

**Influence of PGRs and ZnSO₄ on Fruit Drop and Chemo-
metric Attributes of Ber (*Ziziphus mauritiana* L.)**

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Fruit Science

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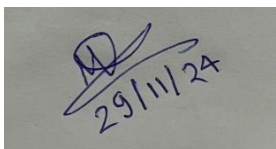


LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2025

DECLARATION

I, hereby declared that the presented work in the thesis entitled “**Influence of PGRs and ZnSO₄ on Fruit Drop and Chemo-metric Attributes of Ber (*Ziziphus mauritiana* L.)**” in fulfilment of degree of Doctor of Philosophy (Ph.D.) is outcome of research work carried out by me under the supervision of Dr. Ab Waheed Wani, Assistant Professor, in the Department of Horticulture of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.



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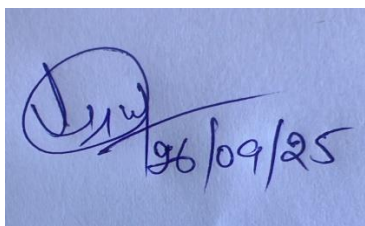
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CERTIFICATE-I

This is to certify that the work reported in the Ph. D. thesis entitled “**Influence of PGRs and ZnSO₄ on Fruit Drop and Chemo-metric Attributes of Ber (*Ziziphus mauritiana* L.)**” submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the **Department of Horticulture**, is a research work carried out by Madhurima Chaudhuri, 12116697, is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.



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CERTIFICATE-II

This is to certify that the thesis entitled “**Influence of PGRs and ZnSO₄ on Fruit Drop and Chemo-metric Attributes of Ber (*Ziziphus mauritiana* L.)**” submitted by **Madhurima Chaudhuri (Registration No.: 12116697)** to the Lovely Professional University, Phagwara, in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Horticulture (Fruit Science)**, has been approved by the Advisory Committee after an oral examination of the student in collaboration with an external examiner.



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ACKNOWLEDGEMENT

First and foremost, I would like to thank God Almighty for giving me the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily. Without his blessings, this achievement would not have been possible.

I am grateful to Lovely Professional University for providing me with an opportunity to pursue my postgraduate degree here.

I am deeply grateful to my supervisor, **Dr. Ab Waheed Wani**, for his invaluable guidance and support, which made this work possible. His expertise and encouragement have been truly inspiring in my academic growth.

I deem it a privilege to express my heartiest gratitude and sincere regard to respected Prof. **Dr. Anis Ahmad Mirza, Head of the department** and **Dr. Shailesh Kumar Singh, Deputy Dean**, for their untiring help as well as blessing for execution of my work. I sincerely thank **Dr. Deepika Saxena, Dr. Sunny Sharma and Dr. Subaya Manzoor** for their invaluable guidance and support during my Ph.D. research, as well as all the faculty members of the **Department of Horticulture**, without whom this research would not have been possible.

I am filled with immense gratitude as I take this rare opportunity to express my deep appreciation to my father, Mr. **Makhan Chaudhuri**, and my mother, Mrs. **Rama Chaudhuri**. For their endless support, love, motivation and encouragement, have been instrumental in helping me reach this goal, and I truly could not have accomplished it without them.

I sincerely thank my classmates and friends, Nidhi, Jyoti, Rahul, Jabroot, Atul, Akshat, Harjinder, Ankush, Shaifali and Lakhwinder for their constant encouragement and support. I am also grateful to the field workers, lab assistants, and colleagues whose help was vital for the timely completion of my Ph.D. research.

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LIST OF ABBREVIATIONS

Abbreviated Form	Full Form
Ha	Hectare
ha-1	Per hectare
MT	Million tonnes
<i>et al.</i>	et alii (and order)
ft.	Foot
Mm	Milli meter
M	Meter
%	Per cent
G	Gram
Cm	Centi meter
cm²	Centi meter square
Mg	Mili gram
mg/g	Milli gram per gram
cv.	Cultivar
FYM	Farm Yard Manure
N: P: K	Nitrogen: Phosphorus: Potassium
ml	Milli liter

/	Per
0°C	Degree Celsius
0°B	Degree Brix
Hrs	Hours
Min.	Minute
Nm	Nano Meter
A	Absorbance at specific wavelength
V	Volume
W	Weight
cm	Centimetre
DAP	Days after planting
LAI	Leaf area index
TSS	Total Soluble Solids
E-W	East-West
N-S	North-South
ISR	Induced Systemic Resistance
FUE	Fertilizer Use Efficiency
c.f.u.	Colony Forming Unit(s)

SCHOOL OF AGRICULTURE

LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA

Title: “Influence of PGRs and ZnSO₄ on Fruit Drop and Chemo-metric Attributes of Ber (*Ziziphus mauritiana* L.)”

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ABSTRACT

Ber is a significant fruit crop in arid regions with fully ripe ber fruits being rich in calcium, vitamin C, vitamin B and vitamin A and other essential nutrients. This research was carried out at Lovely Professional University in Phagwara, focusing on the impact of different plant growth regulators (PGRs) and zinc sulfate (ZnSO_4) on minimizing fruit drop and improving the biochemical properties of ber. The study took place from 2022 to 2024, addressing the significant issue of fruit drop in ber cultivation. The primary causes of fruit drop in ber are hormonal imbalances, embryo abortion, and unfavorable weather conditions. Field trials included foliar applications of plant growth regulators (PGRs) and zinc sulfate (ZnSO_4), applied separately and in combination. The treatments were applied in two phases: the first in mid- October at the flowering stage and the second in the final week of November during the fruitlet pea stage. A randomized block design (RBD) was used in the experiment to evaluate the impact of these treatments on various parameters, including vegetative, morphological, biochemical, and proximate characteristics.

All PGRs and ZnSO_4 treatments outperformed the control treatment. Specifically, the combination of NAA + ZnSO_4 + Salicylic acid (30 ppm + 0.5% + 300 ppm - T₉) yielded the best results for fruit drop reduction, maximize return bloom percentage, fruit retention and to increase the yield parameters, while the combination of GA₃ + ZnSO_4 + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁) showed superior performance for the physical parameters of fruits, increased leaf and fruit nutrient content, increased biochemical and proximate parameters of the fruit compared to control (T₁), in both the trials. From the present study it is concluded that application of NAA + ZnSO_4 + Salicylic acid (30 ppm + 0.5% + 300 ppm) exhibited best results with respect to fruit drop, return bloom percentage, fruit retention percentage, yield and yield efficiency. The maximum range of leaf and fruit nutrient status, along with all chemo-metric attributes and proximate parameters, was observed with the foliar application of GA₃ + ZnSO_4 + Salicylic acid (40 ppm + 0.5% + 300 ppm).

The correlation between leaf nutrients and fruit nutrients with the quality and yield attributes were positively and significantly correlated with each other except fruit drop, acidity and ash content (which were negatively correlated). Based on the findings of this study, it is recommended that the foliar application of plant growth regulators and micronutrient, both individually and in combination, be adopted by

farming communities and research institutions to improve the yield, quality and productivity of ber fruit.

Keywords: Ber, fruit drop, plant growth regulators, ZnSO₄, chemo-metric attributes

CHAPTER 1

INTRODUCTION

Ber fruit, scientifically known as *Ziziphus mauritiana*, is a tropical fruit that is gaining recognition for its flavor, nutritional benefits, and medicinal properties. It is commonly referred to as Indian jujube or Chinese date. This species is tetraploid, with a chromosome number of $2n\ 4x= 48$. Ber can be found in both wild and cultivated forms across warmer climates, extending up to altitudes of 1,500 meters above sea level (Pareek, 2007).

This fruit crop is also extensively cultivated in countries beyond India, including China, Afghanistan, Iran, Russia, Syria, Myanmar, Australia, and the United States. While India remains the top producer of ber, the key states where it is grown are Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, Punjab, Gujarat, Bihar, Maharashtra, and Tamil Nadu. According to **National Horticulture Board (NHB 2021-2022)** data Madhya Pradesh is the highest producer of ber which produces **121.76 lakh tonnes** ber. According to the data reported by KVK Patiala, the total area under ber (*Ziziphus mauritiana*) cultivation in Punjab is approximately 2,673 hectares, with an estimated annual production of about 44,170 tonnes. Although ber is grown across various regions in India, is predominantly found in dry and semi-arid areas. According to the **National Horticulture Board (NHB) 2023** data, the area under ber cultivation in India is approximately **81,000 hectares**, with a production estimate of around **8.6 lakh tonnes**.

Recent studies have emphasized the significance of ber cultivation in water-scarce regions, highlighting its potential to contribute to food security and economic stability. Ber's adaptability to challenging environmental conditions makes it a vital crop in various global agricultural systems Pandey *et al.* (2023). Often referred to as the "fruit of the poor," it is easily found in markets at an affordable price. This fruit crop can be successfully cultivated across diverse soils and climates, still producing satisfactory yields even with only rainwater for irrigation (Krishna *et al.*, 2014).

The nutritional content of ber is quite high and a relatively inexpensive market price, which makes it quite popular with consumers. It has greater protein, beta-carotene, and vitamin C than apples (Rai *et al.*, 1994). Ber fruits are rich in antioxidants like

ascorbic acid, flavonoids, and phenolic compounds (Koley *et al.*, 2016). Moreover, different parts of the ber tree, such as the bark, pruned shoots, roots, and leaves are used for various applications (Meghwal *et al.*, 2007). This fruit is enjoyed both fresh and dried, known for its delightful taste, and is packed with essential minerals like iron and calcium, along with vitamins A, B, and C (Pareek *et al.*, 2002).

Recent research indicates that *Ziziphus mauritiana* may offer significant therapeutic benefits. The fruit possesses hypoglycemic effects, potentially aiding in blood sugar regulation, and highlights its nutritional content as beneficial for metabolic health (Gupta *et al.*, 2023). The phytochemical composition of ber and its various health benefits, emphasizing its potential as a functional food in modern diets (Kumar *et al.*, 2023).

Ber is one of the many fruit crops that is becoming more and more popular with producers due to its high production, favorable returns, and capacity to thrive in wasteland and drought circumstances. Among the many benefits of the jujube tree are its flexibility and food. The Indian ber is primarily cultivated for its fruits, which can be consumed fresh, dried, candied, canned, smoked, pickled, or used in beverages. A variety of products can be made from ber fruits, including ber butter, squash, juice, murabba, pulp, jam and dehydrated items (Pareek, 1983).

A substantial amount of fruit drop occurs in the initial stage of development, specifically in the second half of December. It has been observed that a considerable number of immature fruits fall off during the initial phases of fruit growth and development. This occurrence can be linked to various factors, such as hormonal imbalances, embryo abortion, and unfavorable weather conditions (Singh *et al.*, 1991). PGRs and micronutrients are crucial for fruit development. They act as metabolic sinks, helping to redirect metabolites from one part of the plant to another, especially towards fruit production. PGRs are applied through pre-harvest sprays to minimize fruit drop and enhance the percentage of fruits that are retained during harvest.

The use of NAA notably decreased fruit drop rates and enhanced fruit quality (Kumar *et al.*, 2023). The NAA treated trees exhibited better fruit retention and higher yields compared to untreated controls. The use of NAA can be a practical approach for farmers looking to improve both yield and fruit characteristics Sharma and Singh

(2022). The use of auxins, especially indole-3-acetic acid (IAA), significantly minimized fruit drop in ber (Kumar *et al.*, 2023). In addition, NAA increased fruit set and retention in the treated plants compared to the untreated controls, highlighting its effectiveness in boosting both fruit yield and quality (Singh and Randhawa, 2001).

Gibberellic acid is a plant growth regulator that plays a crucial role in regulating several physiological and biochemical processes in plants, particularly during fruit development. This is especially relevant for ber (*Ziziphus mauritiana*). GA₃ plays a crucial role in minimizing fruit drop and enhancing the fruit's biochemical properties. Research indicates that its application significantly reduces fruit drop and improves the nutritional quality of ber fruits (Kumar *et al.*, 2023). Furthermore, GA₃ treatment not only lowers fruit drop but also significantly increases fruit size, weight, and antioxidant activity (Sharma and Verma, 2022). Additionally, GA₃ application has led to marked improvements in fruit size, weight, and nutritional content, highlighting its value in fruit production (Rani *et al.*, 2023). Gibberellic acid is a plant growth regulator that significantly affects various physiological and biochemical processes, particularly during fruit development. In ber (*Ziziphus mauritiana*), GA₃ plays a crucial role in minimizing fruit drop and enhancing the fruit's biochemical properties. Studies show that its application greatly reduces fruit drop and enhances the nutritional quality of ber fruits (Kumar *et al.*, 2023).

Plants treated with SA showed increased antioxidant levels in the fruits (Kumar and Gupta, 2023). SA application significantly decreased fruit drop rates in Apple by enhancing hormone balance and improving the overall health of the trees Nazari *et al.* (2022). SA treatment effectively lowered fruit drop rates and enhanced fruit quality in citrus through improved physiological responses Jiang *et al.* (2023).

Zinc boosts the production of indole acetic acid from tryptophan, a crucial precursor in auxin synthesis, thereby directly affecting growth and yield parameters. This indicates that foliar application of zinc is crucial not only for boosting plant vigor but also for improving yield. Grains require zinc for its essential role in chlorophyll production, which supports photosynthesis. Additionally, zinc is vital for the enzymatic synthesis of indole-3-acetic acid. A deficiency in zinc can result in problems such as "rosetting" in *M. domestica* and "mottle leaf" in *Persea Americana*. Among the different forms of zinc, ZnSO₄ is the most commonly used for foliar sprays. While extensive research has been conducted on this topic worldwide,

there is still a scarcity of results regarding the importance of these hormones and nutrients (Tripathi *et al.*, 2022).

Considering this background and the possible benefits of PGRs and ZnSO₄ for ber, the current study sought to explore the impact of foliar spray of PGRs and ZnSO₄ on flowering, fruit drop, yield, and biochemical characteristics of ber in Punjab. This study aimed to accomplish the following objectives:

Research Objectives:

1. To investigate the impact of PGRs and ZnSO₄ on the morphological and biochemical characteristics in ber.
2. To assess the effect of PGRs and ZnSO₄ on yield, yield efficiency and return bloom in ber.
3. To examine the effect of PGRs and ZnSO₄ on leaf and fruit nutrient status of ber.
4. To study the correlation between foliar and fruit nutrient status with quality and yield attributes.

CHAPTER II

REVIEW OF LITERATURE

2.1 Effect of PGRs and ZnSO₄ on Flowering and fruiting:

2.1.1 Fruiting and yield:

Pandey *et al.* (2011) showed in their study that the administration of NAA, ZnSO₄, and GA₃ together produced the best fruit retention and enhanced flowering characteristics. Better nutritional absorption and hormonal balance are guaranteed by this combination, which leads to better quality fruits. GA₃ is a well-known plant growth regulator that influences various aspects of plant development, including flowering and fruit development.

Sheran *et al.*, (2024) studied that ZnSO₄ supplementation has been shown to enhance ber blooming characteristics. Zinc has a beneficial effect on blooming because it increases the production of chlorophyll and increases plant vigour in general because ZnSO₄ plays a part in enzyme activation, its application increases fruit-set and improves pollen viability, which reduces fruit loss.

Xin *et al.*, (2024) noticed that ZnSO₄ supplementation has been shown to enhance ber blooming characteristics. Zinc has a beneficial effect on blooming because it increases the production of chlorophyll and increases plant vigour in general.

Shah *et al.*, (2021) said that SA treatment results in increased chlorophyll content, improving the overall health of flowering plants.

SANAULLAH, M. (2024) noticed in their study that Salicylic acid enhances the plant's resilience to environmental stressors, thereby improving fruit retention. It also regulates ethylene production, a hormone associated with fruit ripening and drop, which helps maintain fruit integrity during critical developmental phases.

Cao *et al.* (2013) proposed that applying salicylic acid can notably extend the duration and intensity of flowering in ber. Research has demonstrated that salicylic acid enhances the expression of genes associated with flowering, leading to earlier and more abundant blooms.

Nartvaranant, P. (2018) studied that NAA promotes cell growth and

elongation, which strengthens fruit attachment it dramatically lowers the proportion of fruit drop.

Liaquat *et al.*, (2021) found that ZnSO_4 plays a part in enzyme activation, its application increases fruit-set and improves pollen viability, which reduces fruit loss.

Khan *et al.*, (2023) studied that NAA has been demonstrated to promote the initiation and development of flowers. It improves the overall floral quality and boosts fruit set by reducing abscission rates.

Singh *et al.*, (2022) studied that Salicylic acid modulates the levels of auxins and gibberellins, which are critical for flower development. This modulation enhances photosynthesis and nutrient availability, supporting improved flower quality and quantity.

Gora *et al.* (2021) found that applying salicylic acid at a concentration of 150 ppm in ber resulted shortest time to flower initiation (12.01 days), a fruit set percentage of 11.38%, maximum fruit retention of 54.55%, and a minimum fruit drop percentage of 38.95%. However, the duration of flowering and days to maturity were not significantly affected.

In a study Pradeepkumar *et al.* (2020) observed that GA_3 stimulates flowering in ber by activating the expression of genes associated with flowering. Studies indicate that GA_3 can accelerate the flowering process and enhance the quantity of flowers in each inflorescence.

According to Yadav *et al.* (2021) fruiting attributes such as fruit set, fruit drop, and fruit retention in ber were dramatically impacted by the administration of NAA at 50 ppm.

MOHAMMAD (2022) demonstrated that a 0.6% Zinc sulphate application significantly decreased fruit drop (67.21%) while enhancing fruit retention (32.79%) and increasing yield to 83.36 kg per plant. The fruits also exhibited a specific gravity of 1.10 g/cc, an average length of 3.91 cm, a width of 4.04 cm, a weight of 34.99 g, and a volume of 32.13 cc in aonla cv. NA-7.

Tripathi *et al.* (2023) found that a foliar application of ZnSO_4 (0.1%) combined with Borax(0.6%) was the most effective treatment for promoting early flowering (70 days), reducing fruit drop (35.31%), and achieving the highest fruit

retention (64.72%) in aonla cv. NA-7.

Meena, N. (2019) found that the combination of NAA (200 ppm), GA₃ (100 ppm), and Zinc (1.0%) led to the highest increases in fruit set (49.67%) and fruit retention (65.70%) in acid lime.

Singh *et al.* (2022) suggested that the combined use of synthetic auxins NAA (15 ppm) and GA₃ (50 ppm) along with Thiourea (0.1%) during mid-May and mid-July could effectively reduce yield losses in aonla caused by excessive fruit drop.

