contrast	1.081	1	1.081	16.876	.001
		Linear Term Deviation	1.597	7	.228	3.560	.014
	Within Groups		1.153	18	.064		

	Total		3.831	26			
90Plastic crate	Between Groups	(Combined)	3.299	8	.412	12.437	.000
		Linear Term Contrast	.967	1	.967	29.148	.000
		Linear Term Deviation	2.333	7	.333	10.049	.000
	Within Groups		.597	18	.033		
	Total		3.896	26			
90wooden crate	Between Groups	(Combined)	1.777	8	.222	4.159	.006
		Linear Term Contrast	.623	1	.623	11.665	.003
		Linear Term Deviation	1.154	7	.165	3.087	.025
	Within Groups		.961	18	.053		
	Total		2.738	26			
120Leno bag	Between Groups	(Combined)	3.245	8	.406	14.553	.000
		Linear Term Contrast	1.158	1	1.158	41.559	.000
		Linear Term Deviation	2.087	7	.298	10.695	.000
	Within Groups		.502	18	.028		
	Total		3.747	26			
120Cotton bag	Between Groups	(Combined)	3.100	8	.388	9.269	.000
		Linear Term Contrast	.779	1	.779	18.628	.000
		Linear Term Deviation	2.321	7	.332	7.932	.000
	Within Groups		.753	18	.042		
	Total		3.853	26			
120Poly Bag	Between Groups	(Combined)	3.166	8	.396	6.218	.001
		Linear Term Contrast	.964	1	.964	15.140	.001
		Linear Term Deviation	2.203	7	.315	4.944	.003
	Within Groups		1.146	18	.064		
	Total		4.312	26			
120Plastic crate	Between Groups	(Combined)	1.889	8	.236	8.674	.000
		Linear Term Contrast	.474	1	.474	17.419	.001
		Linear Term Deviation	1.415	7	.202	7.424	.000
	Within Groups		.490	18	.027		
	Total		2.380	26			
120wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150Leno bag	Between Groups	(Combined)	2.312	8	.289	9.404	.000
		Linear Term Contrast	.628	1	.628	20.431	.000
		Linear Term Deviation	1.684	7	.241	7.829	.000
	Within Groups		.553	18	.031		
	Total		2.865	26			
150Cotton bag	Between Groups	(Combined)	2.688	8	.336	8.341	.000
		Linear Term Contrast	.667	1	.667	16.565	.001
		Linear Term Deviation	2.021	7	.289	7.166	.000
	Within Groups		.725	18	.040		
	Total		3.413	26			
150Poly Bag	Between Groups	(Combined)	2.821	8	.353	8.359	.000
		Linear Term Contrast	.758	1	.758	17.963	.000
		Linear Term Deviation	2.063	7	.295	6.987	.000
	Within Groups		.759	18	.042		
	Total		3.581	26			

				Sum of Squares	df	Mean Square	F	Sig.
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

Total phenolic content ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		26.288	8	3.286	7.155	.000
		Linear Term	Contrast	2.502	1	2.502	5.447	.031
			Deviation	23.787	7	3.398	7.400	.000
	Within Groups			8.266	18	.459		
	Total			34.554	26			
30Cotton bag	Between Groups	(Combined)		21.719	8	2.715	8.940	.000
		Linear Term	Contrast	1.002	1	1.002	3.300	.086
			Deviation	20.717	7	2.960	9.746	.000
	Within Groups			5.466	18	.304		
	Total			27.185	26			
30Poly Bag	Between Groups	(Combined)		20.395	8	2.549	6.107	.001
		Linear Term	Contrast	1.312	1	1.312	3.144	.093
			Deviation	19.083	7	2.726	6.530	.001
	Within Groups			7.515	18	.417		
	Total			27.910	26			
30Plastic crate	Between Groups	(Combined)		22.072	8	2.759	7.718	.000
		Linear Term	Contrast	1.790	1	1.790	5.007	.038
			Deviation	20.282	7	2.897	8.105	.000
	Within Groups			6.435	18	.358		
	Total			28.507	26			
30wooden crate	Between Groups	(Combined)		25.570	8	3.196	7.718	.000
		Linear Term	Contrast	2.202	1	2.202	5.318	.033
			Deviation	23.367	7	3.338	8.061	.000
	Within Groups			7.454	18	.414		
	Total			33.024	26			
60Leno bag	Between Groups	(Combined)		26.192	8	3.274	7.052	.000
		Linear Term	Contrast	2.499	1	2.499	5.384	.032
			Deviation	23.693	7	3.385	7.291	.000
	Within Groups			8.356	18	.464		
	Total			34.548	26			
60Cotton bag	Between Groups	(Combined)		27.932	8	3.492	9.559	.000
		Linear Term	Contrast	1.323	1	1.323	3.621	.073
			Deviation	26.609	7	3.801	10.407	.000
	Within Groups			6.575	18	.365		
	Total			34.507	26			

60Poly Bag	Between Groups	(Combined)		16.611	8	2.076	4.645	.003
		Linear Term	Contrast	1.715	1	1.715	3.837	.066
			Deviation	14.896	7	2.128	4.760	.004
	Within Groups			8.046	18	.447		
	Total			24.658	26			
60Plastic crate	Between Groups	(Combined)		21.909	8	2.739	5.250	.002
		Linear Term	Contrast	2.367	1	2.367	4.537	.047
			Deviation	19.543	7	2.792	5.352	.002
	Within Groups			9.390	18	.522		
	Total			31.300	26			
60wooden crate	Between Groups	(Combined)		18.280	8	2.285	5.483	.001
		Linear Term	Contrast	.897	1	.897	2.153	.160
			Deviation	17.383	7	2.483	5.958	.001
	Within Groups			7.502	18	.417		
	Total			25.782	26			
90Leno bag	Between Groups	(Combined)		26.113	8	3.264	5.807	.001
		Linear Term	Contrast	2.635	1	2.635	4.688	.044
			Deviation	23.478	7	3.354	5.966	.001
	Within Groups			10.118	18	.562		
	Total			36.231	26			
90Cotton bag	Between Groups	(Combined)		19.310	8	2.414	4.411	.004
		Linear Term	Contrast	1.184	1	1.184	2.164	.159
			Deviation	18.126	7	2.589	4.732	.004
	Within Groups			9.850	18	.547		
	Total			29.160	26			
90Poly Bag	Between Groups	(Combined)		18.877	8	2.360	5.146	.002
		Linear Term	Contrast	2.204	1	2.204	4.807	.042
			Deviation	16.673	7	2.382	5.194	.002
	Within Groups			8.254	18	.459		
	Total			27.131	26			
90Plastic crate	Between Groups	(Combined)		22.923	8	2.865	3.423	.014
		Linear Term	Contrast	2.132	1	2.132	2.547	.128
			Deviation	20.791	7	2.970	3.548	.014
	Within Groups			15.068	18	.837		
	Total			37.991	26			
90wooden crate	Between Groups	(Combined)		16.771	8	2.096	2.344	.064
		Linear Term	Contrast	.771	1	.771	.862	.365
			Deviation	16.000	7	2.286	2.556	.051
	Within Groups			16.096	18	.894		
	Total			32.867	26			
120Leno bag	Between Groups	(Combined)		27.386	8	3.423	6.843	.000
		Linear Term	Contrast	1.524	1	1.524	3.046	.098
			Deviation	25.863	7	3.695	7.386	.000
	Within Groups			9.004	18	.500		
	Total			36.390	26			
120Cotton bag	Between Groups	(Combined)		19.391	8	2.424	9.053	.000
		Linear Term	Contrast	.864	1	.864	3.227	.089
			Deviation	18.527	7	2.647	9.886	.000
	Within Groups			4.819	18	.268		
	Total			24.210	26			
120Poly Bag	Between	(Combined)		19.729	8	2.466	6.327	.001

				Sum of Squares	df	Mean Square	F	Sig.
	Groups	Linear Term	Contrast	2.089	1	2.089	5.359	.033
			Deviation	17.641	7	2.520	6.465	.001
	Within Groups			7.016	18	.390		
	Total			26.745	26			
120Plastic crate	Between Groups	(Combined)		15.798	8	1.975	4.316	.005
		Linear Term	Contrast	2.152	1	2.152	4.702	.044
			Deviation	13.647	7	1.950	4.260	.006
	Within Groups			8.237	18	.458		
	Total			24.035	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		15.278	8	1.910	7.324	.000
		Linear Term	Contrast	.917	1	.917	3.518	.077
			Deviation	14.360	7	2.051	7.868	.000
	Within Groups			4.693	18	.261		
	Total			19.971	26			
150Cotton bag	Between Groups	(Combined)		12.629	8	1.579	4.131	.006
		Linear Term	Contrast	1.064	1	1.064	2.785	.112
			Deviation	11.565	7	1.652	4.324	.006
	Within Groups			6.878	18	.382		
	Total			19.507	26			
150Poly Bag	Between Groups	(Combined)		18.785	8	2.348	6.117	.001
		Linear Term	Contrast	2.220	1	2.220	5.783	.027
			Deviation	16.565	7	2.366	6.165	.001
	Within Groups			6.910	18	.384		
	Total			25.695	26			
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

Carotene content ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		2189543.144	8	273692.893	13.756	.000
		Linear Term	Contrast	2108098.432	1	2108098.432	105.955	.000
			Deviation	81444.712	7	11634.959	.585	.760
	Within Groups			358132.453	18	19896.247		
	Total			2547675.597	26			
30Cotton	Between	(Combined)		2282462.621	8	285307.828	76.894	.000

bag	Groups	Linear Term	Contrast	2162736.227	1	2162736.227	582.885	.000
			Deviation	119726.394	7	17103.771	4.610	.004
	Within Groups			66787.152	18	3710.397		
	Total			2349249.773	26			
30Poly Bag	Between Groups	(Combined)		1497993.842	8	187249.230	40.369	.000
		Linear Term	Contrast	1333206.923	1	1333206.923	287.425	.000
			Deviation	164786.919	7	23540.988	5.075	.003
	Within Groups			83492.040	18	4638.447		
	Total			1581485.883	26			
30Plastic crate	Between Groups	(Combined)		2238550.758	8	279818.845	82.629	.000
		Linear Term	Contrast	2061656.747	1	2061656.747	608.795	.000
			Deviation	176894.011	7	25270.573	7.462	.000
	Within Groups			60956.173	18	3386.454		
	Total			2299506.931	26			
30wooden crate	Between Groups	(Combined)		1451849.465	8	181481.183	46.607	.000
		Linear Term	Contrast	1299655.272	1	1299655.272	333.773	.000
			Deviation	152194.194	7	21742.028	5.584	.002
	Within Groups			70089.041	18	3893.836		
	Total			1521938.507	26			
60Leno bag	Between Groups	(Combined)		2046810.677	8	255851.335	47.676	.000
		Linear Term	Contrast	1839977.450	1	1839977.450	342.864	.000
			Deviation	206833.227	7	29547.604	5.506	.002
	Within Groups			96596.772	18	5366.487		
	Total			2143407.449	26			
60Cotton bag	Between Groups	(Combined)		2227464.641	8	278433.080	53.833	.000
		Linear Term	Contrast	2030548.883	1	2030548.883	392.595	.000
			Deviation	196915.757	7	28130.822	5.439	.002
	Within Groups			93098.294	18	5172.127		
	Total			2320562.934	26			
60Poly Bag	Between Groups	(Combined)		1387954.831	8	173494.354	23.522	.000
		Linear Term	Contrast	1292331.774	1	1292331.774	175.214	.000
			Deviation	95623.057	7	13660.437	1.852	.138
	Within Groups			132763.076	18	7375.726		
	Total			1520717.908	26			
60Plastic crate	Between Groups	(Combined)		2235942.682	8	279492.835	130.383	.000
		Linear Term	Contrast	1895083.639	1	1895083.639	884.053	.000
			Deviation	340859.044	7	48694.149	22.716	.000
	Within Groups			38585.348	18	2143.630		
	Total			2274528.031	26			
60wooden crate	Between Groups	(Combined)		1543557.174	8	192944.647	43.206	.000
		Linear Term	Contrast	1363894.148	1	1363894.148	305.414	.000
			Deviation	179663.026	7	25666.147	5.747	.001
	Within Groups			80382.991	18	4465.722		
	Total			1623940.165	26			
90Leno bag	Between	(Combined)		2118864.500	8	264858.063	94.289	.000

	Groups	Linear Term	Contrast	1918306.291	1	1918306.291	682.912	.000
			Deviation	200558.210	7	28651.173	10.200	.000
	Within Groups			50562.190	18	2809.011		
	Total			2169426.690	26			
90Cotton bag	Between Groups	(Combined)		2930488.423	8	366311.053	89.042	.000
		Linear Term	Contrast	2569053.027	1	2569053.027	624.481	.000
			Deviation	361435.395	7	51633.628	12.551	.000
	Within Groups			74050.244	18	4113.902		
	Total			3004538.667	26			
90Poly Bag	Between Groups	(Combined)		1366766.736	8	170845.842	35.520	.000
		Linear Term	Contrast	1291023.325	1	1291023.325	268.410	.000
			Deviation	75743.411	7	10820.487	2.250	.079
	Within Groups			86578.143	18	4809.897		
	Total			1453344.879	26			
90Plastic crate	Between Groups	(Combined)		1747972.082	8	218496.510	25.099	.000
		Linear Term	Contrast	1605553.907	1	1605553.907	184.430	.000
			Deviation	142418.174	7	20345.453	2.337	.070
	Within Groups			156698.894	18	8705.494		
	Total			1904670.976	26			
90wooden crate	Between Groups	(Combined)		1523406.702	8	190425.838	27.524	.000
		Linear Term	Contrast	1384401.623	1	1384401.623	200.103	.000
			Deviation	139005.079	7	19857.868	2.870	.034
	Within Groups			124531.791	18	6918.433		
	Total			1647938.493	26			
120Leno bag	Between Groups	(Combined)		1942350.071	8	242793.759	18.116	.000
		Linear Term	Contrast	1589304.793	1	1589304.793	118.583	.000
			Deviation	353045.278	7	50435.040	3.763	.011
	Within Groups			241245.397	18	13402.522		
	Total			2183595.468	26			
120Cotton bag	Between Groups	(Combined)		1683007.904	8	210375.988	37.142	.000
		Linear Term	Contrast	1518028.149	1	1518028.149	268.010	.000
			Deviation	164979.755	7	23568.536	4.161	.007
	Within Groups			101953.188	18	5664.066		
	Total			1784961.092	26			
120Poly Bag	Between Groups	(Combined)		2327830.708	8	290978.838	52.372	.000
		Linear Term	Contrast	2191447.544	1	2191447.544	394.427	.000
			Deviation	136383.164	7	19483.309	3.507	.015
	Within Groups			100008.624	18	5556.035		
	Total			2427839.332	26			
120Plastic crate	Between Groups	(Combined)		2466480.021	8	308310.003	45.203	.000
		Linear Term	Contrast	2084328.685	1	2084328.685	305.596	.000
			Deviation	382151.336	7	54593.048	8.004	.000
	Within Groups			122769.693	18	6820.538		
	Total			2589249.714	26			
120wooden	Between	(Combined)		.000	8	.000	.	.

crate	Groups	Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		1392836.229	8	174104.529	11.898	.000
		Linear Term	Contrast	1105507.520	1	1105507.520	75.546	.000
			Deviation	287328.709	7	41046.958	2.805	.037
	Within Groups			263403.104	18	14633.506		
	Total			1656239.332	26			
150Cotton bag	Between Groups	(Combined)		2179522.305	8	272440.288	35.122	.000
		Linear Term	Contrast	1983051.269	1	1983051.269	255.647	.000
			Deviation	196471.035	7	28067.291	3.618	.013
	Within Groups			139625.904	18	7756.995		
	Total			2319148.209	26			
150Poly Bag	Between Groups	(Combined)		2067165.370	8	258395.671	33.259	.000
		Linear Term	Contrast	2014957.411	1	2014957.411	259.353	.000
			Deviation	52207.959	7	7458.280	.960	.488
	Within Groups			139844.799	18	7769.155		
	Total			2207010.169	26			
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

Copper content ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		.029	8	.004	1.588	.197
		Linear Term	Contrast	.002	1	.002	.716	.409
			Deviation	.027	7	.004	1.712	.169
	Within Groups			.041	18	.002		
	Total			.069	26			
30Cotton bag	Between Groups	(Combined)		.031	8	.004	2.000	.106
		Linear Term	Contrast	.001	1	.001	.463	.505
			Deviation	.030	7	.004	2.220	.082
	Within Groups			.035	18	.002		
	Total			.065	26			
30Poly Bag	Between Groups	(Combined)		.038	8	.005	3.165	.020
		Linear Term	Contrast	.002	1	.002	1.406	.251
			Deviation	.036	7	.005	3.417	.017
	Within Groups			.027	18	.002		

		Total		.066	26			
30Plastic crate	Between Groups	(Combined)		.035	8	.004	4.192	.006
		Linear Term	Contrast	.004	1	.004	4.274	.053
			Deviation	.030	7	.004	4.181	.007
	Within Groups			.019	18	.001		
	Total			.053	26			
30wooden crate	Between Groups	(Combined)		.019	8	.002	3.052	.023
		Linear Term	Contrast	.003	1	.003	3.949	.062
			Deviation	.016	7	.002	2.923	.031
	Within Groups			.014	18	.001		
	Total			.033	26			
60Leno bag	Between Groups	(Combined)		.031	8	.004	1.079	.420
		Linear Term	Contrast	.000	1	.000	.008	.931
			Deviation	.031	7	.004	1.232	.336
	Within Groups			.064	18	.004		
	Total			.094	26			
60Cotton bag	Between Groups	(Combined)		.042	8	.005	3.182	.020
		Linear Term	Contrast	.004	1	.004	2.152	.160
			Deviation	.038	7	.005	3.329	.019
	Within Groups			.030	18	.002		
	Total			.072	26			
60Poly Bag	Between Groups	(Combined)		.044	8	.005	1.769	.150
		Linear Term	Contrast	.003	1	.003	.980	.335
			Deviation	.041	7	.006	1.882	.132
	Within Groups			.056	18	.003		
	Total			.100	26			
60Plastic crate	Between Groups	(Combined)		.019	8	.002	5.415	.001
		Linear Term	Contrast	.000	1	.000	.927	.348
			Deviation	.019	7	.003	6.056	.001
	Within Groups			.008	18	.000		
	Total			.027	26			
60wooden crate	Between Groups	(Combined)		.010	8	.001	1.473	.235
		Linear Term	Contrast	.000	1	.000	.115	.738
			Deviation	.010	7	.001	1.667	.180
	Within Groups			.015	18	.001		
	Total			.024	26			
90Leno bag	Between Groups	(Combined)		.018	8	.002	2.826	.032
		Linear Term	Contrast	.001	1	.001	1.712	.207
			Deviation	.017	7	.002	2.986	.029
	Within Groups			.015	18	.001		
	Total			.033	26			
90Cotton bag	Between Groups	(Combined)		.053	8	.007	8.200	.000
		Linear Term	Contrast	.002	1	.002	2.236	.152
			Deviation	.051	7	.007	9.052	.000
	Within Groups			.015	18	.001		
	Total			.067	26			
90Poly Bag	Between Groups	(Combined)		.015	8	.002	2.566	.046
		Linear Term	Contrast	.000	1	.000	.378	.546
			Deviation	.014	7	.002	2.879	.033
	Within Groups			.013	18	.001		
	Total			.027	26			

90Plastic crate	Between Groups	(Combined)		.039	8	.005	15.045	.000
		Linear Term	Contrast	.014	1	.014	41.482	.000
			Deviation	.026	7	.004	11.269	.000
	Within Groups			.006	18	.000		
	Total			.045	26			
90wooden crate	Between Groups	(Combined)		.012	8	.002	2.280	.070
		Linear Term	Contrast	.000	1	.000	.263	.615
			Deviation	.012	7	.002	2.568	.051
	Within Groups			.012	18	.001		
	Total			.025	26			
120Leno bag	Between Groups	(Combined)		.023	8	.003	1.892	.124
		Linear Term	Contrast	.002	1	.002	1.481	.239
			Deviation	.020	7	.003	1.951	.120
	Within Groups			.027	18	.001		
	Total			.049	26			
120Cotton bag	Between Groups	(Combined)		.012	8	.002	2.226	.076
		Linear Term	Contrast	.001	1	.001	1.220	.284
			Deviation	.011	7	.002	2.370	.066
	Within Groups			.012	18	.001		
	Total			.025	26			
120Poly Bag	Between Groups	(Combined)		.025	8	.003	4.239	.005
		Linear Term	Contrast	.000	1	.000	.512	.483
			Deviation	.024	7	.003	4.771	.004
	Within Groups			.013	18	.001		
	Total			.038	26			
120Plastic crate	Between Groups	(Combined)		.033	8	.004	12.027	.000
		Linear Term	Contrast	.015	1	.015	43.381	.000
			Deviation	.018	7	.003	7.548	.000
	Within Groups			.006	18	.000		
	Total			.039	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		.011	8	.001	.502	.839
		Linear Term	Contrast	.002	1	.002	.637	.435
			Deviation	.009	7	.001	.482	.835
	Within Groups			.049	18	.003		
	Total			.060	26			
150Cotton bag	Between Groups	(Combined)		.010	8	.001	2.022	.102
		Linear Term	Contrast	.001	1	.001	2.057	.169
			Deviation	.009	7	.001	2.017	.109
	Within Groups			.011	18	.001		
	Total			.021	26			
150Poly Bag	Between Groups	(Combined)		.012	8	.001	1.769	.150
		Linear Term	Contrast	.000	1	.000	.111	.743
			Deviation	.012	7	.002	2.005	.111
	Within Groups			.015	18	.001		
	Total			.027	26			
150Plastic	Between	(Combined)		.000	8	.000	.	.