Uniyal and Misra (2015) investigated the impact of foliar sprays of NAA (at 10, 20, and 30 ppm), 2,4-D (at 5, 10, and 20 ppm), GA₃ (at 25, 50, and 100 ppm), and Ethrel (at 50, 100, and 150 ppm) on bael cv. Pant Shivani. All the growth substances tested were effective in reducing fruit drop and improving the quality of bael fruits. The highest fruit set of 78.48% was obtained with NAA at 30 ppm, whereas the lowest fruit drop of 90.64% and the highest fruit retention of 9.36% were recorded with NAA at 20 ppm.

Patel (2023) found that combination of ZnSO₄ (0.8%), Borax (0.4%), NAA (50 ppm), and GA₃ (100 ppm) was the most effective treatment for improving various aspects of guava production. This combination significantly increased fruit setting, retention,

Painkra *et al.* (2012) found that foliar applications of NAA (at 10, 20, 30, and 40 ppm), 2,4-D (at 5, 10, 15, and 20 ppm), and GA₃ (at 50, 100, 150, and 200 ppm) had a significant impact on fruit retention, yield, and quality in Langra mango. The highest fruit retention was observed with NAA at 40 ppm.

Goswami & Shukla. (2012) observed maximum fruit size comprises length, diameter and volume in guava (*Psidium guajava* L.) cv. Sardar with the foliar application of ZnSO₄ @ 0.4%.

Pandey (2012) noted that the treatment of NAA at 20 ppm, GA₃ at 40 ppm, and ZnSO₄ at 0.4% was the most effective for enhancing fruit length (3.98 cm), width (2.99 cm), weight (20.13 g), and yield (118.25 kg) in ber.

Wahdan *et al.*, (2011) conducted an experiment with the mango cultivar "Succary Abiad" to examine the effects of various chemicals and growth regulators on growth, leaf mineral composition, fruiting, yield, and fruit quality in over the course

of two consecutive seasons (2007 and 2008) in sandy soil that was irrigated with an immersed irrigation system. The results showed that spraying urea, NAA, and GA₃ at all concentrations considerably lengthened the shoots compared to the control. In comparison to the control, the fruit's weight and volume increased after each treatment.

Animesh and Bikash (2009) investigated the impact of exogenous micronutrient applications on fruit retention in litchi cv. Bombai, using borax at concentrations of 0.25% and 0.50%, and zinc sulphate at 0.50% and 1.0%. The plants received two sprays: the first at the pea stage and the second 15 days later at the marble stage. They recorded the highest fruit retention (40.08%) in plants treated with 0.50% zinc sulphate.

Rattan and Bal (2008) discovered that 60 ppm NAA during active development phase to Ber cv. Umran resulted in the highest yield.

Sherani *et al.* (2024) found that applying 0.4% ZnSO₄ produced the highest fruit output (94.50 kg/tree) and quality, whereas the control group (ber cv. Umran) had the lowest yield (62.25 kg/tree).

2.1 Effect on fruit morphological parameters

Yadav *et al.* (2021) found that foliar application of NAA @50 ppm significantly improved size and weight in ber, resulting in better marketable quality.

Gami *et al.* (2019) carried out an experiment to assess the impact of pre-harvest spraying with ZnSO₄, KNO₃, and NAA on the development of ber (*Ziziphus mauritiana* L.) cv. Sebunder, under the environmental conditions of the Malwa Plateau. The application of NAA @60 ppm, @KNO₃ 1.5% and @ZnSO₄ 0.5% resulted in the highest values recorded for fruit length (3.17 cm), fruit width (3.00 cm), fruit volume (23.50 ml), number of fruits per tree (1608.33), fruit weight (22.87 g), and yield per tree (36.79 kg).

Tripathi *et al.* (2022) discovered that spraying of ZnSO₄, NAA, and GA₃ significantly affected fruit production in ber. The application of ZnSO₄ at 0.6% was found to be the most effective, resulting in the highest fruit yield/tree at 26.90 kg.

Chaudhry *et al.* (2018) studied the effects of foliar feeding with Urea (2%), ZnSO₄ (0.4%), and KCl (0.2%) and found these treatments to be significantly superior

in enhancing fruit size, weight, pulp weight, fruit yield, and pulp-to-stone ratio. Notably, the maximum fruit retention was achieved with ZnSO₄ (0.4%), which outperformed other treatments. Sharma and Tiwari (2015) found that a foliar spray of NAA at 100 ppm significantly enhanced the physical characteristics of the Allahabad Safeda guava variety. The treatment resulted in maximum fruit volume (174.6 ml), fruit length (6.54 cm), and diameter (5.74 cm) at harvest, along with an average of 251.1 fruits per plant, average fruit weight of 223.37 g.

Arora and Singh (2014) reported a notable improvement in fruit size characteristics of ber, such as length, breadth, weight, and volume, with the application of NAA at 30 ppm.

Kumar *et al.* (2013) found that combination of ZnSO₄ (0.8%), Borax (0.4%), NAA (50 ppm), and GA₃ (100 ppm) was the most effective treatment for improving various aspects of guava production. It also led to a higher average fruit weight.

Singh *et al.* (2012) conducted a study on the effects of Boron (0.1, 0.2, and 0.3%), zinc (0.2, 0.4, and 0.6%), and copper (0.1, 0.2, and 0.3%) on fruit drop, physical characteristics, and yield of aonla fruits cv. Banarasi.

Singh *et al.* (2016) saw in Litchi cv. Dehradun, foliar treatments of copper (0.5% and 1.0%), boron (0.4% and 0.6%), and zinc (0.5% and 1.0%) after blooming at the pealet stage were shown to significantly increase fruit weight, diameter, and length.

Yadav *et al.* (2001) noted that foliar application of urea (1.5% and 3.0%) and potassium sulfate (0.75% and 1.5%), both separately and in combination, was carried out during the pea stage of 8-year-old ber trees (cv. Umran). This treatment enhanced the size and weight of the fruits, with the most significant improvement occurring from the combined spray of urea (3.0%) and potassium sulfate (1.5%).

Tuan and Ruey (2013) studied the impact of GA₃, NAA, and 2,4-D sprays on the quality of wax apples. They found that spraying GA₃ at 10 and 30 ppm, along with 2,4-D at 10 ppm during the small bud and petal fall stages, resulted in the highest fruit length (61.6 mm), width (53.0 mm), and weight (75.9 g). In comparison, the control group had lower measurements, with fruit length at 57.4 mm, diameter at 47.8 mm, and weight at 48.0 g.

Jain and Dashora (2011) applied NAA at concentrations of 100 and 200 mg/l to guava cv. Sardar before the flowering stage and noted, 200 mg/l NAA treatment resulted in the largest fruit diameter.

Gill *et al.* (2009) investigated the effects of PGRs and nutrients on fruit drop, size, and quality in ber cv. Sanuar-2. The plants received foliar sprays of NAA at 20, 30, or 40 ppm and ZnSO₄ at 0.3, 0.4, or 0.5% in late October and again in late November. All treatments decreased fruit drop compared to the control, with the lowest drop (69.6%) occurring at NAA 30 ppm, while the control group experienced the highest drop. Additionally, the highest vitamin C content (104.2 mg/100 g pulp) was recorded in the NAA 30 ppm treatment, highlighting its effectiveness in promoting fruit retention.

Singh *et al.* (2007) discovered that a combined foliar spray of ZnSO₄ (0.5%), CuSO₄ (0.4%), and NAA (10 ppm) resulted in the highest fruit retention (30.60%) and juice content (61.00%), while also decreasing fiber content to 1.15%.

Lal & Sen (2002) observed that applying Borax at 0.8% significantly improved the number of flowers, fruit set, fruit retention, and both the length and diameter of the fruits. All

Borax treatments resulted in increased fruit weight and yield, with 3.0% urea being nearly as effective for guava cv. Allahabad Safeda.

Sharma *et al.* (2005) suggested that applying NAA at 25 ppm enhanced initial fruit set in litchi, while the highest final fruit set was obtained with NAA at 200 ppm. And noted that a 25 ppm application of NAA also reduced fruit drop in litchi cv. Dehradun.

Pandey *et al.* (2011) found that a foliar application of NAA at 20 ppm improved both the length and diameter of fruits in ber cv. Banarasi Karaka.

Tripathi *et al.* (2022) found that applying NAA (200 ppm) along with potassium sulfate (2.0%) and zinc sulfate (0.4 %) as a foliar spray during the fruit-setting stage was highly effective in reducing fruit drop and enhancing fruit retention in ber.

Pandev *et al.* (2012) conducted an experiment on ber cv. Banarasi Karaka to assess the impact of GA₃ (at 20, and 40 ppm), zinc sulfate (at 0.2, 0.4%) and iron (at

0.2, 0.4, and 0.6%) on fruit drop, growth, and quality. They found that a GA₃ spray at 40 ppm significantly decreased fruit drop to 78.20% and improved fruit retention to 21.81%. Overall, the best combination for enhancing fruit drop, growth, and quality in ber was GA₃ (40 ppm), zinc sulfate (0.4%).

Brahmchari and Rubby Rani (2001) conducted a trial to evaluate the effects of two levels each of calcium (1.0% and 2.0%), zinc sulphate (0.5% and 1.0%), and borax (0.4% and 0.8%) via foliar spray on fruit drop, retention, and some physicochemical parameters of litchi. They found that the lowest fruit drop occurred with a zinc sulphate concentration of 1.0%.

Kale *et al.* (2000) observed that the average fruit weight and size in eight ber cultivars significantly increased with the application of GA₃ at 20 ppm.

2.2 Effect on chemical parameters of fruit:

Gami *et al.* (2019) explored the effects of pre-harvest spraying with ZnSO₄, KNO₃, and NAA on the ber quality in the Malwa Plateau region. Their findings indicated that the combination of NAA at 60 ppm, KNO₃ at 1.5%, and ZnSO₄ at 0.5% resulted in maximum TSS at 15.9 °Brix, minimal acidity at 0.26%, and the highest concentrations of ascorbic acid (49.47 mg/100 g of pulp), reducing sugars (6.11%), total sugars (11.87%), and non-reducing sugars (5.76%).

BHOORIYA (2021) reported that the application of NAA at 20 ppm significantly enhanced fruit quality, producing TSS at 11.47%, reducing sugars at 4.48%, ascorbic acid at 239.03 mg/100 g of pulp, and total sugars at 7.43%. Additionally, this treatment led to a notable decrease in acidity, reducing it to 0.20% in guava.

Majumder *et al.* (2017) studied the effects of plant growth regulators (PGRs) and ZnSO₄ on the physico-chemical quality of ber (*Ziziphus mauritiana* L.) cv. BAU Kul-1. They found that applying H₃BO₃ at 0.4% resulted in the highest total soluble solids (TSS) at 11.7°Brix, total sugars at 8.33%, reducing sugars at 5.21%, and a TSS to acid ratio of 107.36, while also achieving the lowest fruit acidity at 0.10%.

Verma *et al.* (2016) examined the effect of foliar micronutrient applications on the quality traits of aonla cv. NA-7 in Kanpur in 2012. The finding indicates combination of 0.1% ZnSO₄ and 0.6% borax was the most effective treatment,

leading to the highest percentages of fruit set (51.71%), fruit weight (37.11 g), fruit length (3.65 cm), fruit volume (35 cc), ascorbic acid content (589 mg/100 g), total soluble solids (9.2°Brix), and yield (80 kg/tree) compared to other treatments.

Sharma and Tiwari (2015) found, the highest total soluble solids (TSS) at 12.6°Brix, acidity at 0.35%, total sugars at 10.42%, reducing sugars at 5.82%, and non-reducing sugars at 4.60% was seen with a foliar spray of GA₃ at 150 ppm

Ngullie *et al.* (2014) investigated the impact of salicylic acid and humic acid on flowering, fruiting, yield, and quality in mango (*Mangifera indica* L.) cv. Kesar. Their study included seven treatments, consisting of a control (water spray) and various concentrations of salicylic acid (1500, 2000, and 2500 ppm) and humic acid (0.1%, 0.2%, and 0.3%). They found that foliar application of 2000 ppm salicylic acid was the most effective treatment, resulting in an increased number of male and hermaphrodite flowers per panicle, a hermaphrodite to male flower ratio of 0.32, improved fruit retention per panicle (1.40), and better fruit quality parameters, such as total soluble solids (TSS), titratable acidity, and sugar content. Conversely, the 0.1% humic acid treatment (T₅) was particularly successful in enhancing fruit weight and overall yield.

According to Kazemi *et al.* (2011) Apple fruits treated with salicylic acid (SA) solution for five minutes showed lower TSS, higher firmness, titratable acidity (TA), peroxidase activity, and superoxide dismutase activity than the control group. Significant variations in the relative electrical conductivity and browning index during storage across all treatments were also observed by the research. In comparison to the control, the vitamin C concentration was generally improved by the SA treatment. Apple storage quality can be improved by using this post-harvest treatment, which was proven to successfully prevent fruit softening and minimize weight loss.

Debbarma and Hazarika (2016) observed that the application of GA₃ at 100 ppm in acid lime resulted in the highest levels of reducing (0.32%), non-reducing (0.31%), and total (0.62%) sugars in the foothill conditions of Arunachal Pradesh.

Painkra *et al.* (2012) found that GA₃ at 150 ppm produced the highest total soluble solids (TSS), while 2,4-Dat 10 ppm led to the lowest acidity.

Pandev *et al.* (2012) determined that the most successful treatment for raising TSS (14.20

°Brix), total sugar (10.71%), acidity (0.17%), and ascorbic acid (78.35 mg/100 g) in ber cv. Banarsi Karaka was a combination of NAA at 20 ppm, GA₃ at 40 ppm, and ZnSO₄ at 0.4%.

Mishra *et al.* (2012) found that spraying litchi cv. Rose Scented trees with GA₃ at 40 ppm minimized fruit cracking while maximizing TSS and total sugars.

Bhowmick and Banik (2011) examined the effects of NAA applied at 20, 40, and 60 ppm on mango cv. Himsagar, revealing that vitamin c content significantly improved with the 40 ppm treatment, reaching 42.40 mg/100 g of fruit pulp. Additionally, a 60 ppm NAA spray raised reducing sugars to 4.59%. The 20 ppm NAA treatment also enhanced TSS to 19.42 °Brix, non- reducing sugars to 11.32%, total sugars to 15.76%, and lowered acidity compared to the control group.

Singh and Tripathi (2010) achieved the highest levels of total sugars, total soluble solids, and ascorbic acid in Strawberry cv. Chandler through foliar application of GA₃ at 100 ppm, boric acid at 0.3%, and ZnSO₄ at 0.4% prior to bud initiation.

Rawat *et al.* (2010) saw that the influence of micronutrient foliar application on the fruit quality of guava cv. L- 49. Their findings indicated that foliar application of Zinc sulphate at 0.4% was the most effective treatment, resulting in significantly higher total soluble solids (11.78°Brix) and lower acidity (0.400%) compared to other treatments.

Gautam *et al.* (2021) suggested applying NAA at 30 ppm enhanced fruit dimensions, weight, yield, TSS, total sugars, vitamin C, and lower acidity in litchi.

According to Chavan *et al.* (2009) applying 150 ppm of NAA at the beginning of flowering, followed by sprays at fruit set and during fruit development, produced the highest TSS (20.15 °Brix) and acidity (0.211%) in sapota. These results were in contrast to control values of 18.35 °Brix and 0.228%, respectively.

Sharma *et al.* (2008) carried out a study on ber, applying zinc sulphate (0.5%), urea (1.0%), potassium sulphate (1.0%), NAA (20 ppm), GA₃ (50 ppm), and water as a control at different growth stages (floral initiation and 20 and 40 days after the first spray). According to their findings, foliar treatment of each of these compounds considerably increased ber fruit output and quality when compared to the control.

Kher *et al.* (2005) found that the application of GA₃ at 90 ppm was the most effective treatment for enhancing the weight and specific gravity of guava fruits while simultaneously decreasing total acid content.

The highest fruit firmness was achieved with CCC at 600 ppm, which produced effects similar to those of GA₃ at 90 ppm. For total soluble solids (TSS), total sugars, and non-reducing sugars, the maximum values were observed with NAA at 60 ppm. Additionally, NAA at 80 ppm and GA₃ at 60 ppm led to the highest levels of reducing sugars and ascorbic acid.

Kaur *et al.* (2004) studied the effects of different foliar sprays, such as GA₃, NAA, 2,4- D, and 2,4,5-T, on Satluj and Purple plums at varying concentrations. They found that a GA₃ concentration of 50 ppm achieved the highest total soluble solids (TSS) at 15.5% and a TSS to titratable acidity (TA) ratio of 22.2, while the acidity was reduced to 0.70%, significantly lower than that of the control.

Brahmachari and Rani (2001) suggested that three applications of GA₃ at 100 ppm, starting from the panicle emergence stage, were discovered to be the best method for raising litchi cv's total soluble solids (TSS).

Research Gap and Justification for Proposed Research

The proposed research intends to explore the comparative effects of different PGRs ZnSO₄ on fruit drop and chemo-metric attributes of ber. Controlling fruit drop has become a significant challenge for farmers, highlighting the need to identify the appropriate PGRs and ZnSO₄ at the correct concentrations. This research focuses on the emerging applications of PGRs and ZnSO₄ to address fruit drop in ber cultivation, ultimately helping to tackle the issues of low- quality and low-quantity production faced by growers at both local and national level.

CHAPTER-III

MATERIAL AND METHODS

The current study titled “**Influence of PGRs and ZnSO₄ on Fruit Drop and Chemo- metric Attributes of Ber (*Ziziphus mauritiana* L.)**” was carried out at the fruit orchard of Lovely Professional University in Punjab during the years 2022-2024. The experiment included eleven different treatments designed to evaluate the effects of PGRs and ZnSO₄ on fruit drop and the physicochemical characteristics of ber. This chapter outlines the experimental techniques, materials, and methods employed to assess the treatments throughout the investigation.

3.1 Experimental site

The current study has conducted at Department of Horticulture at Lovely Professional University, Punjab, India, during 2022-24 on 10 years old plant which were pruned and maintained as per recommended practice.

3.2 Experimental design:

In the experiment, a Randomized Block Design (RBD) was used, comprising three replications with each replication consisting of three plants of the ber. The study involved eleven different treatments.

3.3. Climate and meteorological condition

The region has a subtropical climate, receiving an average annual rainfall of approximately 1100 mm, with the majority falling between mid-June and the end of September. The cold, dry winter months are when frost sporadically appears. There are also a few winter time rains. The winter temperature is about 19 to 2 degree Celsius. April marks the beginning of the summer season, the summer temperature lies between 29 and 45 degree Celsius which lasts until the monsoon season and summer time brings with it frequent scorching breezes. The relative humidity ranged around 34 – 36 % on an average.