				Sum of Squares	df	Mean Square	F	Sig.
crate	Groups	Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

Iron content ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		24.841	8	3.105	5.586	.001
		Linear Term	Contrast	9.271	1	9.271	16.678	.001
			Deviation	15.571	7	2.224	4.002	.008
	Within Groups			10.005	18	.556		
	Total			34.847	26			
30Cotton bag	Between Groups	(Combined)		4.822	8	.603	2.272	.071
		Linear Term	Contrast	2.721	1	2.721	10.255	.005
			Deviation	2.101	7	.300	1.131	.387
	Within Groups			4.776	18	.265		
	Total			9.598	26			
30Poly Bag	Between Groups	(Combined)		4.396	8	.550	1.976	.110
		Linear Term	Contrast	1.429	1	1.429	5.140	.036
			Deviation	2.967	7	.424	1.524	.222
	Within Groups			5.005	18	.278		
	Total			9.401	26			
30Plastic crate	Between Groups	(Combined)		23.381	8	2.923	6.132	.001
		Linear Term	Contrast	4.247	1	4.247	8.911	.008
			Deviation	19.133	7	2.733	5.735	.001
	Within Groups			8.580	18	.477		
	Total			31.960	26			
30wooden crate	Between Groups	(Combined)		23.328	8	2.916	5.658	.001
		Linear Term	Contrast	6.628	1	6.628	12.860	.002
			Deviation	16.701	7	2.386	4.629	.004
	Within Groups			9.277	18	.515		
	Total			32.606	26			
60Leno bag	Between Groups	(Combined)		49.644	8	6.205	10.440	.000
		Linear Term	Contrast	9.135	1	9.135	15.368	.001
			Deviation	40.509	7	5.787	9.736	.000
	Within Groups			10.699	18	.594		
	Total			60.343	26			
60Cotton bag	Between Groups	(Combined)		28.072	8	3.509	18.895	.000
		Linear Term	Contrast	4.116	1	4.116	22.165	.000
			Deviation	23.956	7	3.422	18.428	.000
	Within Groups			3.343	18	.186		
	Total			31.415	26			
60Poly Bag	Between Groups	(Combined)		20.777	8	2.597	7.976	.000
		Linear	Contrast	1.453	1	1.453	4.461	.049

		Term Deviation	19.324	7	2.761	8.478	.000
	Within Groups		5.861	18	.326		
	Total		26.638	26			
60Plastic crate	Between Groups	(Combined)	22.714	8	2.839	13.108	.000
		Linear Term Contrast	2.110	1	2.110	9.743	.006
		Deviation	20.604	7	2.943	13.589	.000
	Within Groups		3.899	18	.217		
	Total		26.613	26			
60wooden crate	Between Groups	(Combined)	27.851	8	3.481	5.416	.001
		Linear Term Contrast	.702	1	.702	1.092	.310
		Deviation	27.149	7	3.878	6.034	.001
	Within Groups		11.570	18	.643		
	Total		39.421	26			
90Leno bag	Between Groups	(Combined)	19.095	8	2.387	48.893	.000
		Linear Term Contrast	2.260	1	2.260	46.297	.000
		Deviation	16.835	7	2.405	49.263	.000
	Within Groups		.879	18	.049		
	Total		19.974	26			
90Cotton bag	Between Groups	(Combined)	30.478	8	3.810	43.081	.000
		Linear Term Contrast	4.679	1	4.679	52.906	.000
		Deviation	25.800	7	3.686	41.678	.000
	Within Groups		1.592	18	.088		
	Total		32.070	26			
90Poly Bag	Between Groups	(Combined)	34.408	8	4.301	42.710	.000
		Linear Term Contrast	5.165	1	5.165	51.286	.000
		Deviation	29.243	7	4.178	41.484	.000
	Within Groups		1.813	18	.101		
	Total		36.221	26			
90Plastic crate	Between Groups	(Combined)	21.160	8	2.645	10.889	.000
		Linear Term Contrast	3.425	1	3.425	14.100	.001
		Deviation	17.735	7	2.534	10.430	.000
	Within Groups		4.373	18	.243		
	Total		25.533	26			
90wooden crate	Between Groups	(Combined)	37.206	8	4.651	6.954	.000
		Linear Term Contrast	7.446	1	7.446	11.134	.004
		Deviation	29.760	7	4.251	6.357	.001
	Within Groups		12.038	18	.669		
	Total		49.243	26			
120Leno bag	Between Groups	(Combined)	29.110	8	3.639	7.203	.000
		Linear Term Contrast	.630	1	.630	1.247	.279
		Deviation	28.480	7	4.069	8.054	.000
	Within Groups		9.093	18	.505		
	Total		38.204	26			
120Cotton bag	Between Groups	(Combined)	25.504	8	3.188	35.878	.000
		Linear Term Contrast	4.038	1	4.038	45.443	.000
		Deviation	21.466	7	3.067	34.511	.000
	Within Groups		1.599	18	.089		
	Total		27.104	26			
120Poly Bag	Between Groups	(Combined)	25.674	8	3.209	41.222	.000
		Linear Term Contrast	2.174	1	2.174	27.920	.000
		Deviation	23.500	7	3.357	43.123	.000

			Sum of Squares	df	Mean Square	F	Sig.
	Within Groups		1.401	18	.078		
	Total		27.075	26			
120Plastic crate	Between Groups	(Combined)	23.123	8	2.890	14.541	.000
		Linear Term Contrast	3.960	1	3.960	19.925	.000
		Deviation	19.162	7	2.737	13.772	.000
	Within Groups		3.578	18	.199		
	Total		26.701	26			
120wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150Leno bag	Between Groups	(Combined)	28.215	8	3.527	6.364	.001
		Linear Term Contrast	5.714	1	5.714	10.311	.005
		Deviation	22.501	7	3.214	5.801	.001
	Within Groups		9.975	18	.554		
	Total		38.189	26			
150Cotton bag	Between Groups	(Combined)	19.020	8	2.378	6.388	.001
		Linear Term Contrast	1.834	1	1.834	4.928	.040
		Deviation	17.186	7	2.455	6.596	.001
	Within Groups		6.700	18	.372		
	Total		25.720	26			
150Poly Bag	Between Groups	(Combined)	22.395	8	2.799	4.211	.005
		Linear Term Contrast	1.037	1	1.037	1.559	.228
		Deviation	21.358	7	3.051	4.589	.004
	Within Groups		11.967	18	.665		
	Total		34.362	26			
150Plastic crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			

Magnesium ANOVA

			Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)	29357.572	8	3669.697	6.017	.001
		Linear Term Contrast	1867.149	1	1867.149	3.061	.097
		Deviation	27490.423	7	3927.203	6.439	.001
	Within Groups		10978.462	18	609.915		
	Total		40336.034	26			
30Cotton bag	Between Groups	(Combined)	22864.987	8	2858.123	3.535	.012
		Linear Term Contrast	4651.962	1	4651.962	5.753	.028
		Deviation	18213.025	7	2601.861	3.218	.021
	Within Groups		14554.231	18	808.568		

				Sum of Squares	df	Mean Square	F	Sig.
	Total			37419.217	26			
30Poly Bag	Between Groups	(Combined)		13648.110	8	1706.014	.906	.533
		Linear Term	Contrast	10861.218	1	10861.218	5.766	.027
			Deviation	2786.892	7	398.127	.211	.978
	Within Groups			33906.775	18	1883.710		
	Total			47554.885	26			
30Plastic crate	Between Groups	(Combined)		32767.437	8	4095.930	9.328	.000
		Linear Term	Contrast	4799.628	1	4799.628	10.931	.004
			Deviation	27967.809	7	3995.401	9.099	.000
	Within Groups			7903.831	18	439.102		
	Total			40671.268	26			
30wooden crate	Between Groups	(Combined)		8667.622	8	1083.453	.972	.487
		Linear Term	Contrast	1523.443	1	1523.443	1.367	.258
			Deviation	7144.179	7	1020.597	.916	.517
	Within Groups			20063.909	18	1114.662		
	Total			28731.531	26			
60Leno bag	Between Groups	(Combined)		32865.389	8	4108.174	5.030	.002
		Linear Term	Contrast	520.812	1	520.812	.638	.435
			Deviation	32344.577	7	4620.654	5.658	.001
	Within Groups			14700.606	18	816.700		
	Total			47565.996	26			
60Cotton bag	Between Groups	(Combined)		19509.667	8	2438.708	2.496	.051
		Linear Term	Contrast	944.946	1	944.946	.967	.338
			Deviation	18564.721	7	2652.103	2.715	.041
	Within Groups			17584.980	18	976.943		
	Total			37094.647	26			
60Poly Bag	Between Groups	(Combined)		1974.041	8	246.755	.528	.821
		Linear Term	Contrast	254.280	1	254.280	.544	.470
			Deviation	1719.761	7	245.680	.525	.804
	Within Groups			8419.281	18	467.738		
	Total			10393.322	26			
60Plastic crate	Between Groups	(Combined)		11166.041	8	1395.755	2.405	.058
		Linear Term	Contrast	1460.454	1	1460.454	2.516	.130
			Deviation	9705.587	7	1386.512	2.389	.065
	Within Groups			10446.769	18	580.376		
	Total			21612.810	26			
60wooden crate	Between Groups	(Combined)		13942.537	8	1742.817	1.830	.137
		Linear Term	Contrast	185.704	1	185.704	.195	.664
			Deviation	13756.833	7	1965.262	2.064	.102
	Within Groups			17139.559	18	952.198		
	Total			31082.097	26			
90Leno bag	Between Groups	(Combined)		23415.931	8	2926.991	6.374	.001
		Linear Term	Contrast	2773.562	1	2773.562	6.039	.024
			Deviation	20642.369	7	2948.910	6.421	.001
	Within Groups			8266.293	18	459.239		
	Total			31682.224	26			
90Cotton bag	Between Groups	(Combined)		10775.588	8	1346.948	1.526	.217
		Linear Term	Contrast	648.509	1	648.509	.735	.403
			Deviation	10127.079	7	1446.726	1.639	.188
	Within Groups			15892.301	18	882.906		
	Total			26667.889	26			

90Poly Bag	Between Groups	(Combined)		6704.855	8	838.107	2.489	.052
		Linear Term	Contrast	3456.522	1	3456.522	10.267	.005
			Deviation	3248.334	7	464.048	1.378	.273
	Within Groups			6059.824	18	336.657		
	Total			12764.679	26			
90Plastic crate	Between Groups	(Combined)		15746.704	8	1968.338	4.714	.003
		Linear Term	Contrast	2623.348	1	2623.348	6.283	.022
			Deviation	13123.357	7	1874.765	4.490	.005
	Within Groups			7515.154	18	417.509		
	Total			23261.858	26			
90wooden crate	Between Groups	(Combined)		12307.718	8	1538.465	2.513	.050
		Linear Term	Contrast	1559.496	1	1559.496	2.548	.128
			Deviation	10748.222	7	1535.460	2.508	.055
	Within Groups			11017.994	18	612.111		
	Total			23325.712	26			
120Leno bag	Between Groups	(Combined)		32129.379	8	4016.172	6.293	.001
		Linear Term	Contrast	1140.503	1	1140.503	1.787	.198
			Deviation	30988.876	7	4426.982	6.937	.000
	Within Groups			11486.806	18	638.156		
	Total			43616.185	26			
120Cotton bag	Between Groups	(Combined)		7463.441	8	932.930	1.288	.310
		Linear Term	Contrast	7.248	1	7.248	.010	.921
			Deviation	7456.193	7	1065.170	1.470	.240
	Within Groups			13041.975	18	724.554		
	Total			20505.416	26			
120Poly Bag	Between Groups	(Combined)		6434.492	8	804.311	1.061	.431
		Linear Term	Contrast	3740.933	1	3740.933	4.935	.039
			Deviation	2693.559	7	384.794	.508	.817
	Within Groups			13643.842	18	757.991		
	Total			20078.334	26			
120Plastic crate	Between Groups	(Combined)		24665.838	8	3083.230	4.757	.003
		Linear Term	Contrast	154.939	1	154.939	.239	.631
			Deviation	24510.899	7	3501.557	5.402	.002
	Within Groups			11667.530	18	648.196		
	Total			36333.368	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		19039.118	8	2379.890	4.912	.002
		Linear Term	Contrast	371.493	1	371.493	.767	.393
			Deviation	18667.625	7	2666.804	5.505	.002
	Within Groups			8720.312	18	484.462		
	Total			27759.430	26			
150Cotton bag	Between Groups	(Combined)		3003.708	8	375.463	.779	.627
		Linear Term	Contrast	669.247	1	669.247	1.388	.254
			Deviation	2334.461	7	333.494	.692	.678
	Within Groups			8679.826	18	482.213		
	Total			11683.533	26			
150Poly Bag	Between	(Combined)		5302.447	8	662.806	1.303	.303

				Sum of Squares	df	Mean Square	F	Sig.
	Groups	Linear Term	Contrast	1391.835	1	1391.835	2.736	.115
			Deviation	3910.612	7	558.659	1.098	.405
	Within Groups			9156.833	18	508.713		
	Total			14459.280	26			
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

Manganese ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		.671	8	.084	2.585	.045
		Linear Term	Contrast	.080	1	.080	2.460	.134
			Deviation	.591	7	.084	2.602	.048
	Within Groups			.584	18	.032		
	Total			1.254	26			
30Cotton bag	Between Groups	(Combined)		.314	8	.039	7.382	.000
		Linear Term	Contrast	.052	1	.052	9.838	.006
			Deviation	.262	7	.037	7.031	.000
	Within Groups			.096	18	.005		
	Total			.410	26			
30Poly Bag	Between Groups	(Combined)		.058	8	.007	2.133	.087
		Linear Term	Contrast	.010	1	.010	2.847	.109
			Deviation	.048	7	.007	2.031	.107
	Within Groups			.061	18	.003		
	Total			.119	26			
30Plastic crate	Between Groups	(Combined)		.612	8	.076	8.883	.000
		Linear Term	Contrast	.039	1	.039	4.531	.047
			Deviation	.573	7	.082	9.505	.000
	Within Groups			.155	18	.009		
	Total			.767	26			
30wooden crate	Between Groups	(Combined)		.060	8	.007	1.299	.305
		Linear Term	Contrast	.002	1	.002	.272	.608
			Deviation	.058	7	.008	1.445	.248
	Within Groups			.103	18	.006		
	Total			.163	26			
60Leno bag	Between Groups	(Combined)		1.465	8	.183	1.098	.409
		Linear Term	Contrast	.251	1	.251	1.503	.236
			Deviation	1.215	7	.174	1.040	.439
	Within Groups			3.004	18	.167		
	Total			4.469	26			
60Cotton bag	Between Groups	(Combined)		.289	8	.036	9.288	.000
		Linear	Contrast	.037	1	.037	9.418	.007

		Term	Deviation	.253	7	.036	9.269	.000
	Within Groups			.070	18	.004		
	Total			.360	26			
60Poly Bag	Between Groups	(Combined)		.078	8	.010	1.364	.276
		Linear Term	Contrast	.006	1	.006	.842	.371
			Deviation	.072	7	.010	1.439	.251
	Within Groups			.128	18	.007		
	Total			.206	26			
60Plastic crate	Between Groups	(Combined)		.339	8	.042	11.992	.000
		Linear Term	Contrast	.151	1	.151	42.635	.000
			Deviation	.189	7	.027	7.615	.000
	Within Groups			.064	18	.004		
	Total			.403	26			
60wooden crate	Between Groups	(Combined)		.018	8	.002	.590	.774
		Linear Term	Contrast	.002	1	.002	.399	.535
			Deviation	.016	7	.002	.617	.735
	Within Groups			.068	18	.004		
	Total			.085	26			
90Leno bag	Between Groups	(Combined)		.830	8	.104	8.024	.000
		Linear Term	Contrast	.163	1	.163	12.583	.002
			Deviation	.667	7	.095	7.373	.000
	Within Groups			.233	18	.013		
	Total			1.062	26			
90Cotton bag	Between Groups	(Combined)		.131	8	.016	1.099	.408
		Linear Term	Contrast	.012	1	.012	.830	.374
			Deviation	.118	7	.017	1.138	.384
	Within Groups			.267	18	.015		
	Total			.398	26			
90Poly Bag	Between Groups	(Combined)		.064	8	.008	.701	.687
		Linear Term	Contrast	.018	1	.018	1.614	.220
			Deviation	.046	7	.007	.570	.771
	Within Groups			.205	18	.011		
	Total			.269	26			
90Plastic crate	Between Groups	(Combined)		.290	8	.036	2.085	.093
		Linear Term	Contrast	.063	1	.063	3.612	.073
			Deviation	.227	7	.032	1.867	.135
	Within Groups			.313	18	.017		
	Total			.602	26			
90wooden crate	Between Groups	(Combined)		.055	8	.007	1.375	.272
		Linear Term	Contrast	.011	1	.011	2.212	.154
			Deviation	.044	7	.006	1.256	.325
	Within Groups			.090	18	.005		
	Total			.145	26			
120Leno bag	Between Groups	(Combined)		.489	8	.061	3.358	.016
		Linear Term	Contrast	.043	1	.043	2.359	.142
			Deviation	.446	7	.064	3.501	.015
	Within Groups			.328	18	.018		
	Total			.817	26			
120Cotton bag	Between Groups	(Combined)		.066	8	.008	1.068	.426
		Linear Term	Contrast	.003	1	.003	.370	.550
			Deviation	.064	7	.009	1.168	.368

			Sum of Squares	df	Mean Square	F	Sig.
	Within Groups		.140	18	.008		
	Total		.206	26			
120Poly Bag	Between Groups	(Combined)	.038	8	.005	.797	.613
		Linear Term Contrast	.012	1	.012	1.925	.182
		Linear Term Deviation	.027	7	.004	.635	.721
	Within Groups		.108	18	.006		
	Total		.146	26			
120Plastic crate	Between Groups	(Combined)	.104	8	.013	3.037	.024
		Linear Term Contrast	.011	1	.011	2.496	.132
		Linear Term Deviation	.094	7	.013	3.114	.025
	Within Groups		.077	18	.004		
	Total		.182	26			
120wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150Leno bag	Between Groups	(Combined)	.969	8	.121	1.857	.131
		Linear Term Contrast	.090	1	.090	1.383	.255
		Linear Term Deviation	.879	7	.126	1.925	.125
	Within Groups		1.175	18	.065		
	Total		2.144	26			
150Cotton bag	Between Groups	(Combined)	.445	8	.056	1.225	.340
		Linear Term Contrast	.018	1	.018	.406	.532
		Linear Term Deviation	.426	7	.061	1.342	.288
	Within Groups		.816	18	.045		
	Total		1.261	26			
150Poly Bag	Between Groups	(Combined)	.017	8	.002	.442	.880
		Linear Term Contrast	.000	1	.000	.003	.958
		Linear Term Deviation	.017	7	.002	.505	.819
	Within Groups		.087	18	.005		
	Total		.105	26			
150Plastic crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			

Potassium content ANOVA

			Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)	1324044.029	8	165505.504	29.332	.000
		Linear Term Contrast	3619.574	1	3619.574	.641	.434
		Linear Term Deviation	1320424.455	7	188632.065	33.431	.000
	Within Groups		101565.149	18	5642.508		

				Sum of Squares	df	Mean Square	F	Sig.
		Total		1425609.178	26			
30Cotton bag	Between Groups	(Combined)		1242509.500	8	155313.688	7.381	.000
		Linear Term	Contrast	1049.318	1	1049.318	.050	.826
			Deviation	1241460.183	7	177351.455	8.428	.000
	Within Groups			378758.883	18	21042.160		
	Total			1621268.384	26			
30Poly Bag	Between Groups	(Combined)		903524.595	8	112940.574	27.651	.000
		Linear Term	Contrast	613.020	1	613.020	.150	.703
			Deviation	902911.575	7	128987.368	31.579	.000
	Within Groups			73521.834	18	4084.546		
	Total			977046.429	26			
30Plastic crate	Between Groups	(Combined)		402371.342	8	50296.418	12.070	.000
		Linear Term	Contrast	34467.690	1	34467.690	8.271	.010
			Deviation	367903.652	7	52557.665	12.612	.000
	Within Groups			75008.613	18	4167.145		
	Total			477379.956	26			
30wooden crate	Between Groups	(Combined)		567831.773	8	70978.972	1.006	.465
		Linear Term	Contrast	27985.424	1	27985.424	.397	.537
			Deviation	539846.349	7	77120.907	1.093	.408
	Within Groups			1269553.474	18	70530.749		
	Total			1837385.247	26			
60Leno bag	Between Groups	(Combined)		689137.166	8	86142.146	8.170	.000
		Linear Term	Contrast	1006.828	1	1006.828	.095	.761
			Deviation	688130.338	7	98304.334	9.324	.000
	Within Groups			189775.469	18	10543.082		
	Total			878912.635	26			
60Cotton bag	Between Groups	(Combined)		389636.924	8	48704.616	2.941	.027
		Linear Term	Contrast	5865.769	1	5865.769	.354	.559
			Deviation	383771.155	7	54824.451	3.310	.019
	Within Groups			298115.631	18	16561.980		
	Total			687752.555	26			
60Poly Bag	Between Groups	(Combined)		512594.447	8	64074.306	24.564	.000
		Linear Term	Contrast	18783.138	1	18783.138	7.201	.015
			Deviation	493811.310	7	70544.473	27.044	.000
	Within Groups			46952.582	18	2608.477		
	Total			559547.030	26			
60Plastic crate	Between Groups	(Combined)		399535.504	8	49941.938	20.123	.000
		Linear Term	Contrast	44068.211	1	44068.211	17.756	.001
			Deviation	355467.293	7	50781.042	20.461	.000
	Within Groups			44673.734	18	2481.874		
	Total			444209.238	26			
60wooden crate	Between Groups	(Combined)		733314.592	8	91664.324	4.542	.004
		Linear Term	Contrast	22.720	1	22.720	.001	.974
			Deviation	733291.872	7	104755.982	5.191	.002
	Within Groups			363249.480	18	20180.527		
	Total			1096564.073	26			
90Leno bag	Between Groups	(Combined)		705708.810	8	88213.601	5.899	.001
		Linear Term	Contrast	5962.756	1	5962.756	.399	.536
			Deviation	699746.055	7	99963.722	6.685	.001
	Within Groups			269155.328	18	14953.074		