3.4. Experimental material

This study involved selecting ten years old ber fruit plants as a planting material that exhibited uniform vigor and productivity as the experimental subjects to examine the effects of foliar spraying with three distinct plant growth regulators (PGRs) and ZnSO₄ on fruit drop, yield, and quality of the ber fruit.

3.5. Experiment treatments

This study involved selecting ber fruit plants that exhibited uniform vigor and productivity as the experimental subjects to examine the effects of foliar spraying with three distinct plant growth regulators (PGRs) and ZnSO₄ on fruit drop, yield, and quality of the ber fruit.

There were eleven treatments, T₁ control (water spray), T₂ (20 ppm NAA), T₃ (30 ppm NAA), T₄ (30 ppm GA₃), T₅ (40 ppm GA₃), T₆ (300 ppm Salicylic acid), T₇ (0.5% ZnSO₄), T₈ NAA + ZnSo₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉ NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁ GA₃ + ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm).

3.6.The details of experimental plan employed in the present investigation are as follows:

Crop name	Ber
Cultivar	Thai Green Apple
Number of Treatments	11
Number of plant growth regulators	3
Number of micronutrient	1
No. of Replication	3
Total Number of Plant	33
Design	Randomized Block Design
Stages of treatment application	Twice 1) Full bloom stage and 2) two weeks after initial fruit set (pealet stage)
Year of experiment:	2022-2025

3.7. Time of application:

The first spray was done during 3rd week of October at flowering stage followed by second superimposed spray during 3rd week of November at fruit set stage. A knapsack sprayer was used to perform the spraying operations.

3.8. Observation recorded and methodology adopted

3.8.1. Vegetative parameters

3.8.1.1. Plant height (m)

The plant height was measured using a bamboo stick from the ground level to the apex of the top most leaf once before spraying and again after harvesting. We have measured the height of the bamboo stick with the help of a measuring tape (m). The measurements were recorded in (m).

3.8.1.2. Plant spread (m)

The spread of the plant was measured in both the North-South (N-S) and East-West (E- W) directions using a measuring tape once before the spraying and again after the harvesting. The measurements were expressed in meters (m).

3.8.1.3. Chlorophyll index (SPAD value)

SPAD-502 meter was used for the measurement of leaf chlorophyll concentration in leaves 90 days after spraying and units were expressed as SPAD.

3.8.1.4. Stem girth

The girth measurement is typically obtained by wrapping a measuring tape around the trunk of the tree, ensuring it is positioned perpendicular to the trunk's axis at the appropriate height.

3.8.2. Floral parameters

3.8.2.1. Return bloom (%)

Return bloom has been measured by counting the previous year flowers and current year flowers.

$$\text{Bloom density \%} = \frac{\text{No. of flower buds}}{\text{BCSA Cm}^2}$$

$$\text{Branch cross section area (BCSA)} = \frac{(\text{Girth})^2}{4p}$$

$$\text{Return bloom (\%)} = \frac{\text{Previous bloom density} - \text{current bloom density}}{\text{Previous year flowers}} \cdot 100$$

3.8.3. Fruiting morphological parameters

3.8.3.1. Initial fruit set:

The initial fruit set per panicle was recorded by counting the total number of fruits on the tagged branches for each replication, allowing for the calculation of the average number of fruits per panicle.

3.8.3.2. Fruit drop (%):

During the fruit set stage, a designated number of shoots were tagged in each direction of the plant to assess the percentage of fruit drop. The numbers of fruits were counted at the pealet stage and again at maturity. The percentage of fruit drop was then calculated using following formula:-

$$\text{Fruit drop (\%)} = \frac{\text{Number of fruits at initial stage} - \text{Number of fruits retained at harvest}}{\text{Previous year initial stage}} \cdot 100$$

3.8.2.3 Per cent fruit retention:

Fruit retention per shoot was calculated by counting the initial fruit set prior to maturity and expressing it as a percentage of the number of fruits per shoot.

$$\text{Fruit retention (\%)} = \frac{\text{Total number fruit set} - \text{Fruit drop}}{\text{Total number of fruit set}} \cdot 100$$

Fruit growth parameters

3.8.3.3. Weight of fruit (g):

The fruits were weighed using an electronic balance at the full maturity stage, and the average weight of ten fruits was calculated and expressed in grams.

3.8.3.4. Fruit length (cm):

The length of ten fruits was measured using Vernier calipers, and the average length was calculated and expressed in centimeters.

3.8.3.5. Fruit diameter (cm):

The width of ten fruits was measured using Vernier calipers, and the average measurement was calculated and expressed in centimeters.

3.8.3.6. Volume of fruit (cc):

The volume of ten fruits was assessed using the water displacement method, by using a measuring cylinder and the average volume was calculated and reported in cubic centimeters (cc).

3.8.3.7. Fruit firmness (N)

Fruit firmness is typically assessed with a penetrometer, which exerts pressure on the fruit to gauge its crispness.

3.8.3.8. Specific gravity:

The specific gravity of ber fruits was calculated using the formula:

$$\text{Specific gravity (\%)} = \frac{\text{Weight of the fruit (g)}}{\text{Volume of the fruit (cc)}}$$

3.3.1. Bio-chemical parameters

To evaluate the quality of the fruit, ten ripe and healthy fruits were randomly picked from each replication when they reached full maturity. The fruits were carefully washed before analysis of the following contents.

3.3.1.1. Total soluble solids (TSS °Brix):

From each treatment, ten fruits were randomly chosen and macerated using a pestle and mortar to obtain the juice. The total soluble solids (TSS) of the juice were assessed with a digital refractometer, capable of measuring from 0 to 32 °Brix. The findings were reported as °Brix.

3.3.1.2. Acidity (%):

A known amount of fruit pulp (5 g) was macerated, diluted with a small quantity of distilled water, and then filtered through muslin cloth. The resulting volume was adjusted to 100 ml. A 5 ml aliquot was taken for titration against 0.1 N sodium hydroxide solution, using phenolphthalein as the indicator. The endpoint was indicated by the development of a light pink color that lasted for at least 15 seconds. The results were expressed as the amount of citric acid per 100 g of fruit pulp.

$$\text{Acidity (\%)} = \frac{\text{Titerate value} \times 64 \times \text{Volume made up}}{\text{Aliquot taken} \times \text{weight} \times \text{sample} \times 100} \times 100$$

3.3.1.3. TSS/Acid ratio:

To calculate the TSS/Acid ratio the TSS value was divided by acidity value.

3.3.1.4. Ascorbic acid (mg/100g pulp):

The measurement was expressed in milligrams per 100 g of pulp, following the A.O.A.C. method (A.O.A.C., 1990). To estimate the ascorbic acid content, 5 g of fruit pulp was crushed with 3 percent metaphosphoric acid as a buffer using a pestle and mortar. The extract was then filtered, and the volume was adjusted to 100 ml. A 5 ml aliquot of this solution was titrated against a 2,6-dichlorophenol indophenol dye solution until a light pink color developed. The results were reported as milligrams of ascorbic acid per 100 g of fruit pulp.

Dye factor = 0.5/ Titrate value of standard ascorbic acid.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titrate Value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot taken for estimation} \times \text{volume of sample taken}} \times 100$$

3.3.1.5. Reducing sugar (%):

An aliquot of 5 ml of diluted fruit juice was taken from the 100 ml sample for titration and mixed with 10 ml of Fehling solutions A and B. This mixture was titrated against a 1.0 percent glucose solution in a boiling environment, using methyl blue as the indicator. Additionally, a blank titration was performed with 10 ml of Fehling solutions A and B. The results were expressed as a percentage of reducing sugar Ranganna (1986).

$$\text{Reducing sugar (\%)} = \frac{\text{Blank titre value} - \text{Sample titre value}}{\text{A Aliquot taken (3ml)} \times \text{Volume of sample taken (5ml)}} \times 100$$

3.3.1.6. Non reducing sugar (%)

Non-reducing sugars were determined by subtracting the amount of reducing sugars from the total sugars. The final results were expressed as a percentage of non-reducing sugars with the formula:

$$\text{Non reducing sugar (\%)} = \text{total sugars} - \text{reducing sugar}$$

3.3.1.7. Total sugars (%):

Total sugar content in canned litchi was determined by Lane and Eynon method reported by Ranganna (1986). The sample extract filtrate of 25 ml was taken to which 2 ml of concentrated hydrochloric acid (HCl) was added and kept for hydrolyzation about 3 days at room temperature. The solution was neutralized with 1 N NaOH solution using phenolphthalein as indicator and HCl was added into the solution till the colourless, finally the volume was made up to 100 ml. This extract solution was then titrated against Fehling's A and B solution as was done previously in case of reducing sugar. The endpoint was also indicated by the brick red colour precipitates. Titre value was used to calculate the percentage of total sugars.

3.3.2. Yield attributes

The yield and the yield efficiency in ber were recorded after the mature fruits were harvested from each plant.

3.3.2.1. Fruit yield/plant (kg):

The weight of fruits per tree and the total yield were measured at harvest (kg/plant). At the final harvest, the cumulative total from each harvest was recorded.

3.3.2.2. Yield efficiency (kg/m²)

.cm² was used to indicate the yield efficiency.

$$\text{Yield efficiency (\%)} = \frac{(\text{Yield})}{\text{Trunk cross sectional area}}$$

$$\text{Trunk cross sectional area} = \frac{(\text{Girth})^2}{4\pi}$$

3.3.2.3. Total phenolic content (mg GAE/g):

The total phenolic content of the individual extracts was determined using the Folin– Ciocalteu method (Zhang *et al.*, 2007). Briefly, 1 ml of the extract solution (ranging from 100- 500 µg/mL) was mixed with 2.5 mL of 10% (w/v) Folin– Ciocalteu reagent. The mixture was allowed to stand for 5 minutes before adding 2.0 mL of 75% Na₂CO₃. It was then incubated at 50°C for 10 minutes while being agitated occasionally. After cooling, the absorbance was measured at 760 nm using a UV spectrophotometer (Shimadzu, UV-1800), with a blank containing no extract as the reference. The results were expressed as milligrams of gallic acid equivalents per gram of dry extract (mg GAE/g). Total sugar content in canned litchi was determined by Lane and Eynon method reported by Ranganna (1986). The sample extract filtrate of 25 ml was taken to which 2 ml of concentrated hydrochloric acid (HCl) was added and kept for hydrolyzation about 3 days at room temperature. The solution was neutralized with 1 N NaOH solution using phenolphthalein as indicator and HCl was added into the solution till the colourless, finally the volume was made up to 100 ml. This extract solution was then titrated against Fehling's A and B solution as was done previously in case of reducing sugar. The endpoint was also indicated by the brick red colour precipitates. Titre value was used to calculate the percentage of total sugar using the formula

3.3.2.4. Total Carotenoid content (%):

Total carotenoid content in a sample was determined using a spectrophotometric method, which involves extracting carotenoids from the sample and measuring their absorbance at specific wavelengths. The formula commonly used to calculate the total carotenoid content is:

$$\text{Total Carotenoid content (\%)} = \frac{A \times V}{DV \times D}$$

Where:

3.3.2.4.1. AAA = Absorbance at the specific wavelength (usually around 450 nm)

3.3.2.4.2. VVV = Volume of the extract (in mL)

3.3.2.4.3. DDD = Dilution factor (if applicable)

3.3.2.4.4. EEE = Extinction coefficient (usually given in mg/mL)

3.3.2.4.5. WWW = Weight of the sample (in grams)

(Rodriguez-Amaya, 2001)

3.3.2.5. Total antioxidant content (%) or antioxidant activity:

The total antioxidant capacity of ber was assessed using the DPPH free radical scavenging assay, as described by Mandave *et al.* (2014), with some modifications. First, 1 ml of the methanolic extract was placed in a test tube, followed by the addition of 3.9 ml of a 0.1 mM methanolic solution of 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical. The absorbance changes were measured at 30-minute intervals at a wavelength of 515 nm using a spectrophotometer.

The total antioxidant capacity (%) was subsequently determined using the following formula:

$$\text{Radical Scavenging Activity (\%)} = \frac{\text{OD control} - \text{OD sample}}{\text{OD control}} \times 100$$

3.3.2.6. Ash content (%):

The ash content was determined by first drying the samples at 105°C for one day in an oven, after which the crucibles were placed in a muffle furnace. The temperature was gradually increased to 600°C, and the samples were ashed for 10 to

12 hours until they turned white (Paquat and Houtfenne method, 1987).

3.3.2.7. Crude protein content (%):

A micro-Kjeldahl flask was prepared with a fruit sample weighing 0.25 g. To this sample, 15 ml of concentrated H_2SO_4 (36 N) was added along with a few glass beads to prevent bumping and a catalyst mixture consisting of 0.42 g CuSO_4 and 9.0 g K_2SO_4 . The sample was digested at 410°C for 45 minutes or until a clear green solution was obtained, ensuring the complete oxidation of all organic materials. After digestion, the solution was diluted with 50 ml of distilled water, and a distillation apparatus was arranged with another micro-Kjeldahl flask. Following this, 45 ml of 15 N NaOH was added, and the mixture was distilled to capture the released ammonia in a boric acid solution containing the indicators methyl red and methylene blue. The nitrogen content was quantified by titrating the borate ion with standardized 0.1 N H_2SO_4 . Additionally, sodium carbonate (0.1 N Na_2CO_3) was utilized as the primary standard for standardizing the H_2SO_4 , and a blank test for the reagent was conducted simultaneously.

3.3.2.8. Fat content (%):

The fat content of fresh and dried pulp samples was estimated using the Soxhlet extraction method as per AOAC (2000). Accurately weighed, finely ground, and moisture-free samples (2–5 g) were placed in filter paper thimbles and loaded into the Soxhlet apparatus. A pre-weighed round-bottom flask containing 100–150 ml of petroleum ether (boiling point $40\text{--}60^\circ\text{C}$) was attached, and extraction was performed for 6–8 hours. Following extraction, the solvent was removed using a rotary evaporator or water bath, and the flask was dried in a hot air oven at 100°C to a constant weight. The fat content was calculated based on the weight gain of the flask.

3.3.2.9. Fiber content (%):

Petroleum ether was utilized as the solvent to extract the fat content from the sample. The solvent was then removed through evaporation, and the remaining fat residue was weighed.

A known amount of the sample was combined with 25 ml of petroleum ether, and the mixture was allowed to sit overnight. Afterward, the petroleum ether was decanted, and the sample was dried. The drying process was carried out until the sample attains constant weight. 5 ml of 1.25 % H₂SO₄ was used to treat the sample and it was processed in the boiling water bath for about 30 minutes. The distilled water was used to wash the residue for three times. 5 ml of

1.25 % NaOH was used to treat the washed residue and it was processed in the boiling water bath for about 30 minutes. Then it was brought back to room temperature. Distilled water was added to adjust the volume to 50 ml, and the absorbance was measured at 590 nm. The crude fiber content (CFC) of the fruit pulp sample was expressed as a percentage. Pure cellulose in the range of 5 to 25 mg served as the standard.

The crude fiber content was determined using the following calculation:

$$\begin{aligned}\% \text{ Crude fibre (\%)} &= \frac{\text{Weight of a crude fibre}}{\text{Weight of sample (g)}} \times 100 \\ &= \frac{WR - WA}{WS} \times 100\end{aligned}$$

Where,

WR = weight of the crucible + residue, W1 = weight of a crucible + ash,

W2 = weight of the sample.

3.3.2.10. Leaf nutrient content (mg) and fruit nutrient content (mg):

Leaf and fruit samples were collected, washed, and dried at 65°C before being crushed and ground in a porcelain mortar for analysis (Kacar *et al.*, 1994). The total nitrogen content of the leaf and fruit samples was measured using the Kjeldahl method (Keeney *et al.*, 1982). For the analysis of other nutrient elements, the samples were ashed at 550°C. Phosphorus (P) was determined using the Barton yellow color method, sulfur (S) was measured turbidimetrically with a spectrophotometer, and boron (B) was analyzed using the azometin-H method (Bayraklı *et al.*, 1987). Additionally, potassium (K) has been measured by flame photometer and other micro nutrients calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), zinc (Zn), and copper (Cu) were calculated the Perkin Elmer 2280 atomic absorption spectrophotometer (Kacar *et al.*, 1994).

Statistical analysis

The statistical analysis of the data recorded from both the experiments were conducted following the methods outlined by Panse and Sukhatme (1985). Two years data was pooled and results were evaluated at a 5% significance level, with significant differences among treatments determined using the 'F' test (variance ratio). This process included calculating the sum of squares and carrying out an analysis of variance (ANOVA). The parameters were analyzed using Opstat software.



Plate 3.1 Spraying in flowering stage



Plate 3.2 Spraying in pea stage



Plate 3.3 Measuring length by Vernier caliper



Plate 3.4 Measuring chlorophyll

by SPAD



Plate 3.5 Measuring vitamin c



Plate 3.6 Harvested fruits

CHAPTER-IV

RESULTS AND DISCUSSION

The current study entitled “**Influence of PGRs and ZnSO₄ on Fruit drop and Chemo- metric Attributes of Ber (*Ziziphus mauritiana* L.)**” was conducted during 2022-24 at Lovely Professional University, Department of Horticulture, Phagwara, (Punjab). The data processed statistically in order to assess their degree of variance due to different diverse treatments under investigation. The pattern of ber crop behavior under different treatments have been illustrated by the use of table and substantiated with suitable figures at appropriate places.

4.1 Vegetative parameters

4.1.1 Plant height (m) and Plant spread (m):

The data analysis clearly showed that both PGRs and ZnSO₄ significantly influenced ber incremental plant height, as measured across the first and second year trials, as well as in the pooled data (Table 4.1). Application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest incremental plant height for both the trials than control. During first year and second year, incremental maximum plant height (0.17 m and 0.19 m) was observed in (40 ppm + 0.5% + 300 ppm- T₁₁) which was statistically at par (0.15 and 0.16 m) with T₁₀ the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀), whereas the minimum incremental plant height (0.3 m and 0.4 m) was observed in control (T₁). For pooled data, similar trend was seen, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) showed highest incremental plant height (0.18 m) followed by the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₀) that was (0.16 m) and lowest (0.3 m). in control (T₁).

From Table 4.1 its evident that the incremental plant spread during first year and second year was recorded maximum (0.14 and 0.16 m) in GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁) respectively, whereas the minimum incremental plant spread (0.03 m and 0.04 m) was observed in control (T₁). For pooled data, similar trend was seen, T₁₁ GA₃+ ZnSO₄ +

Salicylic acid (40 ppm + 0.5% + 300 ppm) showing highest incremental plant spread (0.15 m) followed by T₁₀ (0.14 m) and lowest in T₁ control (0.28 m).