	Total			974864.138	26			
90Cotton bag	Between Groups	(Combined)		475619.682	8	59452.460	3.021	.024
		Linear Term	Contrast	44.055	1	44.055	.002	.963
			Deviation	475575.627	7	67939.375	3.453	.016
	Within Groups			354193.199	18	19677.400		
	Total			829812.881	26			
90Poly Bag	Between Groups	(Combined)		379651.090	8	47456.386	6.143	.001
		Linear Term	Contrast	26.045	1	26.045	.003	.954
			Deviation	379625.045	7	54232.149	7.020	.000
	Within Groups			139048.445	18	7724.914		
	Total			518699.535	26			
90Plastic crate	Between Groups	(Combined)		471565.656	8	58945.707	18.014	.000
		Linear Term	Contrast	11432.168	1	11432.168	3.494	.078
			Deviation	460133.488	7	65733.355	20.089	.000
	Within Groups			58898.698	18	3272.150		
	Total			530464.354	26			
90wooden crate	Between Groups	(Combined)		778021.613	8	97252.702	7.166	.000
		Linear Term	Contrast	8134.830	1	8134.830	.599	.449
			Deviation	769886.783	7	109983.826	8.104	.000
	Within Groups			244290.099	18	13571.672		
	Total			1022311.713	26			
120Leno bag	Between Groups	(Combined)		706483.371	8	88310.421	3.153	.020
		Linear Term	Contrast	16090.330	1	16090.330	.575	.458
			Deviation	690393.041	7	98627.577	3.522	.015
	Within Groups			504078.838	18	28004.380		
	Total			1210562.209	26			
120Cotton bag	Between Groups	(Combined)		590979.467	8	73872.433	4.974	.002
		Linear Term	Contrast	7308.684	1	7308.684	.492	.492
			Deviation	583670.783	7	83381.540	5.614	.001
	Within Groups			267336.383	18	14852.021		
	Total			858315.850	26			
120Poly Bag	Between Groups	(Combined)		766449.340	8	95806.168	11.470	.000
		Linear Term	Contrast	25999.501	1	25999.501	3.113	.095
			Deviation	740449.839	7	105778.548	12.664	.000
	Within Groups			150351.064	18	8352.837		
	Total			916800.404	26			
120Plastic crate	Between Groups	(Combined)		491322.198	8	61415.275	4.861	.003
		Linear Term	Contrast	9897.987	1	9897.987	.783	.388
			Deviation	481424.211	7	68774.887	5.444	.002
	Within Groups			227398.558	18	12633.253		
	Total			718720.756	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		851909.829	8	106488.729	6.957	.000
		Linear Term	Contrast	954.363	1	954.363	.062	.806
			Deviation	850955.466	7	121565.067	7.942	.000
	Within Groups			275502.271	18	15305.682		
	Total			1127412.100	26			

			Sum of Squares	df	Mean Square	F	Sig.
150Cotton bag	Between Groups	(Combined)	555242.338	8	69405.292	3.653	.011
		Linear Term Contrast	21051.398	1	21051.398	1.108	.306
		Linear Term Deviation	534190.941	7	76312.992	4.016	.008
	Within Groups		342023.904	18	19001.328		
	Total		897266.243	26			
150Poly Bag	Between Groups	(Combined)	591413.796	8	73926.724	4.986	.002
		Linear Term Contrast	9824.415	1	9824.415	.663	.426
		Linear Term Deviation	581589.381	7	83084.197	5.603	.001
	Within Groups		266908.487	18	14828.249		
	Total		858322.283	26			
150Plastic crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			

Sodium content ANOVA

			Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)	5193.561	8	649.195	4.629	.003
		Linear Term Contrast	93.312	1	93.312	.665	.425
		Linear Term Deviation	5100.249	7	728.607	5.196	.002
	Within Groups		2524.254	18	140.236		
	Total		7717.815	26			
30Cotton bag	Between Groups	(Combined)	7073.259	8	884.157	4.022	.007
		Linear Term Contrast	2328.626	1	2328.626	10.592	.004
		Linear Term Deviation	4744.633	7	677.805	3.083	.026
	Within Groups		3957.225	18	219.846		
	Total		11030.484	26			
30Poly Bag	Between Groups	(Combined)	4500.127	8	562.516	8.392	.000
		Linear Term Contrast	1732.777	1	1732.777	25.849	.000
		Linear Term Deviation	2767.350	7	395.336	5.898	.001
	Within Groups		1206.606	18	67.034		
	Total		5706.733	26			
30Plastic crate	Between Groups	(Combined)	6154.066	8	769.258	15.407	.000
		Linear Term Contrast	64.980	1	64.980	1.301	.269
		Linear Term Deviation	6089.086	7	869.869	17.422	.000
	Within Groups		898.751	18	49.931		
	Total		7052.817	26			
30wooden crate	Between Groups	(Combined)	6807.652	8	850.956	4.819	.003
		Linear Term Contrast	1482.872	1	1482.872	8.397	.010
		Linear Term Deviation	5324.780	7	760.683	4.308	.006
	Within Groups		3178.571	18	176.587		
	Total		9986.223	26			
60Leno bag	Between	(Combined)	7007.744	8	875.968	3.794	.009

	Groups	Linear Term	Contrast	75.014	1	75.014	.325	.576
			Deviation	6932.731	7	990.390	4.290	.006
	Within Groups			4155.713	18	230.873		
	Total			11163.457	26			
60Cotton bag	Between Groups	(Combined)		810.566	8	101.321	.337	.940
		Linear Term	Contrast	33.351	1	33.351	.111	.743
			Deviation	777.215	7	111.031	.369	.909
	Within Groups			5414.810	18	300.823		
	Total			6225.376	26			
60Poly Bag	Between Groups	(Combined)		3701.957	8	462.745	.693	.693
		Linear Term	Contrast	645.740	1	645.740	.967	.338
			Deviation	3056.217	7	436.602	.654	.707
	Within Groups			12020.115	18	667.784		
	Total			15722.073	26			
60Plastic crate	Between Groups	(Combined)		3471.169	8	433.896	2.241	.074
		Linear Term	Contrast	76.167	1	76.167	.393	.538
			Deviation	3395.002	7	485.000	2.505	.055
	Within Groups			3485.200	18	193.622		
	Total			6956.369	26			
60wooden crate	Between Groups	(Combined)		3010.807	8	376.351	1.236	.334
		Linear Term	Contrast	109.465	1	109.465	.360	.556
			Deviation	2901.342	7	414.477	1.362	.280
	Within Groups			5479.570	18	304.421		
	Total			8490.377	26			
90Leno bag	Between Groups	(Combined)		7569.020	8	946.128	31.538	.000
		Linear Term	Contrast	542.153	1	542.153	18.072	.000
			Deviation	7026.867	7	1003.838	33.462	.000
	Within Groups			539.992	18	30.000		
	Total			8109.012	26			
90Cotton bag	Between Groups	(Combined)		1399.162	8	174.895	1.264	.321
		Linear Term	Contrast	162.222	1	162.222	1.173	.293
			Deviation	1236.940	7	176.706	1.277	.316
	Within Groups			2489.935	18	138.330		
	Total			3889.097	26			
90Poly Bag	Between Groups	(Combined)		1580.211	8	197.526	1.634	.184
		Linear Term	Contrast	619.199	1	619.199	5.123	.036
			Deviation	961.012	7	137.287	1.136	.385
	Within Groups			2175.725	18	120.874		
	Total			3755.936	26			
90Plastic crate	Between Groups	(Combined)		2872.841	8	359.105	10.983	.000
		Linear Term	Contrast	184.144	1	184.144	5.632	.029
			Deviation	2688.698	7	384.100	11.748	.000
	Within Groups			588.519	18	32.696		
	Total			3461.360	26			
90wooden crate	Between Groups	(Combined)		3222.411	8	402.801	3.369	.015
		Linear Term	Contrast	595.686	1	595.686	4.983	.039
			Deviation	2626.725	7	375.246	3.139	.024
	Within Groups			2151.879	18	119.549		
	Total			5374.290	26			
120Leno bag	Between Groups	(Combined)		8180.103	8	1022.513	6.201	.001
		Linear	Contrast	538.930	1	538.930	3.269	.087

		Term	Deviation	7641.174	7	1091.596	6.620	.001
	Within Groups			2967.940	18	164.886		
	Total			11148.043	26			
120Cotton bag	Between Groups	(Combined)		1188.502	8	148.563	.740	.657
		Linear Term	Contrast	81.608	1	81.608	.406	.532
			Deviation	1106.894	7	158.128	.787	.607
	Within Groups			3615.484	18	200.860		
	Total			4803.986	26			
120Poly Bag	Between Groups	(Combined)		1228.435	8	153.554	1.837	.135
		Linear Term	Contrast	51.029	1	51.029	.611	.445
			Deviation	1177.405	7	168.201	2.012	.110
	Within Groups			1504.500	18	83.583		
	Total			2732.934	26			
120Plastic crate	Between Groups	(Combined)		6449.000	8	806.125	9.563	.000
		Linear Term	Contrast	81.568	1	81.568	.968	.338
			Deviation	6367.433	7	909.633	10.791	.000
	Within Groups			1517.293	18	84.294		
	Total			7966.293	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		9893.230	8	1236.654	3.881	.008
		Linear Term	Contrast	500.233	1	500.233	1.570	.226
			Deviation	9392.996	7	1341.857	4.211	.006
	Within Groups			5735.165	18	318.620		
	Total			15628.394	26			
150Cotton bag	Between Groups	(Combined)		1435.145	8	179.393	.919	.524
		Linear Term	Contrast	206.146	1	206.146	1.056	.318
			Deviation	1228.999	7	175.571	.899	.528
	Within Groups			3515.131	18	195.285		
	Total			4950.276	26			
150Poly Bag	Between Groups	(Combined)		2147.920	8	268.490	1.424	.253
		Linear Term	Contrast	651.739	1	651.739	3.457	.079
			Deviation	1496.180	7	213.740	1.134	.386
	Within Groups			3393.499	18	188.528		
	Total			5541.419	26			
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		50.699	8	6.337	15.255	.000
		Linear Term	Contrast	8.607	1	8.607	20.718	.000
			Deviation	42.092	7	6.013	14.475	.000
	Within Groups			7.478	18	.415		
	Total			58.176	26			
30Cotton bag	Between Groups	(Combined)		37.907	8	4.738	18.987	.000
		Linear Term	Contrast	12.752	1	12.752	51.098	.000
			Deviation	25.155	7	3.594	14.399	.000
	Within Groups			4.492	18	.250		
	Total			42.399	26			
30Poly Bag	Between Groups	(Combined)		41.183	8	5.148	19.598	.000
		Linear Term	Contrast	19.450	1	19.450	74.046	.000
			Deviation	21.733	7	3.105	11.819	.000
	Within Groups			4.728	18	.263		
	Total			45.912	26			
30Plastic crate	Between Groups	(Combined)		60.687	8	7.586	10.847	.000
		Linear Term	Contrast	23.112	1	23.112	33.047	.000
			Deviation	37.574	7	5.368	7.675	.000
	Within Groups			12.589	18	.699		
	Total			73.276	26			
30wooden crate	Between Groups	(Combined)		21.566	8	2.696	8.133	.000
		Linear Term	Contrast	9.262	1	9.262	27.942	.000
			Deviation	12.304	7	1.758	5.303	.002
	Within Groups			5.966	18	.331		
	Total			27.532	26			
60Leno bag	Between Groups	(Combined)		39.050	8	4.881	3.769	.009
		Linear Term	Contrast	9.851	1	9.851	7.607	.013
			Deviation	29.198	7	4.171	3.221	.021
	Within Groups			23.312	18	1.295		
	Total			62.361	26			
60Cotton bag	Between Groups	(Combined)		24.495	8	3.062	12.543	.000
		Linear Term	Contrast	10.858	1	10.858	44.483	.000
			Deviation	13.636	7	1.948	7.980	.000
	Within Groups			4.394	18	.244		
	Total			28.889	26			
60Poly Bag	Between Groups	(Combined)		29.909	8	3.739	48.474	.000
		Linear Term	Contrast	16.507	1	16.507	214.032	.000
			Deviation	13.401	7	1.914	24.823	.000
	Within Groups			1.388	18	.077		
	Total			31.297	26			
60Plastic crate	Between Groups	(Combined)		15.722	8	1.965	3.891	.008
		Linear Term	Contrast	2.253	1	2.253	4.461	.049
			Deviation	13.468	7	1.924	3.809	.010
	Within Groups			9.092	18	.505		
	Total			24.814	26			
60wooden crate	Between Groups	(Combined)		13.514	8	1.689	4.139	.006
		Linear	Contrast	4.887	1	4.887	11.977	.003

		Term	Deviation	8.626	7	1.232	3.020	.028
	Within Groups			7.345	18	.408		
	Total			20.859	26			
90Leno bag	Between Groups	(Combined)		38.559	8	4.820	3.945	.007
		Linear Term	Contrast	18.164	1	18.164	14.866	.001
			Deviation	20.395	7	2.914	2.385	.065
	Within Groups			21.993	18	1.222		
	Total			60.553	26			
90Cotton bag	Between Groups	(Combined)		23.346	8	2.918	21.856	.000
		Linear Term	Contrast	10.585	1	10.585	79.276	.000
			Deviation	12.761	7	1.823	13.653	.000
	Within Groups			2.403	18	.134		
	Total			25.749	26			
90Poly Bag	Between Groups	(Combined)		29.969	8	3.746	33.745	.000
		Linear Term	Contrast	19.084	1	19.084	171.911	.000
			Deviation	10.885	7	1.555	14.007	.000
	Within Groups			1.998	18	.111		
	Total			31.967	26			
90Plastic crate	Between Groups	(Combined)		13.596	8	1.699	12.765	.000
		Linear Term	Contrast	1.223	1	1.223	9.190	.007
			Deviation	12.372	7	1.767	13.276	.000
	Within Groups			2.396	18	.133		
	Total			15.992	26			
90wooden crate	Between Groups	(Combined)		14.774	8	1.847	1.362	.278
		Linear Term	Contrast	5.192	1	5.192	3.828	.066
			Deviation	9.582	7	1.369	1.009	.457
	Within Groups			24.414	18	1.356		
	Total			39.188	26			
120Leno bag	Between Groups	(Combined)		31.858	8	3.982	11.991	.000
		Linear Term	Contrast	15.465	1	15.465	46.563	.000
			Deviation	16.394	7	2.342	7.052	.000
	Within Groups			5.978	18	.332		
	Total			37.836	26			
120Cotton bag	Between Groups	(Combined)		18.244	8	2.280	14.464	.000
		Linear Term	Contrast	8.858	1	8.858	56.179	.000
			Deviation	9.386	7	1.341	8.504	.000
	Within Groups			2.838	18	.158		
	Total			21.082	26			
120Poly Bag	Between Groups	(Combined)		29.195	8	3.649	44.246	.000
		Linear Term	Contrast	16.520	1	16.520	200.291	.000
			Deviation	12.675	7	1.811	21.954	.000
	Within Groups			1.485	18	.082		
	Total			30.679	26			
120Plastic crate	Between Groups	(Combined)		16.670	8	2.084	6.133	.001
		Linear Term	Contrast	1.575	1	1.575	4.637	.045
			Deviation	15.094	7	2.156	6.347	.001
	Within Groups			6.115	18	.340		
	Total			22.785	26			
120wooden	Between	(Combined)		.000	8	.000	.	.

crate	Groups	Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		26.608	8	3.326	12.131	.000
		Linear Term	Contrast	12.556	1	12.556	45.794	.000
			Deviation	14.052	7	2.007	7.322	.000
	Within Groups			4.935	18	.274		
	Total			31.543	26			
150Cotton bag	Between Groups	(Combined)		10.175	8	1.272	6.854	.000
		Linear Term	Contrast	4.920	1	4.920	26.516	.000
			Deviation	5.255	7	.751	4.046	.008
	Within Groups			3.340	18	.186		
	Total			13.515	26			
150Poly Bag	Between Groups	(Combined)		23.844	8	2.981	26.395	.000
		Linear Term	Contrast	14.224	1	14.224	125.969	.000
			Deviation	9.620	7	1.374	12.170	.000
	Within Groups			2.033	18	.113		
	Total			25.877	26			
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

Nitrate content ANOVA

				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		36998.513	8	4624.814	9.276	.000
		Linear Term	Contrast	1843.328	1	1843.328	3.697	.070
			Deviation	35155.185	7	5022.169	10.073	.000
	Within Groups			8974.443	18	498.580		
	Total			45972.956	26			
30Cotton bag	Between Groups	(Combined)		11539.692	8	1442.461	43.902	.000
		Linear Term	Contrast	4278.593	1	4278.593	130.220	.000
			Deviation	7261.099	7	1037.300	31.570	.000
	Within Groups			591.420	18	32.857		
	Total			12131.112	26			
30Poly Bag	Between Groups	(Combined)		13094.225	8	1636.778	71.261	.000
		Linear Term	Contrast	2479.468	1	2479.468	107.949	.000
			Deviation	10614.757	7	1516.394	66.020	.000
	Within Groups			413.439	18	22.969		
	Total			13507.664	26			

30Plastic crate	Between Groups	(Combined)		3535.772	8	441.972	2.717	.037
		Linear Term	Contrast	1629.915	1	1629.915	10.020	.005
			Deviation	1905.857	7	272.265	1.674	.179
	Within Groups			2928.043	18	162.669		
	Total			6463.816	26			
30wooden crate	Between Groups	(Combined)		15390.597	8	1923.825	56.898	.000
		Linear Term	Contrast	1530.200	1	1530.200	45.256	.000
			Deviation	13860.397	7	1980.057	58.561	.000
	Within Groups			608.615	18	33.812		
	Total			15999.212	26			
60Leno bag	Between Groups	(Combined)		35675.811	8	4459.476	12.161	.000
		Linear Term	Contrast	61.964	1	61.964	.169	.686
			Deviation	35613.847	7	5087.692	13.874	.000
	Within Groups			6600.515	18	366.695		
	Total			42276.326	26			
60Cotton bag	Between Groups	(Combined)		8367.586	8	1045.948	24.582	.000
		Linear Term	Contrast	2705.758	1	2705.758	63.592	.000
			Deviation	5661.828	7	808.833	19.010	.000
	Within Groups			765.876	18	42.549		
	Total			9133.462	26			
60Poly Bag	Between Groups	(Combined)		13276.534	8	1659.567	24.643	.000
		Linear Term	Contrast	4789.513	1	4789.513	71.119	.000
			Deviation	8487.022	7	1212.432	18.003	.000
	Within Groups			1212.206	18	67.345		
	Total			14488.740	26			
60Plastic crate	Between Groups	(Combined)		4033.882	8	504.235	20.660	.000
		Linear Term	Contrast	2.436	1	2.436	.100	.756
			Deviation	4031.446	7	575.921	23.598	.000
	Within Groups			439.306	18	24.406		
	Total			4473.188	26			
60wooden crate	Between Groups	(Combined)		17757.029	8	2219.629	75.661	.000
		Linear Term	Contrast	1769.770	1	1769.770	60.327	.000
			Deviation	15987.258	7	2283.894	77.852	.000
	Within Groups			528.054	18	29.336		
	Total			18285.082	26			
90Leno bag	Between Groups	(Combined)		37762.910	8	4720.364	12.220	.000
		Linear Term	Contrast	4964.190	1	4964.190	12.852	.002
			Deviation	32798.719	7	4685.531	12.130	.000
	Within Groups			6952.918	18	386.273		
	Total			44715.827	26			
90Cotton bag	Between Groups	(Combined)		6415.938	8	801.992	15.412	.000
		Linear Term	Contrast	3093.579	1	3093.579	59.448	.000
			Deviation	3322.358	7	474.623	9.121	.000
	Within Groups			936.686	18	52.038		
	Total			7352.624	26			
90Poly Bag	Between Groups	(Combined)		13243.556	8	1655.444	11.797	.000
		Linear Term	Contrast	5914.278	1	5914.278	42.148	.000
			Deviation	7329.278	7	1047.040	7.462	.000
	Within Groups			2525.791	18	140.322		
	Total			15769.347	26			
90Plastic	Between	(Combined)		9195.492	8	1149.436	61.961	.000

crate	Groups	Linear Term Contrast	244.114	1	244.114	13.159	.002
		Linear Term Deviation	8951.377	7	1278.768	68.933	.000
	Within Groups		333.918	18	18.551		
	Total		9529.409	26			
90wooden crate	Between Groups	(Combined)	15620.790	8	1952.599	9.109	.000
		Linear Term Contrast	2184.189	1	2184.189	10.189	.005
		Linear Term Deviation	13436.601	7	1919.514	8.955	.000
	Within Groups		3858.435	18	214.357		
	Total		19479.225	26			
120Leno bag	Between Groups	(Combined)	22679.579	8	2834.947	40.634	.000
		Linear Term Contrast	4860.754	1	4860.754	69.670	.000
		Linear Term Deviation	17818.825	7	2545.546	36.486	.000
	Within Groups		1255.833	18	69.769		
	Total		23935.412	26			
120Cotton bag	Between Groups	(Combined)	7888.503	8	986.063	28.180	.000
		Linear Term Contrast	4013.794	1	4013.794	114.708	.000
		Linear Term Deviation	3874.708	7	553.530	15.819	.000
	Within Groups		629.843	18	34.991		
	Total		8518.346	26			
120Poly Bag	Between Groups	(Combined)	19156.987	8	2394.623	125.934	.000
		Linear Term Contrast	3777.218	1	3777.218	198.646	.000
		Linear Term Deviation	15379.769	7	2197.110	115.547	.000
	Within Groups		342.267	18	19.015		
	Total		19499.254	26			
120Plastic crate	Between Groups	(Combined)	12442.074	8	1555.259	53.481	.000
		Linear Term Contrast	127.630	1	127.630	4.389	.051
		Linear Term Deviation	12314.444	7	1759.206	60.494	.000
	Within Groups		523.453	18	29.081		
	Total		12965.528	26			
120wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Linear Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150Leno bag	Between Groups	(Combined)	5981.771	8	747.721	6.351	.001
		Linear Term Contrast	1036.272	1	1036.272	8.802	.008
		Linear Term Deviation	4945.499	7	706.500	6.001	.001
	Within Groups		2119.161	18	117.731		
	Total		8100.932	26			
150Cotton bag	Between Groups	(Combined)	16828.662	8	2103.583	44.808	.000
		Linear Term Contrast	9377.193	1	9377.193	199.740	.000
		Linear Term Deviation	7451.469	7	1064.496	22.674	.000
	Within Groups		845.047	18	46.947		
	Total		17673.709	26			
150Poly Bag	Between Groups	(Combined)	20976.200	8	2622.025	12.882	.000
		Linear Term Contrast	2918.689	1	2918.689	14.339	.001
		Linear Term Deviation	18057.510	7	2579.644	12.674	.000
	Within Groups		3663.828	18	203.546		
	Total		24640.028	26			
150Plastic crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Contrast	.000	1	.000	.	