Gibberellic acid is a well-known growth regulator that promotes cell elongation and division. It activates the production of enzymes that break down cell walls, permitting cells to expand and lengthen. This effect leads to increased height in plants. GA₃ application resulted in significant increases in plant height due to enhanced cell elongation in ber plants (Singh *et al.*, 2020). SA applications resulted in higher levels of growth-promoting hormones in ber plants, which corresponded with increased height and spread (Yadav *et al.*, 2023). Foliar sprays of gibberellic acid, salicylic acid, and zinc sulfate contribute to increased plant height and spread through mechanisms such as enhanced cell elongation, improved photosynthesis, better nutrient uptake and stimulation of growth hormones. Recent studies provide evidence supporting these mechanisms and highlight the effectiveness of these treatments in promoting growth in fruit plants (Yadav *et al.*, 2023).

Table 4.1: Effect of PGRs and ZnSO₄ on incremental plant height and incremental plant spread on ber

Treatments	Incremental Plant height (m)			Incremental Plant spread (m)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	0.03	0.04	0.03^a	0.03	0.04	0.28^e
T ₂	0.07	0.07	0.07^a	0.05	0.06	0.90^{bc}
T ₃	0.08	0.08	0.08^a	0.06	0.07	0.94^{bc}
T ₄	0.10	0.10	0.10^a	0.08	0.08	1.23^{ab}
T ₅	0.06	0.06	0.06^a	0.09	0.10	0.09^a
T ₆	0.05	0.07	0.06^a	0.04	0.05	0.64^{cd}
T ₇	0.04	0.09	0.07^a	0.07	0.05	0.58^{de}
T ₈	0.12	0.11	0.12^a	0.10	0.11	0.10^{bc}
T ₉	0.13	0.13	0.13^a	0.11	0.13	0.96^{bc}
T ₁₀	0.15	0.16	0.16^a	0.12	0.15	1.28^a
T ₁₁	0.17	0.19	0.18^a	0.14	0.16	1.36^a
CD (p≤0.05)	0.02	0.03		0.06	0.08	
SE±(m)	0.01	0.02		0.02	0.03	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5%

+ 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.2 Yield parameters

4.2.1 Initial Fruit set %, fruit retention % and fruit drop %

The data provided in Table 4.14 showed that in first year and second year, the application of NAA+ ZnSO₄ + Salicylic acid (30 ppm + 0.5 % + 300 ppm – T₉) recorded highest initial fruit set % (98.94 and 99.45 %) and the minimum initial fruit set % was (91.02 and 91.09 %), observed in control treatment (T₁) respectively. Same trend followed in pooled data, application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded highest initial fruit set % (99.19 %) followed by the application of NAA+ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm- T₉) (98.59 %) and the lowest initial fruit set % (91.05 %) was observed in control (T₁) treatment.

NAA helps reduce flower and fruit drop, zinc supports enzyme activity and auxin synthesis, and salicylic acid boosts hormonal balance and plant defense, all contributing to better fruit set (Tripathi *et al.*, 2009; Singh *et al.*, 2024 and Hayat *et al.*, 2010). Zinc, being a crucial micronutrient, is involved in several enzymatic activities, including auxin synthesis and carbohydrate metabolism, which directly support fruit set and retention (Singh *et al.*, 2024). Moreover, salicylic acid is known for its role in enhancing plant defense responses and improving flowering and fruit setting by influencing hormonal balance and antioxidant activity (Hayat *et al.*, 2010). The control (T₁) consistently showed the lowest fruit set, emphasizing the need for growth regulator application. Similar positive effects of such combinations on fruit set in ber and other fruit crops have been reported (Singh *et al.*, 2023). Therefore, T₉ proves to be an effective treatment for enhancing fruit set and productivity in ber.

The data presented in Table 4.2 clearly showed that in first year and second year trial the application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded highest fruit retention % (35.47 % and 35.61 %) which was statistically at par with the application of NAA+ZnSO₄+Salicylic acid (20 ppm+ 0.5%+ 300 ppm- T₈) and the minimum fruit retention (%) was (20.21 % and 20.45 %) observed in control treatment (T₁) respectively. Same trend followed in pooled data, application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded highest fruit retention % that was (35.54 %) followed by the application of

NAA+ZnSO₄+Salicylic acid (20 ppm + 0.5% + 300 ppm- T₈) that was (33.88 %) and the lowest fruit retention % (20.33 %) was observed in control (T₁) treatment.

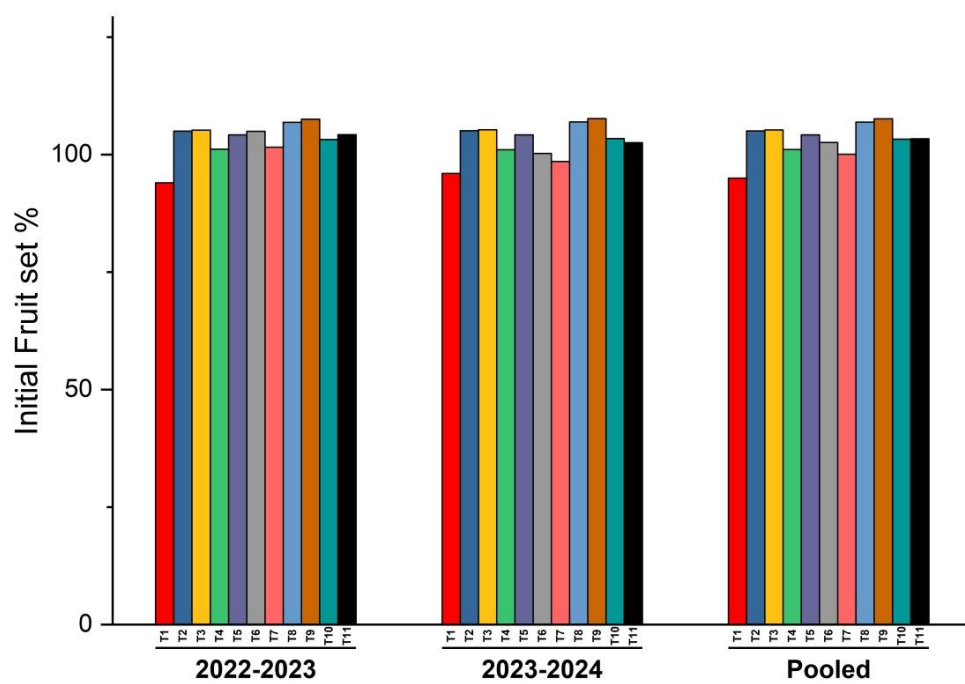
It is clear from the data presented in Table 4.2 that in first year and second year the application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded lowest fruit drop % (64.19 % and 64.17 %) and the maximum fruit drop % (80.09 % and 79.12 %) was observed in control treatment (T₁). Same trend followed in pooled data, application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded lowest fruit drop % that was (64.15 %) followed by the application of NAA+ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm- T₈) that was (65.61 %) and the highest fruit drop % (77.80 %) was observed in control (T₁) treatment respectively.

Fruit drop is an abscission process regulated by the interplay of hormones (Krishnamoorthy, 1993) within plants. The abscission of immature fruits is linked to lower levels of auxins, which can be countered by the application of synthetic auxins such as NAA. The effectiveness of gibberellins in reducing fruit drop seems to be indirect, operating through a synergistic relationship with auxins. Similarly, zinc's role in minimizing fruit drop appears to be indirect, as it is essential for the synthesis of tryptophan, a precursor to auxin, which may contribute to decreased fruit drop. Auxin triggers nutrients towards sink (fruit) and maintains source sink relationship that reduces the drop (Wani *et al.*, 2017). Consistent findings regarding significant fruit drop have been documented by Sharma *et al.* (2005), Painkra *et al.* (2012), Singh *et al.* (2012). The exogenous application of NAA likely raised auxin levels in plants, contributing to the reduction of fruit drop. Similar findings have been reported by Arora *et al.* (2014) and Singh *et al.* (2020) in ber, indicating that NAA, whether used alone or in combination, enhances fruit retention and helps prevent drop. NAA's positive impact on fruit retention can be attributed to its role in promoting cell division, elongation, and increasing intercellular space in mesocarpic cells, leading to improved plant health and healthier fruit, which ultimately supports fruit retention (Sharma *et al.*, 2008).

Table 4.2: Effect of PGRs and ZnSO₄ on Initial fruit set (%), fruit retention (%) and fruit drop of ber

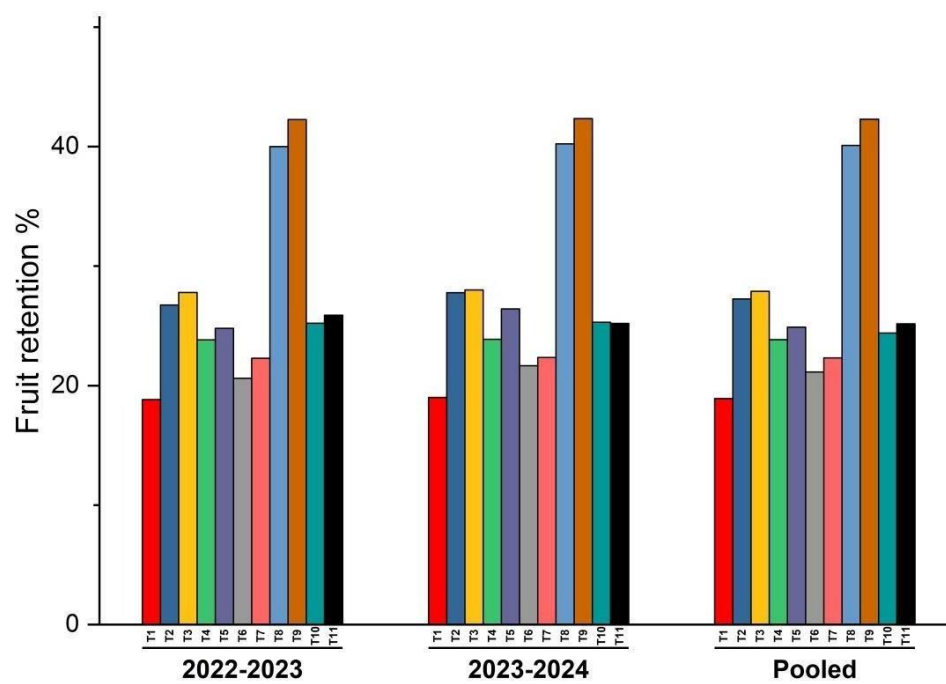
Treatment	Initial Fruit Set (%)			Fruit Retention (%)			Fruit Drop (%)		
	2022–23	2023–24	Pooled	2022–23	2023–24	Pooled	2022–23	2023–24	Pooled
T ₁	91.02	91.09	91.05^e	20.21	20.45	20.33^h	77.60	77.70	77.80^a
T ₂	96.35	97.71	97.03^{cd}	30.28	30.89	30.59^{cd}	68.39	68.48	68.57^c
T ₃	98.20	98.64	97.89^{cd}	31.24	31.45	31.35^c	68.12	67.98	67.84^c
T ₄	90.04	93.12	92.82^d	24.42	25.11	24.77^f	73.03	73.32	73.61^{abc}
T ₅	92.53	94.26	93.95^{cd}	25.54	25.77	25.66^e	72.66	72.69	72.73^{ab}
T ₆	98.47	95.07	94.52^{cd}	27.54	28.24	27.89^g	70.30	70.49	70.69^{bc}
T ₇	92.23	92.69	92.46^{bc}	22.66	22.94	22.80^{de}	75.25	75.34	75.43^{bc}
T ₈	96.15	99.33	98.59^{ab}	33.65	34.07	33.86^b	65.70	65.66	65.61^d
T ₉	98.94	99.45	99.19^a	35.47	35.61	35.54^a	64.19	64.17	64.15^d
T ₁₀	95.14	95.14	94.76^{cd}	29.46	29.93	29.70^e	68.54	68.66	68.79^{bc}
T ₁₁	94.28	95.23	95.18^{cd}	29.93	30.19	30.06^e	68.30	68.42	68.54^{bc}
CD ((p≤0.05))	3.52	3.53		2.48	2.49		2.88	2.94	
SE ±(m)	1.24	1.25		0.89	0.90		1.15		

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)



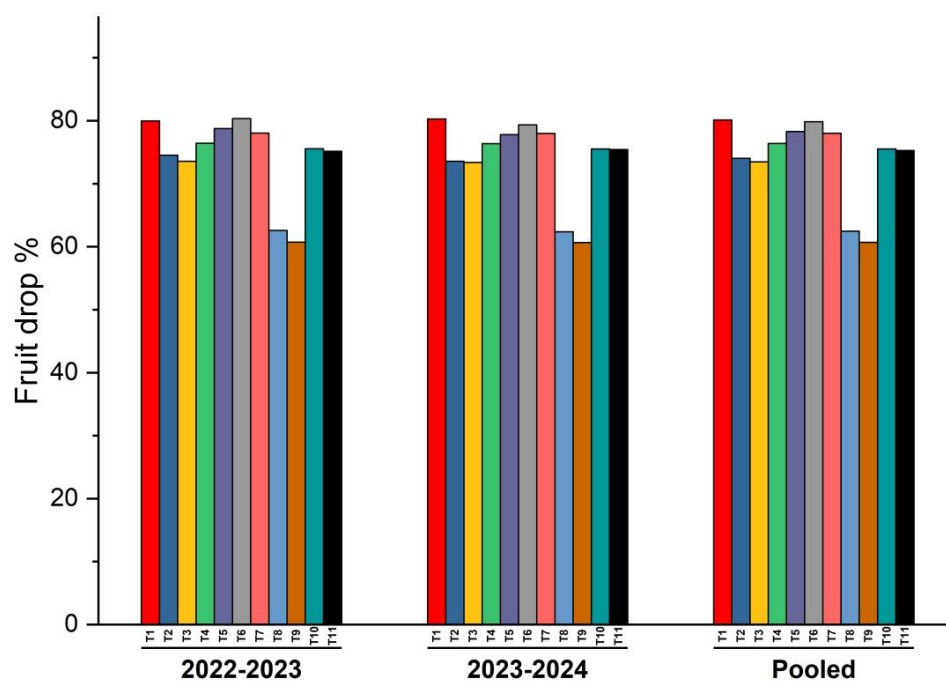
* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

4.1 Graphical representation of initial fruit set (%)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

4.2 Graphical representation of fruit retention (%)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

4.3 Graphical representation of fruit drop (%)

4.2.2 Yield and yield efficiency:

It is evident from the data presented in Table 4.3 that in first year and second year trial the application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded highest yield (27.79 and 28.00 kg/tree) and having at par values with the application of NAA+ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm- T₈) and the minimum yield was observed in control treatment (T₁) which was (17.81 and 18.82 kg/tree), respectively. In case of pooled data, same trend was followed, application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded highest yield (27.90 kg/tree) followed by the application of NAA+ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm- T₈) that was (27.40 kg/tree) and the lowest yield (18.32 kg/tree) was observed in control (T₁) treatment.

The data presented in Table 4.3 that in first year and second year, the application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded highest yield efficiency (0.65 and 0.86 kg/cm²) which was statistically at par with the treatment T₈ NAA+ZnSO₄+Salicylic acid (30 ppm+ 0.5%+ 300 ppm- T₈) and the minimum yield efficiency (0.38 and 0.40 kg/cm²) observed in control treatment (T₁). Same trend has followed in pooled data, application of NAA+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₉) recorded highest yield efficiency that was (0.76 kg/cm²) followed by the application of NAA+ZnSO₄+Salicylic acid (20 ppm + 0.5% + 300 ppm- T₈) that was (0.74 kg/cm²) and the lowest yield efficiency (0.39 kg/cm²) was observed in control (T₁) treatment.

Naphthalene acetic acid (NAA) is a synthetic auxin that has been widely used in horticulture to improve the growth and yield of various fruit crops, including ber (*Ziziphus mauritiana*). The application of NAA can lead to significant increases in both yield and yield efficiency through several physiological and biochemical mechanisms. The application of NAA significantly increased fruit set and size in ber, resulting in higher overall yield (Singh *et al.*, 2020). NAA treatments significantly reduced premature fruit drop in ber, contributing to higher yield (Tripathi *et al.*, 2022). The increase in yield owing to NAA applied in combination is associated with a high rate of enzymatic activity as well as biosynthesis of auxin, as well as an increase in the number and size of fruit, which ultimately increased the yield per plant (Singh *et al.*, 2010). The increase in yield per plant is primarily attributed to improved fruit retention, reduced fruit drop, and enhanced size and weight of the fruit resulting

from the combined application of NAA and ZnSO₄. These findings are consistent with results from several studies, including those by Arora *et al.*, (2014) and Tripathi (2022) in ber and Anand *et al.* (2003) litchi cv. Dehradun. The combined use of NAA, Zn, and SA results in better hormonal coordination, balancing auxin, ethylene, and salicylic pathways. This ensures proper fruit initiation, development and maturation—leading to significantly higher yield per tree (kaya *et al.*, 2023).

Table 4.3: Effect of PGRs and ZnSO₄ on Yield (kg/tree) and Yield efficiency (kg/cm²) of ber

Treatments	Yield (kg /tree)			Yield efficiency (kg/ cm ²)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	17.81	18.82	18.32^g	0.38	0.40	0.39^h
T ₂	23.56	23.7	23.63^c	0.55	0.59	0.57^{def}
T ₃	25.44	25.59	25.52^b	0.59	0.60	0.60^{bcd}
T ₄	18.68	18.78	18.74^g	0.54	0.55	0.54^{fg}
T ₅	20.60	20.83	20.72^{ef}	0.52	0.54	0.53^g
T ₆	22.28	22.04	22.16^{de}	0.55	0.58	0.56^{efg}
T ₇	19.82	22.45	21.14^a	0.59	0.60	0.58^{cde}
T ₈	27.29	27.50	27.40^{ab}	0.64	0.83	0.74^a
T ₉	27.79	28.00	27.90^a	0.65	0.86	0.76^a
T ₁₀	19.96	20.12	20.04^f	0.60	0.62	0.61^{bc}
T ₁₁	20.48	21.02	20.75^{ef}	0.62	0.64	0.63^b
CD (p≤0.05)	1.21	0.31		0.02	0.03	
SE(m)	0.40	0.45		0.01	0.02	

Whereas, T₁- Control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.2.3 Fruit weight (g) and Fruit width/diameter (cm):

It is evident from the data presented in Table 4.4 and Fig. 4.4 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit weight (45.19 g and 46.10 g) and having at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit weight was observed in control treatment (T₁) which was (31.25 g and 32.56 g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit weight that was (45.67 g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (44.95 g) and the lowest fruit weight (31.90 g) was observed in control (T₁) treatment.