		Term Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			
150wooden crate	Between Groups	(Combined)	.000	8	.000	.	.
		Linear Term Contrast	.000	1	.000	.	
		Deviation	.000	7	.000	.	
	Within Groups		.000	18	.000		
	Total		.000	26			

Phosphate content ANOVA

			Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)	3005.630	8	375.704	7.225	.000
		Linear Term Contrast	145.566	1	145.566	2.799	.112
		Deviation	2860.064	7	408.581	7.857	.000
	Within Groups		936.040	18	52.002		
	Total		3941.669	26			
30Cotton bag	Between Groups	(Combined)	40482.840	8	5060.355	2.628	.042
		Linear Term Contrast	1563.030	1	1563.030	.812	.380
		Deviation	38919.810	7	5559.973	2.887	.033
	Within Groups		34664.389	18	1925.799		
	Total		75147.229	26			
30Poly Bag	Between Groups	(Combined)	29748.626	8	3718.578	132.336	.000
		Linear Term Contrast	8688.613	1	8688.613	309.208	.000
		Deviation	21060.013	7	3008.573	107.068	.000
	Within Groups		505.793	18	28.100		
	Total		30254.419	26			
30Plastic crate	Between Groups	(Combined)	11285.181	8	1410.648	4.091	.006
		Linear Term Contrast	194.605	1	194.605	.564	.462
		Deviation	11090.577	7	1584.368	4.594	.004
	Within Groups		6207.426	18	344.857		
	Total		17492.608	26			
30wooden crate	Between Groups	(Combined)	3243.929	8	405.491	.430	.887
		Linear Term Contrast	295.732	1	295.732	.314	.582
		Deviation	2948.198	7	421.171	.447	.859
	Within Groups		16955.529	18	941.974		
	Total		20199.458	26			
60Leno bag	Between Groups	(Combined)	4876.024	8	609.503	24.235	.000
		Linear Term Contrast	234.065	1	234.065	9.307	.007
		Deviation	4641.959	7	663.137	26.368	.000
	Within Groups		452.687	18	25.149		
	Total		5328.711	26			
60Cotton bag	Between Groups	(Combined)	13221.926	8	1652.741	.769	.634
		Linear Term Contrast	786.467	1	786.467	.366	.553
		Deviation	12435.459	7	1776.494	.826	.579
	Within Groups		38697.601	18	2149.867		
	Total		51919.527	26			
60Poly Bag	Between Groups	(Combined)	38740.536	8	4842.567	93.780	.000
		Linear Contrast	12135.037	1	12135.037	235.005	.000

		Term	Deviation	26605.499	7	3800.786	73.605	.000
	Within Groups			929.472	18	51.637		
	Total			39670.007	26			
60Plastic crate	Between Groups	(Combined)		23294.492	8	2911.812	3.791	.009
		Linear Term	Contrast	640.523	1	640.523	.834	.373
			Deviation	22653.969	7	3236.281	4.214	.006
	Within Groups			13824.661	18	768.037		
	Total			37119.153	26			
60wooden crate	Between Groups	(Combined)		3844.492	8	480.562	.662	.717
		Linear Term	Contrast	89.084	1	89.084	.123	.730
			Deviation	3755.408	7	536.487	.740	.642
	Within Groups			13057.237	18	725.402		
	Total			16901.729	26			
90Leno bag	Between Groups	(Combined)		9399.362	8	1174.920	47.412	.000
		Linear Term	Contrast	1360.480	1	1360.480	54.899	.000
			Deviation	8038.882	7	1148.412	46.342	.000
	Within Groups			446.064	18	24.781		
	Total			9845.426	26			
90Cotton bag	Between Groups	(Combined)		8175.615	8	1021.952	.372	.922
		Linear Term	Contrast	990.012	1	990.012	.360	.556
			Deviation	7185.603	7	1026.515	.373	.906
	Within Groups			49492.909	18	2749.606		
	Total			57668.524	26			
90Poly Bag	Between Groups	(Combined)		21714.181	8	2714.273	6.448	.001
		Linear Term	Contrast	4909.829	1	4909.829	11.664	.003
			Deviation	16804.352	7	2400.622	5.703	.001
	Within Groups			7576.972	18	420.943		
	Total			29291.153	26			
90Plastic crate	Between Groups	(Combined)		15325.729	8	1915.716	3.335	.016
		Linear Term	Contrast	1408.010	1	1408.010	2.451	.135
			Deviation	13917.719	7	1988.246	3.461	.016
	Within Groups			10339.999	18	574.444		
	Total			25665.729	26			
90wooden crate	Between Groups	(Combined)		19011.965	8	2376.496	1.244	.330
		Linear Term	Contrast	451.915	1	451.915	.237	.633
			Deviation	18560.049	7	2651.436	1.388	.269
	Within Groups			34374.106	18	1909.673		
	Total			53386.070	26			
120Leno bag	Between Groups	(Combined)		1678.283	8	209.785	.282	.963
		Linear Term	Contrast	101.385	1	101.385	.136	.716
			Deviation	1576.898	7	225.271	.303	.943
	Within Groups			13388.446	18	743.803		
	Total			15066.729	26			
120Cotton bag	Between Groups	(Combined)		28677.168	8	3584.646	7.063	.000
		Linear Term	Contrast	15867.598	1	15867.598	31.264	.000
			Deviation	12809.570	7	1829.939	3.606	.013
	Within Groups			9135.632	18	507.535		
	Total			37812.800	26			
120Poly Bag	Between Groups	(Combined)		40628.052	8	5078.506	10.832	.000
		Linear Term	Contrast	9983.895	1	9983.895	21.295	.000
			Deviation	30644.157	7	4377.737	9.337	.000

	Within Groups			8439.053	18	468.836		
	Total			49067.105	26			
120Plastic crate	Between Groups	(Combined)		23688.792	8	2961.099	2.919	.028
		Linear Term	Contrast	502.670	1	502.670	.495	.491
			Deviation	23186.122	7	3312.303	3.265	.020
	Within Groups			18261.873	18	1014.549		
	Total			41950.665	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		19954.524	8	2494.316	2.071	.095
		Linear Term	Contrast	22.684	1	22.684	.019	.892
			Deviation	19931.840	7	2847.406	2.364	.067
	Within Groups			21679.395	18	1204.411		
	Total			41633.919	26			
150Cotton bag	Between Groups	(Combined)		37201.427	8	4650.178	10.263	.000
		Linear Term	Contrast	12285.594	1	12285.594	27.113	.000
			Deviation	24915.833	7	3559.405	7.855	.000
	Within Groups			8156.131	18	453.118		
	Total			45357.558	26			
150Poly Bag	Between Groups	(Combined)		49244.176	8	6155.522	8.185	.000
		Linear Term	Contrast	3954.703	1	3954.703	5.259	.034
			Deviation	45289.473	7	6469.925	8.603	.000
	Within Groups			13536.717	18	752.040		
	Total			62780.892	26			
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

Sulphate content ANOVA

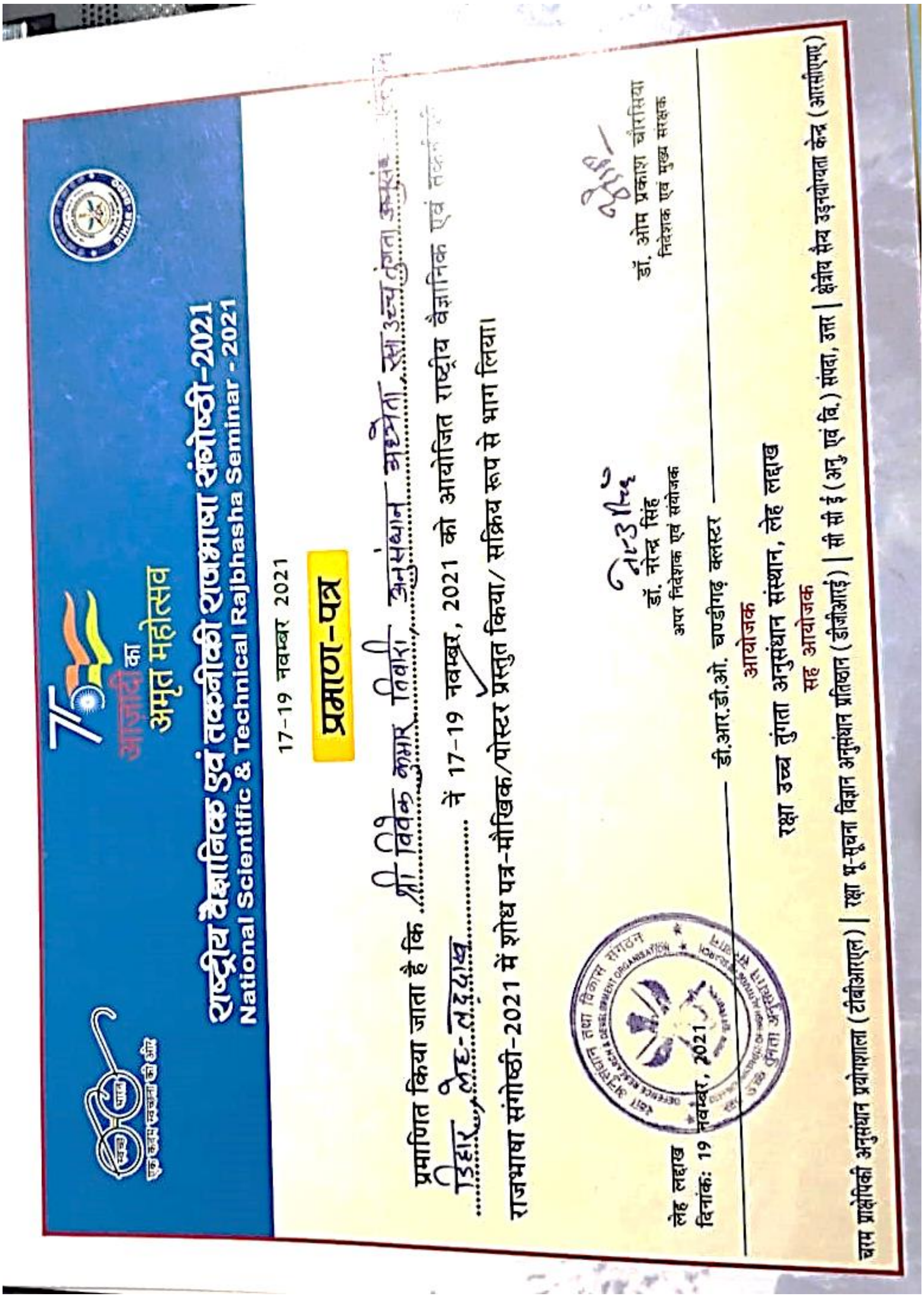
				Sum of Squares	df	Mean Square	F	Sig.
30Leno bag	Between Groups	(Combined)		83724.153	8	10465.519	5.423	.001
		Linear Term	Contrast	1760.814	1	1760.814	.912	.352
			Deviation	81963.339	7	11709.048	6.068	.001
	Within Groups			34734.108	18	1929.673		
	Total			118458.261	26			
30Cotton bag	Between Groups	(Combined)		169039.773	8	21129.972	74.309	.000
		Linear Term	Contrast	32095.004	1	32095.004	112.871	.000
			Deviation	136944.770	7	19563.539	68.801	.000

				Sum of Squares	df	Mean Square	F	Sig.
	Within Groups			5118.320	18	284.351		
	Total			174158.093	26			
30Poly Bag	Between Groups	(Combined)		92942.066	8	11617.758	60.633	.000
		Linear Term	Contrast	37781.517	1	37781.517	197.183	.000
			Deviation	55160.549	7	7880.078	41.126	.000
	Within Groups			3448.915	18	191.606		
	Total			96390.980	26			
30Plastic crate	Between Groups	(Combined)		32800.671	8	4100.084	3.866	.008
		Linear Term	Contrast	12020.685	1	12020.685	11.334	.003
			Deviation	20779.985	7	2968.569	2.799	.037
	Within Groups			19089.844	18	1060.547		
	Total			51890.514	26			
30wooden crate	Between Groups	(Combined)		89367.182	8	11170.898	151.957	.000
		Linear Term	Contrast	76404.577	1	76404.577	1039.324	.000
			Deviation	12962.605	7	1851.801	25.190	.000
	Within Groups			1323.247	18	73.514		
	Total			90690.430	26			
60Leno bag	Between Groups	(Combined)		67836.415	8	8479.552	5.470	.001
		Linear Term	Contrast	2871.207	1	2871.207	1.852	.190
			Deviation	64965.209	7	9280.744	5.986	.001
	Within Groups			27905.032	18	1550.280		
	Total			95741.448	26			
60Cotton bag	Between Groups	(Combined)		54441.752	8	6805.219	1.706	.165
		Linear Term	Contrast	14359.441	1	14359.441	3.599	.074
			Deviation	40082.311	7	5726.044	1.435	.252
	Within Groups			71815.258	18	3989.737		
	Total			126257.010	26			
60Poly Bag	Between Groups	(Combined)		81096.782	8	10137.098	6.197	.001
		Linear Term	Contrast	18511.584	1	18511.584	11.316	.003
			Deviation	62585.198	7	8940.743	5.465	.002
	Within Groups			29446.879	18	1635.938		
	Total			110543.661	26			
60Plastic crate	Between Groups	(Combined)		60371.534	8	7546.442	4.004	.007
		Linear Term	Contrast	46208.089	1	46208.089	24.516	.000
			Deviation	14163.446	7	2023.349	1.073	.419
	Within Groups			33926.789	18	1884.822		
	Total			94298.324	26			
60wooden crate	Between Groups	(Combined)		79184.025	8	9898.003	77.893	.000
		Linear Term	Contrast	62860.078	1	62860.078	494.680	.000
			Deviation	16323.947	7	2331.992	18.352	.000
	Within Groups			2287.301	18	127.072		
	Total			81471.327	26			
90Leno bag	Between Groups	(Combined)		56577.887	8	7072.236	5.859	.001
		Linear Term	Contrast	3014.740	1	3014.740	2.497	.131
			Deviation	53563.147	7	7651.878	6.339	.001
	Within Groups			21729.099	18	1207.172		
	Total			78306.986	26			
90Cotton bag	Between Groups	(Combined)		21259.412	8	2657.427	2.144	.085
		Linear Term	Contrast	3.808	1	3.808	.003	.956
			Deviation	21255.605	7	3036.515	2.450	.059
	Within Groups			22309.384	18	1239.410		

	Total			43568.796	26			
90Poly Bag	Between Groups	(Combined)		96494.867	8	12061.858	20.478	.000
		Linear Term	Contrast	52459.866	1	52459.866	89.063	.000
			Deviation	44035.002	7	6290.715	10.680	.000
	Within Groups			10602.384	18	589.021		
	Total			107097.251	26			
90Plastic crate	Between Groups	(Combined)		56213.712	8	7026.714	76.471	.000
		Linear Term	Contrast	13084.511	1	13084.511	142.398	.000
			Deviation	43129.201	7	6161.314	67.053	.000
	Within Groups			1653.963	18	91.887		
	Total			57867.675	26			
90wooden crate	Between Groups	(Combined)		78101.651	8	9762.706	47.652	.000
		Linear Term	Contrast	61120.516	1	61120.516	298.333	.000
			Deviation	16981.134	7	2425.876	11.841	.000
	Within Groups			3687.729	18	204.874		
	Total			81789.379	26			
120Leno bag	Between Groups	(Combined)		62603.154	8	7825.394	4.840	.003
		Linear Term	Contrast	11467.739	1	11467.739	7.093	.016
			Deviation	51135.415	7	7305.059	4.518	.005
	Within Groups			29102.832	18	1616.824		
	Total			91705.986	26			
120Cotton bag	Between Groups	(Combined)		17668.732	8	2208.591	.923	.521
		Linear Term	Contrast	21.239	1	21.239	.009	.926
			Deviation	17647.493	7	2521.070	1.054	.430
	Within Groups			43054.552	18	2391.920		
	Total			60723.284	26			
120Poly Bag	Between Groups	(Combined)		73009.494	8	9126.187	12.184	.000
		Linear Term	Contrast	31422.364	1	31422.364	41.950	.000
			Deviation	41587.130	7	5941.019	7.931	.000
	Within Groups			13482.793	18	749.044		
	Total			86492.287	26			
120Plastic crate	Between Groups	(Combined)		50840.884	8	6355.110	7.006	.000
		Linear Term	Contrast	34504.509	1	34504.509	38.039	.000
			Deviation	16336.375	7	2333.768	2.573	.050
	Within Groups			16327.476	18	907.082		
	Total			67168.360	26			
120wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150Leno bag	Between Groups	(Combined)		22518.581	8	2814.823	1.128	.391
		Linear Term	Contrast	4427.990	1	4427.990	1.775	.199
			Deviation	18090.591	7	2584.370	1.036	.441
	Within Groups			44903.635	18	2494.646		
	Total			67422.217	26			
150Cotton bag	Between Groups	(Combined)		36776.174	8	4597.022	1.147	.381
		Linear Term	Contrast	19629.081	1	19629.081	4.899	.040
			Deviation	17147.094	7	2449.585	.611	.739
	Within Groups			72122.306	18	4006.795		
	Total			108898.480	26			

150Poly Bag	Between Groups	(Combined)		24027.969	8	3003.496	3.160	.020
		Linear Term	Contrast	10265.887	1	10265.887	10.800	.004
			Deviation	13762.082	7	1966.012	2.068	.101
	Within Groups			17109.242	18	950.513		
	Total			41137.212	26			
150Plastic crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			
150wooden crate	Between Groups	(Combined)		.000	8	.000	.	.
		Linear Term	Contrast	.000	1	.000	.	
			Deviation	.000	7	.000	.	
	Within Groups			.000	18	.000		
	Total			.000	26			

LIST OF CONFERENCES



एक कदम स्वच्छता की ओर

आज़ादी का अमृत महोत्सव

राष्ट्रीय वैज्ञानिक एवं तकनीकी राजभाषा संगोष्ठी-2021

National Scientific & Technical Rajbhasha Seminar - 2021

17-19 नवम्बर 2021

प्रमाण-पत्र

प्रमाणित किया जाता है कि श्री विवेक कुमार तिवारी, अनुसंधान अध्येता, रक्षा उच्च तुंगता अनुसंधान संस्थान, लेह-लद्दाख ने 17-19 नवम्बर, 2021 को आयोजित राष्ट्रीय वैज्ञानिक एवं तकनीकी राजभाषा संगोष्ठी-2021 में शोध पत्र-मौखिक/पोस्टर प्रस्तुत किया/ सक्रिय रूप से भाग लिया।

लेह लद्दाख

दिनांक: 19 नवम्बर, 2021

डॉ. नरेन्द्र सिंह
अपर निदेशक एवं संयोजक

डॉ. ओम प्रकाश चौरसिया
निदेशक एवं मुख्य सरंक्षक

डी.आर.डी.ओ. चण्डीगढ़ क्लस्टर

आयोजक

रक्षा उच्च तुंगता अनुसंधान संस्थान, लेह लद्दाख

सह आयोजक

चरम प्राक्षेपिकी अनुसंधान प्रयोगशाला (टीबीआरएल) | रक्षा भू-सूचना विज्ञान अनुसंधान प्रतिष्ठान (डीजीआरई) | सी सी ई (अनु एवं वि) संपदा, उत्तर | क्षेत्रीय सैन्य उड़नयोग्यता केंद्र (आरसीएमए)

Certificate No. 2007 (SABCD-2022)

Organizers

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5th International Conference

(Advances in Smart Agriculture and Biodiversity Conservation for Sustainable Development) (SABCD - 2022)

Certificate

This is to certify that Prof./ Dr./ Mr./ Ms. Vivek Kumar Tiwari of Defence Institute of High Altitude Research - DRDO, Leh-Ladakh [illegible] actively participated as Keynote Speaker / Invited Speaker / Resource Person / Delegates / Research Scholar / Stu[illegible] Delivered Lecture / Presented a Paper (Oral / Poster / Participation) entitled Effect of Foliar application [illegible] of micronutrients (Zn&B) on growth yield and quality of carrot at High Altitude Cold desert [illegible] in the 5th International Conference on "Advances in Smart Agriculture and Biodiversity Conservation for Sustainable Development (SABCD - 2022)" held at Conference Hall, Jaipur National University, Jaipur, Rajasthan, India during March, 04 - 06, 2022.

Prof. Amar P. Garg
(Organizing Chairman)

Prof. R. L. Raina
(Vice Chancellor, JNU)
Jaipur, Rajasthan

Dr. Joginder Singh
(Organizing Secretary)

LIST OF PUBLICATIONS