It is evident from the data presented in Table 4.4 and fig 4.5, that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit diameter (5.36 cm and 5.40 cm) and the minimum fruit diameter was observed in control treatment (T₁) which was (2.10 cm and 2.14 cm). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit diameter that was (5.38 cm) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (4.39 cm) and the lowest fruit diameter (2.12 cm) was observed in control (T₁) treatment.

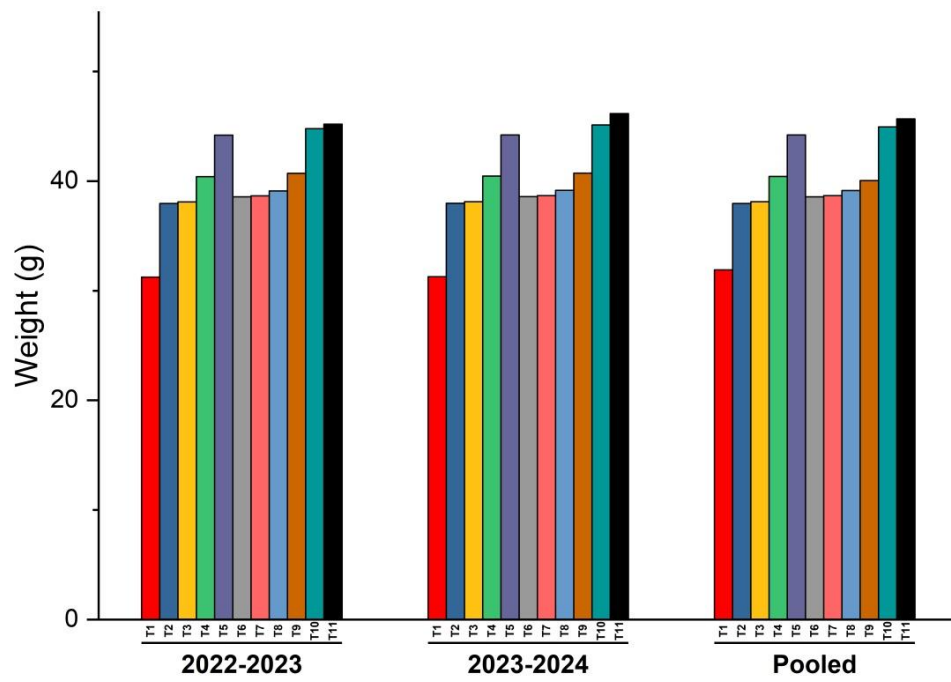
GA₃ promotes cell elongation and division, leading to larger fruit size. It enhances the growth of the ovary, which is crucial for fruit development. GA₃ stimulates metabolic processes that contribute to sugar accumulation in fruits, which increases both weight and size. The increase in fruit size associated with NAA, GA₃ and ZnSO₄ may be attributed to the enhanced synthesis of metabolites and improved mobilization of nutrients and minerals from other parts of the plant to the developing

fruits. It is well known that fruits serve as highly active metabolic sinks. The growth promotion effects of GA₃ and ZnSO₄ from their roles in hormonal metabolism, as well as in stimulating cell division, elongation, and expansion. These findings align with the research of Singh *et al.* (2017). The increase in fruit weight can be attributed to the strengthening of the middle lamella and, consequently, the cell wall, which may have facilitated a greater passage of solutes into the fruits. This enhancement could have resulted in increased length and diameter of the fruit, as well as greater individual fruit weight. A positive and significant correlation was observed between fruit length and weight, as well as between fruit diameter and weight. These findings are supported by the studies of Banker and Prasad (1990), Kale *et al.* (2000), Wangbin *et al.* (2008), Arora and Singh (2014), and Rokaya *et al.* (2016).

Table 4.4: Effect of PGRs and ZnSO₄ on Fruit weight (gm) and Fruit width/diameter (cm) of ber

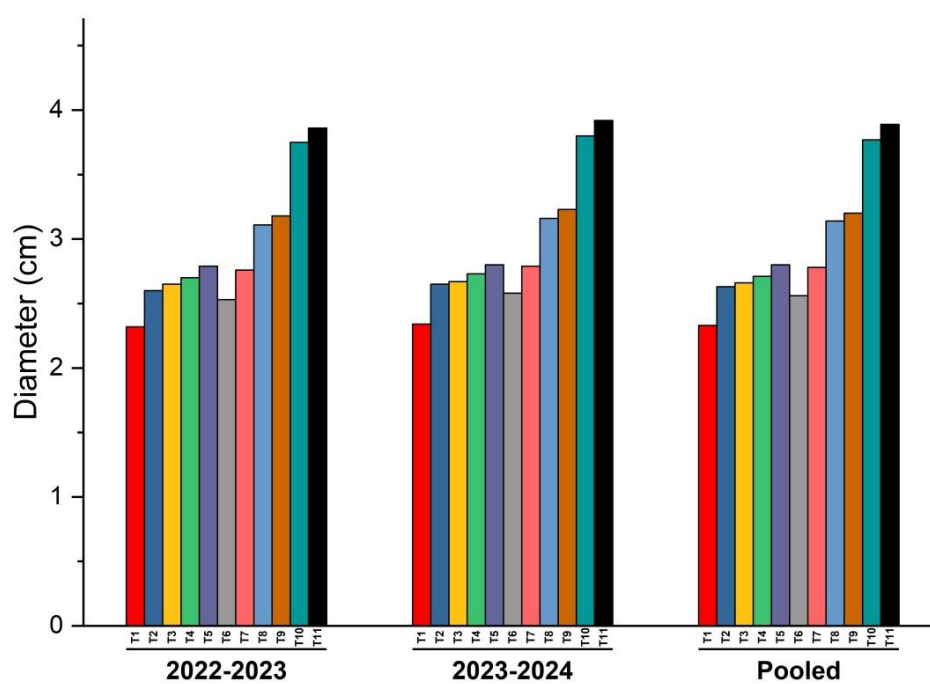
Treatments	Weight (g)			Diameter (cm)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	31.25	31.27	31.90^e	2.10	2.14	2.12^j
T ₂	37.95	37.98	37.96^d	2.27	2.36	2.31ⁱ
T ₃	38.10	38.12	38.11^d	2.70	2.82	2.75^g
T ₄	40.41	40.45	40.43^b	3.40	3.49	3.44^d
T ₅	44.19	44.21	44.21^a	3.79	3.86	3.85^c
T ₆	38.56	38.58	38.56^{cd}	2.50	2.58	2.54^h
T ₇	38.66	38.68	38.67^{cd}	2.46	2.57	2.51^h
T ₈	39.10	39.16	39.13^{bcd}	2.88	2.96	2.92^f
T ₉	40.70	40.72	40.04^{bc}	3.10	3.16	3.13^e
T ₁₀	44.78	45.12	44.95^a	4.23	4.56	4.39^b
T ₁₁	45.19	46.16	45.67^a	5.36	5.40	5.38^a
CD (p≤0.05)	1.66	2.07		0.13	0.14	
SE±(m)	0.55	0.69		0.03	0.04	

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉ - NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Fig: 4.4 Graphical representation of fruit weight (g)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Fig: 4.5 Graphical representation of fruit diameter (cm)

4.2.4 Fruit firmness (N) and Fruit length (cm):

It is clear from the data provided in Table 4.5 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit firmness (5.82 and 5.84 N) which was statistically at par with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm+ 0.5% + 300 ppm- T₁₀) and the minimum fruit firmness was observed in control treatment (T₁) which was (2.80 and 2.82 N). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit firmness that was (5.83 N) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (5.78 N) and the lowest fruit firmness (2.81 N) was observed in control (T₁) treatment.

It is clear from the data provided in Table 4.5 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit length (4.96 cm and 5.06 cm) which was statistically at par with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit length was observed in control treatment (T₁) which was (2.30 and 2.33 cm). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit length that was (5.01 cm) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (4.89 cm) and the lowest fruit length (2.31 cm) was observed in control (T₁) treatment.

The increase in fruit length may be because of GA₃ and ZnSO₄. A positive and significant correlation was observed between fruit length and weight, as well as between fruit diameter and weight. These findings are supported by the studies of Banker and Prasad (1990), Singh *et al.* (2017), Wangbin *et al.* (2008), Arora and Singh (2014), and Rokaya *et al.* (2016).

Table 4.5: Effect of PGRs and ZnSO₄ on Fruit firmness (lbs) and length (cm) of ber

Treatment s	Firmness (N)			Length (cm)		
	2022-2023	2022-2023	pooled	2022-2023	2023-2024	Pooled
T ₁	2.80	2.82	2.81^f	2.30	2.33	2.31^g
T ₂	3.60	3.64	3.62^{de}	2.50	2.56	2.53^f
T ₃	3.65	3.66	3.65^{de}	2.80	2.85	2.82^e
T ₄	3.70	3.73	3.71^{de}	3.30	3.37	3.33^{cd}
T ₅	3.76	3.78	3.77^d	3.41	3.46	3.43^c
T ₆	3.51	3.54	3.52^e	2.55	2.60	2.57^f
T ₇	3.66	3.68	3.67^e	3.17	3.19	3.18^d
T ₈	4.67	4.69	4.68^c	3.33	3.41	3.37^c
T ₉	4.71	4.73	4.72^{bc}	3.62	4.69	4.15^b
T ₁₀	5.78	5.79	5.78^{ab}	4.88	4.90	4.89^a
T ₁₁	5.82	5.84	5.83^a	4.96	5.06	5.01^a
CD (p≤0.05)	0.043	0.05		0.06	0.08	
SE±(m)	0.06	0.07		0.05	0.07	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.2.5 Fruit volume (cc) and specific gravity (g/cm³):

It is clear from the data presented in Table 4.6 that in first year and second year trials the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit volume (33.08 and 46.23 cc) and the minimum fruit volume (21.71 and 22.54 cc) was observed in control treatment (T₁). Similarly in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit volume that was (39.66 cc) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (38.07 cc) and the lowest fruit volume (22.12 cc) was observed in control (T₁) treatment.

The improvement in fruit volume observed with GA₃ + ZnSO₄ + Salicylic acid treatments can be attributed to several factors. Gibberellic acid (GA₃) is a plant growth regulator known for its role in cell elongation, fruit development, and overall growth, which has been shown to improve various quality attributes of fruits, including firmness (Ali *et al.*, 2008). Zinc sulfate (ZnSO₄) is essential for several physiological functions, including enzyme activation and protein synthesis. Zinc has been known to promote cell wall integrity and contribute to fruit firmness by enhancing lignin and cellulose synthesis, both of which are critical components of cell wall strength (Hussain *et al.*, 2014). GA₃ regulates the semi-permeability of the cell wall, allowing for increased water mobilization into fruits, which ultimately contributes to maximum fruit volume. These findings align with recent studies, such as those by Shah *et al.* (2023) and Zha *et al.*, (2022), which further elucidate the role of GA₃ in enhancing fruit growth and development. On the other hand, Salicylic acid is a well-known plant hormone involved in stress responses and plant defense mechanisms, and has been shown to improve the mechanical properties of fruits by enhancing cell wall rigidity and contributing to better tissue structure (Hayat *et al.*, 2010). The combined effect of these compounds likely results in increased metabolic activity and stronger cellular structures in the fruit, thus leading to enhanced firmness.

It is evident from the data presented in Table 4.6 that in first year and second year for specific gravity was non-significant with all the treatments.

Table 4.6: Effect of PGRs and ZnSO₄ on Fruit volume (cc) and specific gravity (g/cm³) of ber

Treatments	Volume (cc)			Specific gravity (g/cm ³)		
	2022-2023	2022-2023	2022-2023	2022-2023	2023-2024	Pooled
T ₁	21.71	22.54	22.12^f	0.97	0.96	0.96^a
T ₂	26.32	38.25	32.29^e	0.98	0.99	0.98^a
T ₃	28.01	39.65	33.83^{cde}	0.95	0.96	0.95^a
T ₄	29.70	41.25	35.48^c	0.98	0.97	0.97^a
T ₅	30.47	45.28	37.88^b	0.99	0.97	0.98^a
T ₆	25.63	39.51	32.57^e	0.98	0.97	0.97^a
T ₇	27.30	39.61	33.46^{de}	0.98	0.97	0.97^a
T ₈	26.94	40.15	33.55^{de}	0.99	0.97	0.98^a
T ₉	28.68	41.12	34.90^{cd}	0.98	0.97	0.97^a
T ₁₀	30.89	45.25	38.07^{ab}	0.98	0.98	0.98^a
T ₁₁	33.08	46.23	39.66^a	0.98	0.97	0.97^a
CD (p≤0.05)	1.51	1.87		NS	NS	
SE±(m)	0.51	0.63		0.01	0.02	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5%

+ 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.2.6 Return bloom (%):

The data in Table 4.7 indicates that in the first year, the highest return bloom percentage (16.15 %) was recorded with the application of NAA+ZnSO₄+Salicylic acid (30 ppm + 0.5% + 300 ppm – T₉). In the second year also, NAA+ZnSO₄+Salicylic acid (30 ppm + 0.5% + 300 ppm – T₉) achieved the highest return bloom percentage at (16.20 %), comparable to the combination of NAA, ZnSO₄, and Salicylic acid (20 ppm + 0.5% + 300 ppm – T₈) that was (16.10 and 16.13 %) for the trials respectively. The control treatment (T₁) had the lowest initial fruit set percentages at (5.23 % and 5.26 %) for both the years. In the pooled data, the highest return bloom percentage (16.17%) was observed in treatment, NAA+ZnSO₄+Salicylic acid (30 ppm + 0.5% + 300 ppm – T₉), followed by NAA+ZnSO₄+Salicylic acid (20 ppm + 0.5% + 300 ppm – T₈) that was (16.11 %), while the control again recorded the lowest return bloom percentage (5.24 %).

NAA, a synthetic auxin, significantly influences plant growth by regulating flowering. This application leads to increased flower bud differentiation and bloom percentage. In the case of ber, flowering is linked to reduced vegetative growth, suggesting that factors produced in leaves might promote flowering while inhibiting vegetative growth. NAA is recognized for its flowering-promoting effects (Das *et al.*, 2020), and its role in early flowering likely stems from its ability to direct metabolites toward developing flower buds, thus accelerating floral development (Kumari *et al.*, 2018). NAA in combination with ZnSO₄ results induction, initiation and differentiation of flower buds in the next year at proper stage and time as auxin does not delay plastochrone as compared with GA₃ that delays plastochrone leads flower bud inhibition in the next year resulting reduction in return bloom (Wani *et al.*, 2017).

Table 4.7: Effect of PGRs and ZnSO₄ on Return bloom of ber

Treatment	Return Bloom %		
	2022-2023	2023-2024	pooled
T ₁	5.23	5.26	5.24^g
T ₂	9.12	9.16	9.14^c
T ₃	10.01	10.08	10.04^b
T ₄	6.05	6.08	6.06^f
T ₅	6.06	6.11	6.08^f
T ₆	6.16	6.19	6.17^f
T ₇	8.16	8.20	8.18^d
T ₈	16.10	16.13	16.11^a
T ₉	16.15	16.20	16.17^a
T ₁₀	7.12	7.14	7.13^e
T ₁₁	7.15	7.17	7.16^e
CD (p≤0.05)	0.31	0.40	
SE±(m)	0.10	0.13	

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉ - NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3 Fruit bio-chemical parameters

4.3.1 Biochemical analysis

4.3.1.1 Chlorophyll content (SPAD):

It is evident from the data presented in Table 4.8 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest chlorophyll content (59.78 and 60.18) and the minimum chlorophyll content was observed in control treatment (T₁) which was (46.02 and 47.21). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest chlorophyll content that was (59.98) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (57.51) and the lowest chlorophyll content (46.61) was observed in control (T₁) treatment.

Chlorophyll production is one of the many metabolic processes that zinc is a necessary micronutrient involved in. It facilitates the production of tryptophan, an auxin precursor that indirectly affects photosynthetic activity and chlorophyll concentration. By maintaining the structure of chloroplasts and boosting the enzyme activity necessary for chlorophyll synthesis, zinc supplementation has been shown to raise the concentration of chlorophyll (Sharma *et al.*, 2023).

The synergistic action of GA₃, SA, and ZnSO₄ can lead to increased leaf area and expansion. Larger leaf surfaces enhance light interception and, consequently, photosynthesis, resulting in greater chlorophyll content (Yadav *et al.*, 2023). By combining the advantages of GA₃, SA and ZnSO₄ for chlorophyll production, stability, and protection, their combined application produces a synergistic effect on chlorophyll content. Zn promotes the structural integrity and enzymatic processes associated with chlorophyll creation, SA shields chlorophyll from oxidative damage, while GA₃ and NAA increase chlorophyll synthesis and accumulation.

According to research by Chaudhuri *et al.* (2023), using this combination raised the amount of chlorophyll in a number of fruit and vegetable crops, such as tomato and ber, by 20–30% when compared to control treatments.

Table 4.8: Effect of PGRs and ZnSO₄ on Chlorophyll index (SPAD) value

Treatments	Chlorophyll index (SPAD) Value		
	2022-2023	2023-2024	Pooled
T ₁	46.02	47.21	46.61^g
T ₂	55.45	53.16	54.30^{def}
T ₃	56.23	57.25	56.74^c
T ₄	55.61	56.45	56.03^{cd}
T ₅	55.98	58.22	57.10^{bc}
T ₆	53.47	54.27	53.87^{df}
T ₇	56.32	57.25	56.78^c
T ₈	56.76	55.26	56.01^{cde}
T ₉	56.94	58.26	57.60^{bc}
T ₁₀	57.60	58.23	57.91^{ab}
T ₁₁	59.78	60.18	59.98^a
CD (p≤0.05)	2.48	1.61	
SE±(m)	0.83	0.54	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.2 Fruit TSS (⁰Brix) and Acidity (%):

It is obvious from the data presented in Table 4.9 and fig 4.6 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit TSS (14.85 and 15.78 ⁰Brix) and having closely at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit TSS (10.25 and 10.33 ⁰Brix) was observed in control treatment (T₁). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit TSS that was (15.32 ⁰Brix) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (15.05 ⁰Brix) and the lowest fruit TSS (10.29 ⁰Brix) was observed in control (T₁) treatment.

Data with respect to effect of various Plant Growth Regulators and ZnSO₄ spray on acidity of fruit have been given in Table 4.9 and fig 4.7. The perusal of data for both first and second year trial indicated that lowest acidity of (0.30 and 0.29 %) noted in the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) and the highest fruit acidity (0.47 and 0.46 %) was observed in control treatment (T₁). Same trend followed in pooled data, the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded lowest fruit acidity that was (0.32 %) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (0.28 %) and the highest fruit acidity (0.46 %) was observed in control (T₁) treatment.

The application of GA₃, salicylic acid, and ZnSO₄ leads to an increase in TSS through enhanced sugar accumulation, improved metabolic efficiency, and better overall fruit development, ultimately resulting in fruits with higher concentrations of soluble solids (Ali *et al.*, 2007). ZnSO₄ supports the production of auxins, which are important for fruit development and can enhance TSS accumulation by regulating

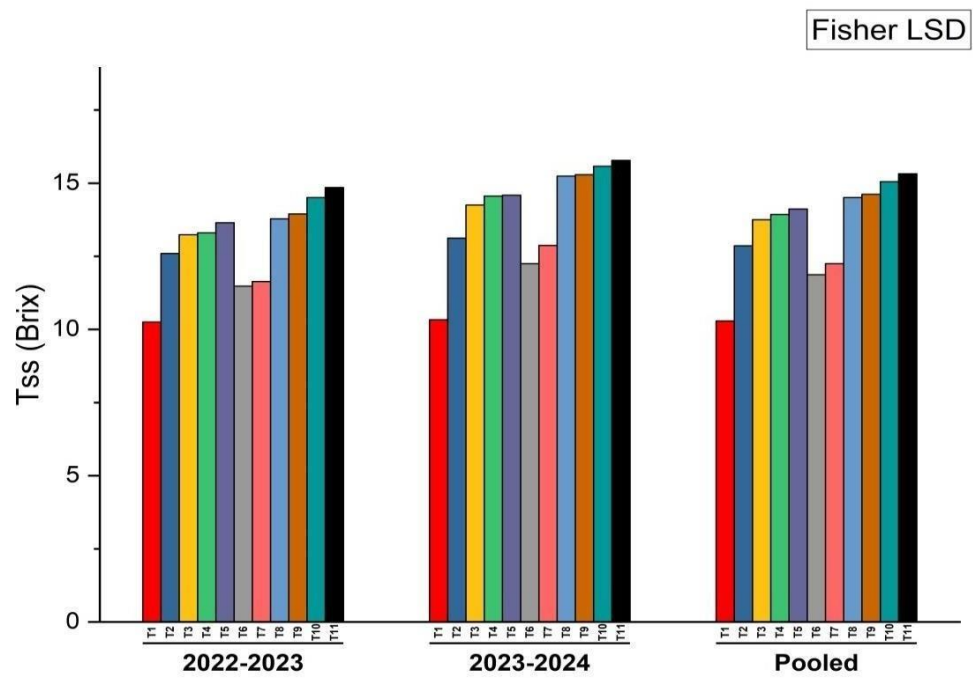
metabolic processes (Cakmak and Kirkby *et al.*, 2008). Salicylic acid promotes photosynthesis and nutrient uptake, contributing to higher TSS levels in fruits by enhancing metabolic and physiological functions (Raskin *et al.*, 1990). The reduction in acidity levels of fruits may be attributed to the increase in total soluble solids (TSS) and total sugars. Under the influence of these chemicals, the acids may have been converted into sugars and their derivatives through processes involving the reversal of the glycolytic pathway or may have been utilized as substrates in respiration, or possibly both. These results are consistent with the findings of Pratap *et al.*, (2023) in guava.

Table 4.9: Effect of PGRs and ZnSO₄ on TSS (⁰Brix) and Acidity (%) of ber

Treatments	TSS (⁰ Brix)			Acidity (%)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	10.25	10.33	10.29^g	0.47	0.46	0.46^a
T ₂	12.60	13.12	12.86^e	0.43	0.41	0.44^{ab}
T ₃	13.24	14.25	13.75^d	0.39	0.41	0.42^b
T ₄	13.30	14.56	13.93^d	0.38	0.40	0.39^c
T ₅	13.65	14.59	14.12^{cd}	0.36	0.38	0.37^{cd}
T ₆	11.48	12.25	11.87^f	0.40	0.42	0.43^b
T ₇	11.64	12.87	12.25^f	0.44	0.45	0.43^b
T ₈	13.78	15.24	14.51^{bc}	0.36	0.35	0.35^{de}
T ₉	13.95	15.29	14.62^{bc}	0.34	0.35	0.33^{ef}
T ₁₀	14.51	15.58	15.05^{ab}	0.31	0.33	0.32^f
T ₁₁	14.85	15.78	15.32^a	0.30	0.29	0.28^g
CD (p≤0.05)	0.38	0.66		0.02	0.02	

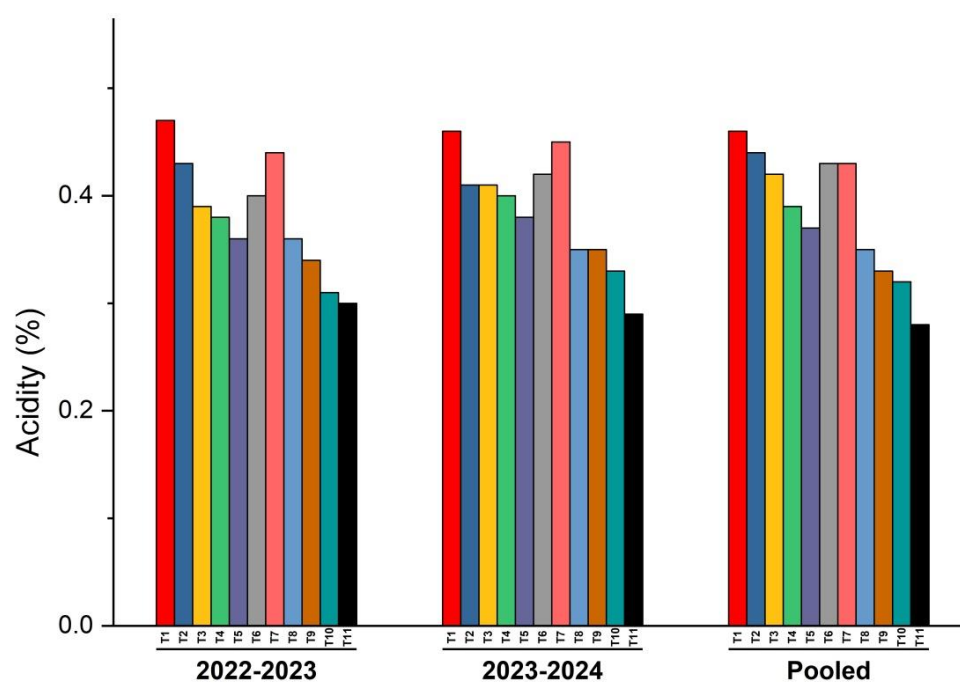
SE±(m)	0.12	0.22		0.00	0.00	
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Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Fig: 4.6 Graphical representation of fruit TSS (g)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Fig: 4.7 Graphical representation of fruit acidity (%)

4.3.1.3 TSS: Acidity and total sugars (%):

Data with respect to effect of various plant growth regulators and ZnSO₄ spray on acidity of fruit have been given in Table 4.10. The perusal of data for both first and second year trial indicated that the highest TSS: acid of (51.55 and 54.78 %) noted in the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) and the lowest fruit TSS: acid that was observed in control treatment (T₁) which was (21.80 and 22.49 %). Same trend followed in pooled data, the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit TSS: acid that was (53.17 %) and the lowest fruit TSS: acid (22.14 %) was observed in control (T₁) treatment.

The data of Table 4.10 clearly showed that foliar application of all the PGRs and ZnSO₄ increased the total sugars in fruits markedly over control. The perusal of data for both first and second year trial indicated that the highest total sugars of (9.59 and 9.62 %) noted in the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) and having closely at par values with the application of GA₃ +ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the lowest fruit total sugars that was observed in control treatment (T₁) which was (5.84 and 5.86 %). Same trend followed in pooled data, the application of GA₃+ZnSO₄+ Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit total sugars that was (9.60 %) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (9.43 %) and the lowest fruit total sugars (5.85 %) was observed in control (T₁) treatment.

These findings align with the results of Singh and Vashistha (1997), who reported increased total sugars in ber cv. Gola with 0.5% ZnSO₄ and 0.5% borax. Similarly, Kale *et al.* (2000) also observed higher TSS and total sugars in ber with the application of GA₃, and zinc sulphate. The increase in total sugars from the combined use of GA₃, and zinc sulfate is likely due to the roles of zinc in enhancing photosynthesis, leading to higher accumulations of oligosaccharides and polysaccharides, as well as regulating the enzymatic activity involved in metabolizing carbohydrates into simple sugars.

Table 4.10: Effect of PGRs and ZnSO₄ on TSS: Acid and total sugars (%) of ber

Treatments	TSS:acid			Total sugars %		
	2022-2023	2023-2024	2022-2023	2022-2023	2023-2024	Pooled
T ₁	21.80	22.49	22.14^g	5.84	5.86	5.85^f
T ₂	29.32	30.56	29.94^f	6.36	6.38	6.37^e
T ₃	32.33	34.79	33.56^e	6.40	6.42	6.41^e
T ₄	34.14	37.35	35.75^{de}	7.58	7.61	7.59^{cd}
T ₅	36.91	39.47	38.19^d	7.63	7.66	7.64^{cd}
T ₆	27.36	29.20	28.28^f	7.76	7.77	7.76^c
T ₇	26.56	29.36	27.96^f	7.39	7.40	7.39^d
T ₈	38.90	43.01	40.96^c	8.10	8.12	8.11^b
T ₉	41.09	45.02	43.06^c	8.22	8.24	8.23^b
T ₁₀	45.37	48.72	47.05^b	9.43	9.44	9.43^a
T ₁₁	51.55	54.78	53.17^a	9.59	9.62	9.60^a
CD (p≤0.05)	2.45	3.02		0.29	0.38	
SE±(m)	0.82	1.01		0.10	0.13	

Whereas, T₁- Control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.4 Fruit reducing sugar (%) and non-reducing (%) sugar:

Data with respect to effect of various Plant Growth Regulators and ZnSO_4 spray on reducing sugar of fruit have been given in Table 4.11. The perusal of data for both first and second year trial indicated that the highest reducing sugar of (6.36 and 6.39 %) noted in the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) and having at par values with the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) and the lowest fruit reducing sugar that was observed in control treatment (T_1) which was (3.50 and 3.51 %). Same trend followed in pooled data, the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit reducing sugar that was (6.37 %) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (6.31 %) and the lowest fruit reducing sugar (3.50 %) was observed in control (T_1) treatment.

Data with respect to effect of various Plant Growth Regulators and ZnSO_4 spray on fruit non reducing sugar have been given in Table 4.11. The perusal of data for both first and second year trial indicated that the highest fruit non-reducing sugar of (3.23 and 3.24 %) noted in the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) and the lowest fruit non-reducing sugar that was observed in control treatment (T_1) which was (2.34 and 2.35 %). Same trend followed in pooled data, the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit non- reducing sugar that was (3.23 %) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (3.12 %) and the lowest fruit non-reducing sugar (2.34 %) was observed in control (T_1) treatment.

Table 4.11: Effect of PGRs and ZnSO₄ on reducing sugar (%) and non-reducing (%) sugar of ber

Treatments	Reducing sugar %			Non reducing sugar %		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	3.50	3.51	3.50 ^g	2.34	2.35	2.34 ^f
T ₂	3.53	3.54	3.53 ^f	2.83	2.84	2.33 ^{ef}
T ₃	3.55	3.57	3.56 ^f	2.85	2.85	3.34 ^e
T ₄	4.59	4.61	4.06 ^{de}	2.99	3.00	2.99 ^{cd}
T ₅	4.61	4.62	4.61 ^{cd}	3.02	3.04	3.03 ^{bcd}
T ₆	4.80	4.82	4.81 ^c	2.96	2.95	2.95 ^{bc}
T ₇	4.98	4.99	4.98 ^e	2.41	2.41	2.41 ^d
T ₈	5.10	5.13	5.11 ^b	3.00	2.98	2.99 ^b
T ₉	5.12	5.14	5.13 ^b	3.10	3.10	3.10 ^b
T ₁₀	6.30	6.33	6.31 ^a	3.13	3.11	3.12 ^a
T ₁₁	6.36	6.39	6.37 ^a	3.23	3.24	3.23 ^a
CD (p≤0.05)	0.24	0.18		0.13	0.12	
SE±(m)	0.05	0.06		0.04	0.04	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.5 Fruit Ascorbic acid (mg/100g):

Data with respect to effect of various Plant Growth Regulators and ZnSO_4 spray on acidity of fruit have been given in Table 4.12. The perusal of data for both first and second year trial indicated that the highest ascorbic acid (103.90 and 104.30 mg/100g) was noted in the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) which was significantly at par with the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}), which and the lowest fruit ascorbic acid that was observed in control treatment (T_1) which was (85.20 and 86.20 mg/100g). Same trend followed in pooled data, the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit ascorbic acid that was (104.10 mg/100) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (101.60 mg/100g) and the lowest fruit ascorbic acid (85.70 mg/100g) was observed in control (T_1) treatment.

GA_3 application significantly increased ascorbic acid content in ber fruits, likely due to enhanced metabolic activity and improved fruit quality (Mohammad *et al*, 2022). Salicylic acid treatment in various fruit crops, including ber, led to higher vitamin C content, attributed to improved metabolic activity and fruit ripening processes (Patel *et al.*, 2023). The improved metabolic efficiency of the trees and the stimulation of various enzymatic activities involved in physiological processes likely contributed to the rise in ascorbic acid content. Additionally, the application of zinc may have enhanced ascorbic acid levels by promoting plant growth and ensuring a greater supply of metabolic precursors essential for its synthesis Pandey and Kumar (2023).

Table 4.12: Effect of PGRs and ZnSO₄ on Ascorbic acid (mg/100g) of ber

Treatments	Ascorbic acid (mg/100g)		
	2022-2023	2023-2024	Pooled
T ₁	85.20	86.20	85.70^d
T ₂	95.20	97.30	96.20^c
T ₃	96.30	98.20	97.30^{bc}
T ₄	96.50	97.40	96.90^{bc}
T ₅	97.60	99.40	98.05^{bc}
T ₆	96.20	96.10	96.20^c
T ₇	95.60	95.90	95.70^c
T ₈	97.70	97.70	97.70^{bc}
T ₉	98.80	98.80	98.80^{bc}
T ₁₀	101.60	101.60	101.60^{ab}
T ₁₁	103.90	104.30	104.10^a
CD (p≤0.05)	4.59	4.85	CD (p≤0.05)
SE±(m)	1.54	1.63	SE±(m)

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.6 Fruit Total phenolic content (%):

Data with respect to effect of various Plant Growth Regulators and ZnSO₄ spray on acidity of fruit have been given in Table 4.13. The perusal of data for both first and second year trial indicated that the highest phenolic content of (9.55 and 9.70 mg/100g) noted in the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) and the lowest fruit phenolic content (4.19 and 4.21 mg/100g) was observed in control treatment (T₁). In the pooled data, the highest fruit phenolic content was observed with the application of GA₃ + ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁), which recorded (9.62 mg/100g) and followed by the treatment T₁₀ - GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), which showed a phenolic content of (8.59 mg/100g). The control treatment (T₁) resulted in the lowest phenolic content (4.20 mg/100g).

Gibberellic acid (GA₃), ZnSO₄, and salicylic acid (SA) significantly boost phenolic content in fruits by enhancing enzyme activity and metabolic pathways related to phenolic synthesis. GA₃ stimulates secondary metabolite production, ZnSO₄ supports enzymatic systems, and SA activates defense mechanisms that promote phenolic accumulation. These results align with earlier studies (Hamouda *et al.*, 2009; Singh *et al.*, 2017) showing that combined application of growth regulators and micronutrients improves fruit quality. The low phenolic content in the control treatment highlights the importance of these treatments for better nutritional and health benefits.

Table 4.13: Effect of PGRs and ZnSO₄ on Total phenolic content (mg/100g) of ber

Treatments	Phenolic content (mg/100g)		
	2022-2023	2023-2024	Pooled
T ₁	4.19	4.21	4.20 ^g
T ₂	5.68	5.69	5.68 ^e
T ₃	5.69	5.72	5.70 ^e
T ₄	6.12	6.15	6.13 ^d
T ₅	7.16	7.17	7.67 ^c
T ₆	6.29	6.31	6.29 ^b
T ₇	5.74	5.77	5.75 ^e
T ₈	7.71	7.78	7.74 ^c
T ₉	7.79	7.86	7.82 ^c
T ₁₀	8.53	8.66	8.59 ^b
T ₁₁	9.55	9.70	9.62 ^a
CD (p≤0.05)	0.31	0.33	
SE±(m)	0.07	0.09	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5%+ 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.7 Fruit Total Carotenoid (mg/100g) and Total Antioxidant (% inhibition):

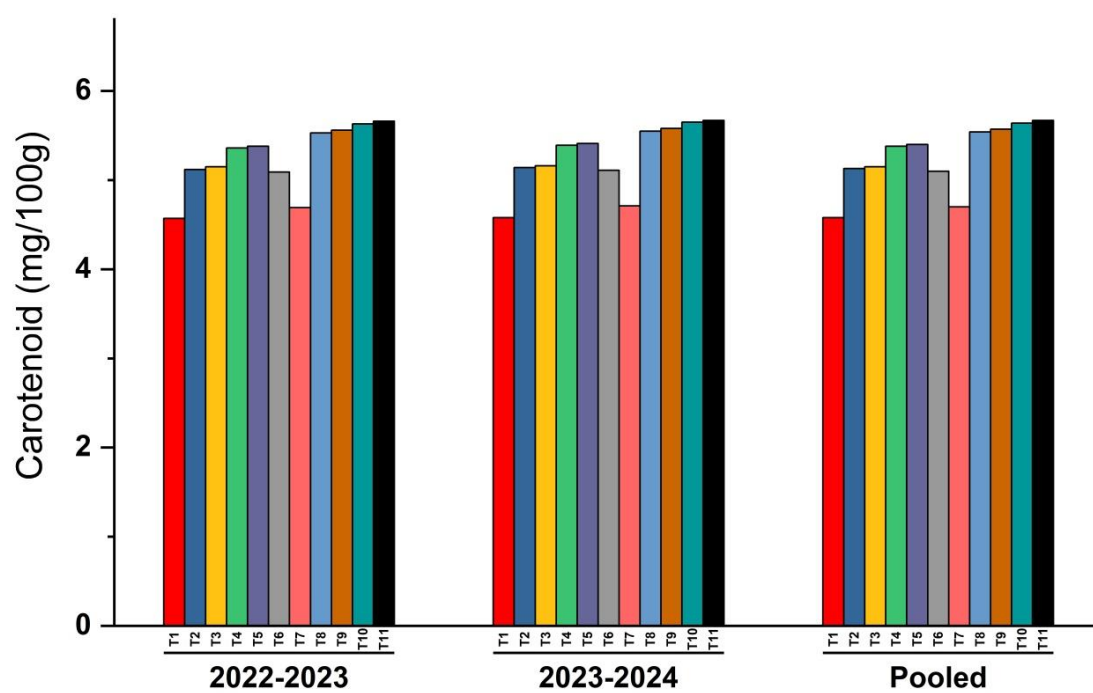
Data regarding the effects of various Plant Growth Regulators and ZnSO₄ spray on fruit carotenoid are presented in Table 4.14 and Figure 4.8. The analysis of results from both the first and second year of trials revealed that the highest carotenoid content (5.66 mg/100g) in the first year and (5.67 mg/100g) in the second year, was achieved with the treatment of GA₃ + ZnSO₄ + Salicylic acid at concentrations of 40 ppm, 0.5%, and 300 ppm, respectively (T₁₁). This treatment showed comparable results to that of GA₃ + ZnSO₄ + Salicylic acid at 30 ppm, 0.5%, and 300 ppm (T₁₀), while T₉ and T₈ the lowest carotenoid content (4.57 mg/100g and 4.58 mg/100g) was recorded in the control treatment (T₁). The pooled data reflected the same trend, with the GA₃ + ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁) yielding the highest carotenoid content at (5.67 mg/100g), followed closely by the GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm - T₁₀) at (5.64 mg/100g). In contrast, the control treatment (T₁) exhibited the lowest carotenoid content at (4.58 mg/100g).

Data regarding the effects of various Plant Growth Regulators and ZnSO₄ spray on fruit carotenoid are presented in Table 4.14 and fig 4.9. The analysis of results from both the first and second year of trials revealed that the highest antioxidant content (23.38 %) in the first year and (23.41 %) in the second year, was achieved with the treatment of GA₃ + ZnSO₄ + Salicylic acid at concentrations of 40 ppm, 0.5%, and 300 ppm, respectively (T₁₁). This treatment showed comparable results to that of GA₃ + ZnSO₄ + Salicylic acid at 30 ppm, 0.5%, and 300 ppm (T₁₀), while the lowest antioxidant content of (14.23 and 15.30 %) was recorded in the control treatment (T₁). The pooled data reflected the same trend, with the GA₃ + ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁) yielding the highest antioxidant content at (23.40 %), followed closely by the GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm - T₁₀) at (22.13 %). In contrast, the control treatment (T₁) exhibited the lowest antioxidant content at (4.77 %).

Table 4.14: Effect of PGRs and ZnSO₄ on Total Carotenoid (%) and Total Antioxidant activity of ber

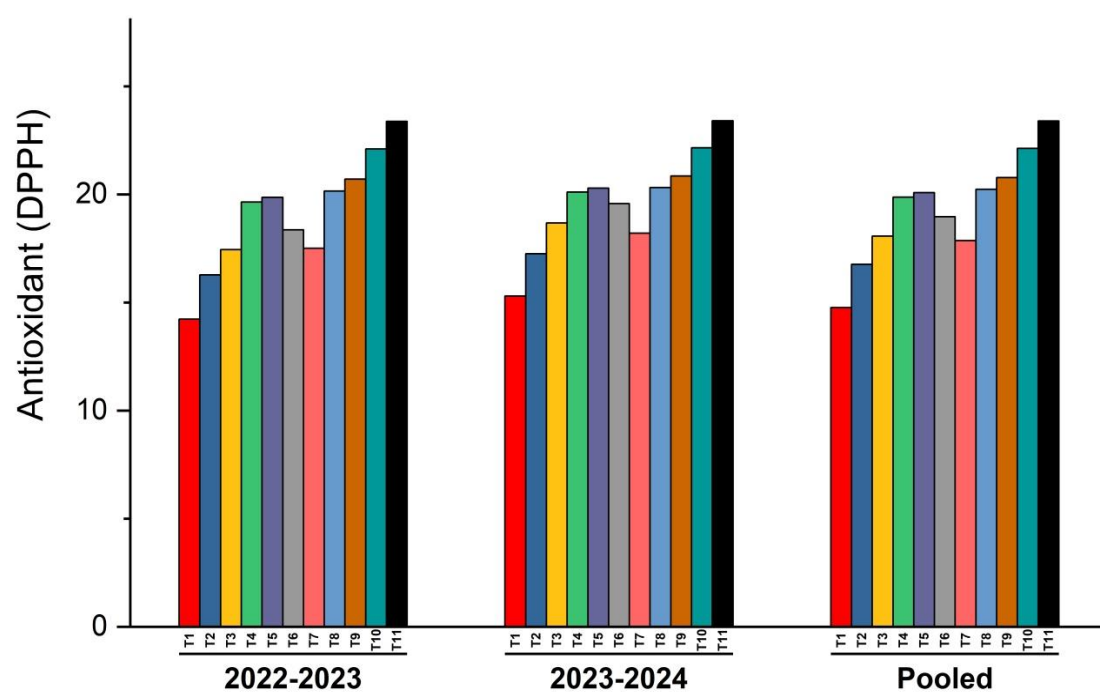
Treatments	Carotenoid (mg/100g)			Antioxidant activity		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	4.57	4.58	4.58^d	14.23	15.30	14.77^f
T ₂	5.12	5.14	5.13^c	16.28	17.26	16.77^{ef}
T ₃	5.15	5.16	5.15^c	17.45	18.68	18.07^{cde}
T ₄	5.36	5.39	5.38^b	19.65	20.11	19.88^{cde}
T ₅	5.38	5.41	5.40^b	19.87	20.29	20.08^{bcd}
T ₆	5.09	5.11	5.10^c	18.36	19.58	18.97^{cde}
T ₇	4.69	4.71	4.70^d	17.51	18.21	17.86^{de}
T ₈	5.53	5.55	5.54^{ab}	20.16	20.32	20.24^{bcd}
T ₉	5.56	5.58	5.57^{ab}	20.71	20.85	20.78^{bc}
T ₁₀	5.63	5.65	5.64^a	22.10	22.16	22.13^{ab}
T ₁₁	5.66	5.67	5.67^a	23.38	23.41	23.40^a
CD (p≤0.05)	0.20	0.22		0.80	1.10	
SE±(m)	0.07	0.08		0.29	0.32	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Fig: 4.8 Graphical representation of fruit carotenoid (mg/100 g)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Fig: 4.9 Graphical representation of fruit antioxidant (DPPH)

4.3.1 Proximate analysis

4.3.1.1 Ash content (%) and Protein content (%):

The effects of various Plant Growth Regulators and ZnSO₄ spray on fruit acidity are presented in Table 4.15. Analyzing the data from both the first and second year of trials, it was found that the highest levels of ash content in fruit were recorded at (2.38 % and 2.40%) with the application of GA₃ + ZnSO₄ + Salicylic acid at concentrations of 40 ppm, 0.5%, and 300 ppm (T₁₁) which was statistically at par with GA₃ + ZnSO₄ + Salicylic acid at 30 ppm, 0.5%, and 300 ppm (T₁₀). In contrast, the control treatment (T₁) exhibited the lowest ash content levels at (2.19 % and 2.20 %). Similarly in the pooled data, the application of GA₃ + ZnSO₄ + Salicylic acid (40ppm + 0.5% + 300 ppm - T₁₁) resulted in the highest ash content at (2.39 %). Following this, the GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm - T₁₀) recorded (2.37 %), while the control treatment (T₁) had the lowest (2.20 %) was ash content.

The effects of various Plant Growth Regulators and ZnSO₄ spray on fruit protein content are given in Table 4.15. Analyzing the data from both the first and second year of trials, it was found that the highest levels of protein content in fruit were recorded at (6.06 % and 6.09 %)with the application of GA₃ + ZnSO₄ + Salicylic acid at concentrations of 40 ppm, 0.5%, and300 ppm (T₁₁). In contrast, the control treatment (T₁) exhibited the lowest protein content levels (3.16 % and 3.17 %). The same pattern was observed in the pooled data, where the application ofGA₃ + ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁) resulted in the highest protein content at (6.07 %) followed by GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm - T₁₀) recorded (5.90 %), while the control treatment (T₁) had the lowest protein content level (3.17 %).

Table 4.15: Effect of PGRs and ZnSO₄ on ash content (%) and protein content (%) of ber

Treatments	Ash content (%)			Protein content (%)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	2.19	2.20	2.20^d	3.16	3.17	3.17^e
T ₂	2.23	2.25	2.24^{cd}	4.14	4.16	4.15^{cd}
T ₃	2.27	2.29	2.28^{bcd}	4.35	4.36	4.36^c
T ₄	2.30	2.32	2.31b^{cd}	5.09	5.11	5.10^b
T ₅	2.34	2.36	2.35^{bc}	5.12	5.15	5.13^b
T ₆	2.12	2.14	2.13^a	4.10	4.12	4.11^d
T ₇	2.17	2.23	2.20^d	4.13	4.15	4.14^d
T ₈	2.31	2.35	2.33^{bc}	5.10	5.11	5.10^b
T ₉	2.33	2.36	2.35^{bc}	5.15	5.16	5.15^b
T ₁₀	2.36	2.38	2.37^b	5.89	5.92	5.90^a
T ₁₁	2.38	2.40	2.39^b	6.06	6.09	6.07^a
CD (p≤0.05)	0.10	0.11		0.13	0.15	
SE±(m)	0.03	0.04		0.04	0.06	

Whereas, T₁-control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.2 Fruit Crude fat content (%) and fibre content:

The effects of various Plant Growth Regulators and ZnSO₄ spray on fruit fat content are summarized in Table 4.16. Analyzing the data from both the first and second year of trials, it was found that the highest levels of fat content in fruit were recorded at (0.47 % and 0.50 %) with the application of GA₃ + ZnSO₄ + Salicylic acid at concentrations of 40 ppm, 0.5%, and 300 ppm (T₁₁). In contrast, the control treatment (T₁) exhibited (0.18 % and 0.20 %), the lowest fat content. The same pattern was observed in the pooled data, where the application of GA₃ + ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁) resulted in the highest fat content at (0.49 %) followed by GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm - T₁₀) recorded (0.45 %), while the control treatment (T₁) had the lowest fat content level at (0.19 %).

The effects of various Plant Growth Regulators and ZnSO₄ spray on fruit fiber content are presented in Table 4.16. Analyzing the data from both the first and second year of trials, it was found that the highest levels of fiber content in fruit were recorded at (5.36 % and 5.39 %) with the application of GA₃ + ZnSO₄ + Salicylic acid at concentrations of 40 ppm, 0.5%, and 300 ppm (T₁₁). This treatment produced results comparable to those of GA₃ + ZnSO₄ + Salicylic acid at 30 ppm, 0.5%, and 300 ppm (T₁₀). In contrast, the control treatment (T₁) exhibited the lowest fiber content levels at (2.46 % and 2.58 %). The same pattern was observed in the pooled data, where the application of GA₃ + ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁) resulted in the highest fiber content at (5.38 %) followed by GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm - T₁₀) (i.e 5.33 %), while the control treatment (T₁) had the lowest fiber content level (2.52 %).

The above findings are in agreement with (Khan *et al.*, 2023) revealed that with the application of GA₃ enhance the growth and development in plant. It

influences cell elongation and division, which can lead to larger and more robust fruit. The increased fruit size allows for greater accumulation of various nutrients, including fats and fibers. Salicylic acid (SA) application has been shown to enhance the nutritional quality of fruits, including ber (*Ziziphus mauritiana*), by increasing fiber content (Khan *et al.*, 2023). The findings strongly indicate that GA₃, ZnSO₄ and salicylic acid can enhance the fat and fiber content in ber fruits.

Table 4.16: Effect of PGRs and ZnSO₄ on Crude fat content (%) and fiber content (%) of ber

Treatments	Fat content (%)			Fiber content (%)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	0.18	0.20	0.19ⁱ	2.46	2.58	2.52^e
T ₂	0.24	0.27	0.26^g	3.24	3.26	3.25^d
T ₃	0.25	0.28	0.27^g	3.28	3.29	3.29^d
T ₄	0.29	0.30	0.29^f	4.21	4.25	4.23^b
T ₅	0.32	0.34	0.33^e	4.28	4.30	4.29^b
T ₆	0.21	0.24	0.23^h	2.24	2.29	2.26^f
T ₇	0.22	0.23	0.23^h	3.20	3.39	3.29^d
T ₈	0.38	0.40	0.39^d	3.40	3.56	3.48^c
T ₉	0.41	0.43	0.42^c	4.26	4.37	4.31^b
T ₁₀	0.43	0.46	0.45^b	5.31	5.36	5.33^a
T ₁₁	0.47	0.50	0.49^a	5.36	5.39	5.38^a
CD (p≤0.05)	0.01	0.02		1.12	0.13	
SE±(m)	0.02	0.03		0.38	0.39	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.3 Fruit Crude moisture content (%)

The effects of various Plant Growth Regulators and ZnSO₄ spray on fruit protein content are summarized in Table 4.17. Analyzing the data from both the first and second year of trials, it was found that the highest levels of moisture content in fruit were recorded at (33.41 % and 35.21 %) with the application of GA₃ + ZnSO₄ + Salicylic acid at concentrations of 40 ppm, 0.5%, and 300 ppm (T₁₁). In contrast, the control treatment (T₁) exhibited the lowest moisture content levels at (18.41 % and 19.23 %). The same pattern was observed in the pooled data, where the application of GA₃ + ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm - T₁₁) resulted in the highest moisture content at (34.31 %) followed by GA₃ + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm - T₁₀) recorded (25.75 %), while the control treatment (T₁) had the lowest moisture content level at (18.82 %).

The findings above are consistent with (Kumar *et al.*, 2022) revealed that the application of GA₃ also enhances the mobilization of stored nutrients within the plant, which can contribute to increase the moisture content. GA₃ and ZnSO₄ on ber fruit quality and found that their combined application significantly improved the moisture content. The authors attributed these improvements to enhanced metabolic processes and better nutrient uptake facilitated by zinc (Kumar *et al.*, 2022). The use of GA₃ and SA is crucial for improving the growth and development of "Zaghloul" fruit. Zinc supplementation significantly improved the nutritional quality of ber fruit, leading to increased protein and fiber content. They attributed these improvements to enhanced enzymatic activities and better overall plant health (Kumar *et al.* 2022). The application of ZnSO₄ increased moisture and fiber levels in ber fruit (Sharma *et al.*, 2023). The application of GA₃ and ZnSO₄ together led to significant increases in the physiological parameters of ber plants, which translated into better fruit quality, including higher moisture content (Singh *et al.*, 2022).

Table 4.17: Effect of PGRs and ZnSO₄ on Crude moisture content (%) of ber.

Treatments	Moisture content (%)		
	2022-2023	2023-2024	pooled
T ₁	18.41	19.23	18.82^g
T ₂	22.21	23.11	22.66^e
T ₃	23.63	24.12	23.88^d
T ₄	25.46	26.25	25.86^c
T ₅	27.55	29.32	28.44^b
T ₆	20.87	21.26	21.06^f
T ₇	22.16	24.28	23.22^{de}
T ₈	25.31	27.25	26.28^c
T ₉	27.50	28.57	28.03^b
T ₁₀	30.25	21.25	25.75^c
T ₁₁	33.41	35.21	34.31^a
CD (p≤0.05)	1.05	1.12	
SE±(m)	0.35	0.38	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.4 Leaf and fruit nutrient status:

4.3.1.4.1 Leaf and Fruit Nitrogen (mg/100g) content:

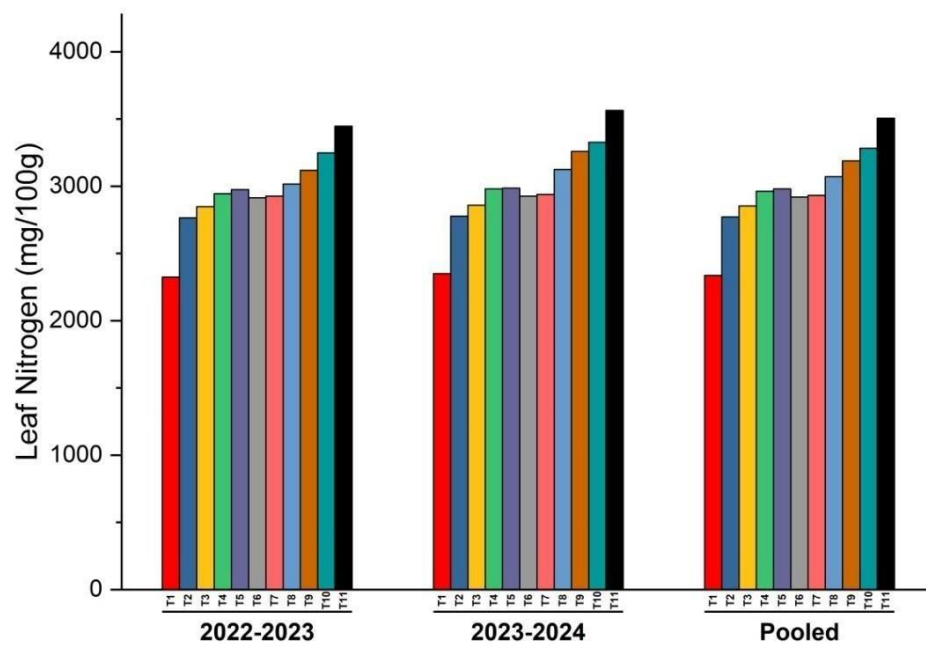
Data presented in Table 4.18 and fig 4.10 show that in first year and second year the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf nitrogen content (3447.10 and 3564.23 mg/100g, and the minimum leaf nitrogen content (2323.90 and 2350.23 mg/100g was observed in control treatment (T₁). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf nitrogen content that was (3505.66 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (3282.39 mg/100g) and the lowest leaf nitrogen content (2337.06 mg/100g) was observed in control (T₁) treatment.

Data presented in Table 4.18 and fig 4.11 indicated that in first year and second year the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit nitrogen content (639.55 and 670.23 mg/100g) which was statistically at par with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit nitrogen content (389.62 and 396.23 mg/100g) was observed in control treatment (T₁). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit nitrogen content that was (654.89 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (636.30 mg/100g) and the lowest fruit nitrogen content (392.92 mg/100g) was observed in control (T₁) treatment.

Table 4.18: Effect of PGRs and ZnSO₄ on Leaf and Fruit Nitrogen content of ber

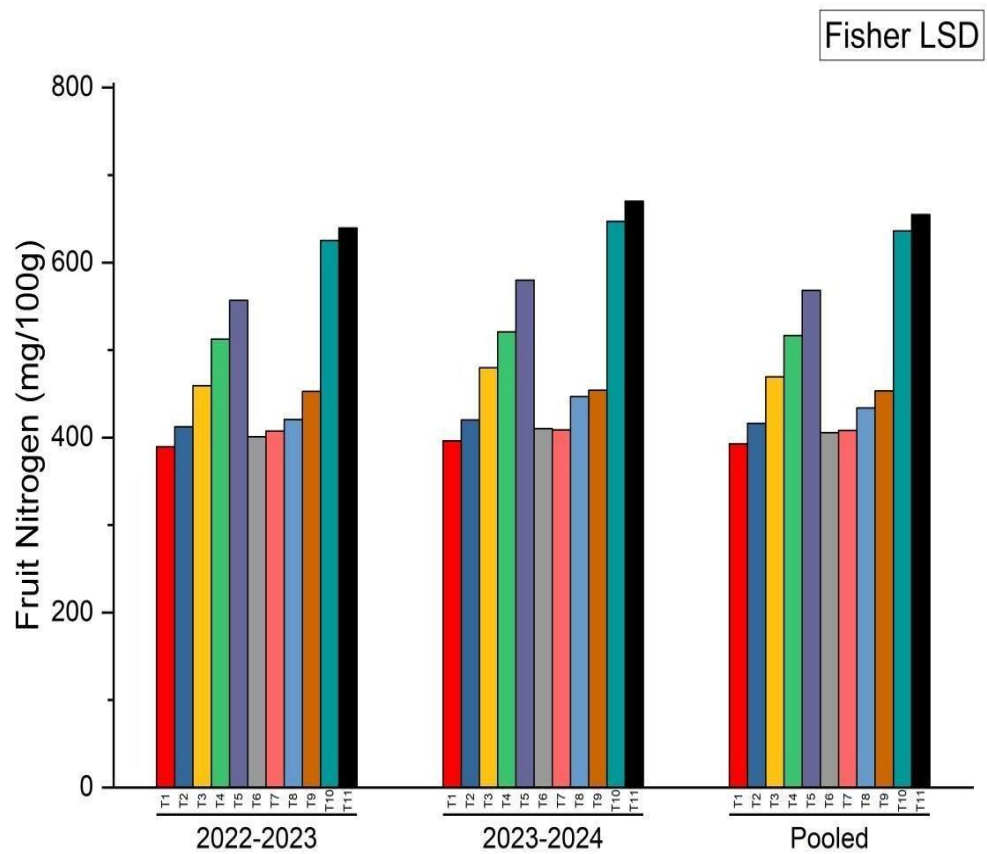
Treatments	Leaf Nitrogen (mg/100g)			Fruit Nitrogen mg/100g)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	2323.90	2350.23	2337.06 ^f	389.62	396.23	392.92 ^g
T ₂	2765.60	2778.12	2771.86 ^g	412.32	420.23	416.27 ^f
T ₃	2848.50	2859.25	2853.87 ^{ef}	459.23	479.69	469.45 ^d
T ₄	2945.23	2980.58	2962.90 ^{de}	512.58	520.90	516.74 ^d
T ₅	2975.40	2986.21	2980.80 ^{de}	556.72	579.92	568.32 ^c
T ₆	2913.90	2926.23	2920.06 ^e	401.01	410.42	405.71 ^b
T ₇	2926.30	2939.69	2932.99 ^{de}	407.42	408.82	408.11 ^g
T ₈	3015.90	3126.08	3070.98 ^{cd}	420.72	446.92	433.82 ^{ef}
T ₉	3118.60	3259.56	3189.08 ^{bc}	452.83	454.12	453.47 ^{de}
T ₁₀	3247.90	3326.89	3282.39 ^b	625.41	647.20	636.30 ^a
T ₁₁	3447.10	3564.23	3505.66 ^a	639.55	670.23	654.89 ^a
CD (p≤0.05)	144.51	102.32		19.90	22.25	
SE±(m)	48.64	34.44		6.70	7.49	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Fig: 4.10 Graphical representation of leaf nitrogen (mg/100 g)



* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Fig: 4.11 Graphical representation of fruit nitrogen (mg/100 g)

4.3.1.4.2 Leaf and Fruit Phosphorus (mg/100g) content:

Data presented in Table 4.19 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf phosphorus content (283.20 and 287.93 mg/100g) which was statistically at par with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum leaf Phosphorus content (204.50 and 205.60 mg/100g) was observed in control treatment (T₁) which. Similar pattern has observed in the pooled data, the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) has recorded the highest leaf Phosphorus content that was (283.25 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (274.80 mg/100g) and the lowest leaf Phosphorus content (204.70 mg/100g) was observed in control (T₁) treatment.

Data presented in Table 4.19 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit Phosphorus content (102.50 and 103.25 mg/100g) which was statistically at par with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit Phosphorus content was observed in control treatment (T₁) which was (64.52 and 64.61 mg/100g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit Phosphorus content, (102.67 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (101.31 mg/100g) and the lowest fruit Phosphorus content (64.66 mg/100g) was observed in control (T₁) treatment.

Table 4.19: Effect of PGRs and ZnSO₄ on Leaf and Fruit Phosphorus content of ber

Treatments	Leaf Phosphorus (mg/100 gm)			Fruit Phosphorus (mg/100 gm)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	204.50	205.60	204.70^e	64.52	64.61	64.66^f
T ₂	224.90	223.30	225.10^{cde}	86.52	86.82	86.67^d
T ₃	235.70	237.10	235.90^{bcde}	86.92	87.12	87.02^d
T ₄	252.10	255.20	252.15^{abcd}	91.53	91.92	91.68^c
T ₅	265.60	268.80	265.70^{abc}	92.53	92.92	92.62^{bc}
T ₆	221.60	223.70	221.65^{de}	72.32	72.52	72.42^e
T ₇	231.40	234.70	231.55^{cde}	75.43	75.62	75.53^e
T ₈	248.70	251.80	248.75^{abcd}	95.02	95.32	95.22^{bc}
T ₉	256.90	259.10	257.00^{abcd}	96.76	97.13	96.85^b
T ₁₀	274.70	279.90	274.80^{ab}	101.00	101.62	101.31^a
T ₁₁	283.20	287.93	283.25^a	102.50	103.25	102.67^a
CD (p≤0.05)	9.47	11.12		3.27	4.46	
SE±(m)	3.19	3.74		1.10	1.50	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.4.3 Leaf and fruit Potassium (mg/100g) content:

Data presented in Table 4.20 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf Potassium content (1874.00 and 1880.30 mg/100g) and having closely at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum leaf Potassium content was observed in control treatment (T₁) which was (1194.00 and 1196.10 mg/100g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf Potassium content that was (1877.00 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (1848.00 mg/100g) and the lowest leaf Potassium content (1195.00 mg/100g) was observed in control (T₁) treatment.

Data presented in Table 4.20 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit Potassium content (375.11 and 383.62 mg/100g) and having closely at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit Potassium content (101.25 and 101.62 mg/100g) was observed in control treatment (T₁) . Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit Potassium content that was (379.36 mg/100 g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (367.88 mg/100g) and the lowest fruit Potassium content (101.43 mg/100g) was observed in control (T₁) treatment.

Table 4.20: Effect of PGRs and ZnSO₄ on Leaf and Fruit Potassium content of ber

Treatments	Leaf Potassium (mg/100g)			Fruit Potassium (mg/100g)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	1194.00	1196.10	1195.00^g	101.25	101.62	101.43^g
T ₂	1456.50	1458.70	1457.60^e	223.61	236.12	229.86^d
T ₃	1573.00	1575.20	1574.00^d	234.52	241.53	238.02^d
T ₄	1632.40	1636.60	1634.50^{cd}	278.43	284.52	281.48^b
T ₅	1684.70	1688.90	1686.80^c	284.53	293.62	289.07^b
T ₆	1232.00	1236.20	1234.10^g	201.22	203.03	202.13^f
T ₇	1325.40	1327.60	1326.50^f	215.96	217.82	216.8^e
T ₈	1658.70	1662.90	1660.80^c	256.45	265.12	260.79^c
T ₉	1772.00	1777.20	1774.60^b	274.51	286.53	280.52^b
T ₁₀	1845.40	1850.60	1848.00^a	361.24	374.52	367.88^a
T ₁₁	1874.00	1880.30	1877.00^a	375.11	383.62	379.36^a
CD (p≤0.05)	53.17	69.07		10.80	13.48	
SE±(m)	17.89	23.25		3.63	4.53	

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉ - NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.4.4 Leaf and fruit Iron (mg/100g) content:

Data presented in Table 4.21 show that in first year and second year trial the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest leaf iron content (26.90 and 32.20 mg/100g) and the minimum leaf iron content was observed in control treatment (T_1) which was (16.50 and 16.80 mg/100g). Same trend followed in pooled data, application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest leaf iron content that was (28.05 mg/100g) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (26.60 mg/100g) and the lowest leaf iron content (16.65 mg/100g) was observed in control (T_1) treatment.

Data presented in Table 4.21 that in first year and second year the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit iron content (8.01 and 13.12 mg/100g) and the minimum fruit iron content was observed in control treatment (T_1) which was (4.68 and 4.69 mg/100g). Same trend followed in pooled data, application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit iron content that was (8.06 mg/100g) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (7.89 mg/100g) and the lowest fruit iron content (4.68 mg/100g) was observed in control (T_1) treatment.

Table 4.21: Effect of PGRs and ZnSO₄ on Leaf and Fruit Iron content of ber

Treatments	Leaf Iron (mg/100g)			Fruit Iron (mg/100g)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	16.50	16.80	16.65^g	4.68	4.69	4.68^c
T ₂	18.60	20.90	18.75^e	5.42	6.42	5.42^c
T ₃	19.70	22.90	19.80^d	5.65	7.74	5.66^{bc}
T ₄	20.60	23.65	20.70^{cd}	6.18	8.18	6.18^{abc}
T ₅	21.00	25.64	21.15^c	6.54	8.54	6.54^{abc}
T ₆	17.40	19.50	17.45^{fg}	5.12	6.12	5.12^c
T ₇	17.90	18.09	17.95^{ef}	5.52	6.52	5.52^{bc}
T ₈	19.80	22.10	19.95^d	6.82	7.82	6.38^{abc}
T ₉	20.10	23.30	20.20^{cd}	7.05	9.05	7.05^{abc}
T ₁₀	26.40	29.80	26.60^b	7.82	10.96	7.89^{ab}
T ₁₁	27.90	32.20	28.05^a	8.01	13.12	8.06^a
CD (p≤0.05)	1.40	1.42		0.14	0.15	
SE±(m)	4.53	4.53		0.10	0.11	

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5%+ 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.7.1 Leaf and fruit Copper (mg/100g) content:

Data presented in Table 4.22 that in first year and second year trial the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest leaf copper content (8.59 and 8.92 mg/100g) and having at par values with the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) and the minimum leaf copper content (4.01 and 4.23 mg/100g) was observed in control treatment (T_1). Same trend followed in pooled data, application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest leaf copper content that was (8.76 mg/100g) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (8.49 mg/100g) and the lowest leaf copper content (6.06 mg/100g) was observed in control (T_1) treatment.

Data presented in Table 4.22 that in first year and second year trial the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit copper content (4.36 and 5.15 mg/100g) and having at par values with the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) and the minimum fruit copper content (1.26 and 1.38 mg/100g) was observed in control treatment (T_1). Same trend followed in pooled data, application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit copper content that was (4.75 mg/100g) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (4.39 mg/100g) and the lowest fruit copper content (1.32 mg/100g) was observed in control (T_1) treatment.

Table 4.22: Effect of PGRs and ZnSO₄ on Leaf and Fruit Copper content of ber

Treatments	Leaf Copper (mg/100g)			Fruit Copper (mg/100g)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	4.01	4.23	6.06^f	1.26	1.38	1.32^g
T ₂	6.82	7.02	6.92^{cd}	3.26	3.39	3.32^e
T ₃	7.02	7.26	7.14^{bc}	3.58	3.66	3.62^d
T ₄	7.26	7.45	7.36^b	3.69	3.74	3.71^c
T ₅	7.43	7.52	7.48^b	3.85	3.96	3.90^c
T ₆	6.65	6.68	6.67^{de}	3.21	3.45	3.33^f
T ₇	6.42	6.47	6.44^e	2.69	2.96	2.82^{ef}
T ₈	7.08	7.36	7.22^{bc}	3.79	3.87	3.83^c
T ₉	7.29	7.59	7.44^b	3.83	3.96	3.92^c
T ₁₀	8.34	8.63	8.49^a	4.21	4.58	4.39^b
T ₁₁	8.59	8.92	8.76^a	4.36	5.15	4.75^a
CD (p≤0.05)	0.34	0.39		0.12	0.16	
SE(m)	0.11	0.13		0.04	0.05	

Whereas., T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉- NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.7.2 Leaf and fruit Manganese (mg/100g) content:

Data shown in Table 4.23 that in first year and second year trial the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf manganese content (5.11 and 5.16 mg/100g) and having at par values with the application of GA₃+ZnSO₄ +

Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum leaf manganese content was observed in control treatment (T₁) which was (4.21 and 4.23 mg/100g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf manganese content that was (5.13 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (5.06 mg/100g) and the lowest leaf manganese content (4.22 mg/100g) was observed in control (T₁) treatment.

Data shown in Table 4.23 that in first year and second year trail the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₉) recorded highest fruit manganese content (3.18 and 3.21 mg/100g) and having at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit manganese content was observed in control treatment (T₁) which was (0.80 and 0.95 mg/100g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₉) recorded highest fruit manganese content that was (4.52 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (4.39 mg/100g) and the lowest fruit manganese content (0.87 mg/100g) was observed in control (T₁) treatment.

Table 4.23: Effect of PGRs and ZnSO₄ on Leaf and Fruit Manganese content of ber

Treatments	Leaf Manganese (mg/100g)			Fruit Manganese (mg/100g)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	4.21	4.23	4.22^f	0.80	0.95	0.87ⁱ
T ₂	6.30	6.36	6.33^c	2.86	2.90	2.88^e
T ₃	6.41	6.50	6.45^c	3.12	3.19	3.15^d
T ₄	4.11	4.18	4.14^f	1.34	1.36	1.35^h
T ₅	3.02	3.09	3.05^g	1.39	1.41	1.40^g
T ₆	5.40	5.47	5.43^d	3.30	3.34	3.32^c
T ₇	5.61	5.63	5.62^d	3.36	3.39	3.37^c
T ₈	7.56	7.68	7.62^b	4.10	4.18	4.14^b
T ₉	8.70	8.86	8.77^a	5.26	5.30	5.28^a
T ₁₀	5.05	5.08	5.06^e	2.16	2.19	2.17^f
T ₁₁	5.11	5.16	5.13^e	3.18	3.21	3.19^d
CD (p≤0.05)	0.17	0.28		0.10	0.13	
SE±(m)	0.05	0.06		0.03	0.04	

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉ - NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.7.3 Leaf and fruit Calcium (mg/100g) content:

Data provided in Table 4.24 that in first year and second year trail the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf calcium content (1612.60 and 1685.90 mg/100g) and having at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum leaf calcium content was observed in control treatment (T₁) which was (1194.00 and 1194.50 mg/100g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf calcium content that was (1688.25 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (1578.55 mg/100g) and the lowest leaf calcium content (1194.24 mg/100g) was observed in control (T₁) treatment.

Data presented in Table 4.24 that in first year and second year trail the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit calcium content (216.25 and 222.36 mg/100g) and having at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit calcium content was observed in control treatment (T₁) which was (125.00 and 126.33 mg/100g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit calcium content that was (219.30 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (214.57 mg/100g) and the lowest fruit calcium content (125.66 mg/100g) was observed in control (T₁) treatment.

Table 4.24: Effect of PGRs and ZnSO₄ on Leaf and Fruit Calcium content of ber

Treatments	Leaf Calcium (mg/100g)			Fruit Calcium (mg/100g)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	1194.00	1194.50	1194.24^h	125.00	126.33	125.66^g
T ₂	1257.00	1258.50	1257.25^{fg}	160.25	162.56	161.40^e
T ₃	1287.60	1289.20	1288.90^{ef}	165.26	166.58	165.91^{de}
T ₄	1320.00	1322.90	1321.45^e	170.87	172.51	171.69^{cd}
T ₅	1372.90	1377.50	1375.20^d	174.54	176.86	175.70^c
T ₆	1214.10	1217.60	1215.35^{gh}	130.69	132.36	131.52^g
T ₇	1231.90	1232.40	1232.14^{gh}	150.58	152.65	151.61^f
T ₈	1447.40	1457.60	1452.49^c	185.65	188.56	187.10^b
T ₉	1485.00	1498.40	1490.20^c	187.36	190.26	188.81^b
T ₁₀	1546.90	1610.20	1578.55^b	210.58	218.56	214.57^a
T ₁₁	1650.60	1725.90	1688.25^a	216.25	222.36	219.30^a
CD (p≤0.05)	44.74	65.03		7.83	6.20	
SE±(m)	15.06	21.89		2.63	2.08	

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉ - NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.7.4 Leaf and fruit Boron (mg/100g) content:

Data provided in Table 4.25 that in first year and second year trail the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest leaf Boron content (110.00 and 112.00 mg/100g) and having at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the lowest Boron content was observed in control treatment (T₁) which was (69.00 and 7.00 mg/100g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest Boron content that was (111.00 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (108.00 mg/100g) and the lowest Boron content (69.50 mg/100g) was noted in control (T₁) treatment.

Data presented in Table 4.25 that in first year and second year trail the application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit boron content (20.76 and 20.81 mg/100g) and having at par values with the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) and the minimum fruit boron content was observed in control treatment (T₁) which was (10.27 and 11.23 mg/100g). Same trend followed in pooled data, application of GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm- T₁₁) recorded highest fruit boron content that was (20.79 mg/100g) followed by the application of GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm- T₁₀) that was (19.31 mg/100g) and the lowest fruit Zinc content (10.75 mg/100g) was seen in control (T₁) treatment.

Table 4.25: Effect of PGRs and ZnSO₄ on Leaf and Fruit Boron content of ber

Treatments	Leaf Boron (mg/100g)			Fruit Boron (mg/100g)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	69.00	70.00	69.50^g	10.27	11.23	10.75^g
T ₂	75.00	78.00	76.50^{ef}	14.25	14.56	14.41^d
T ₃	78.00	81.00	79.50^{de}	14.98	15.10	15.04^d
T ₄	80.00	82.00	81.00^{cde}	18.54	18.69	18.61^b
T ₅	82.00	83.00	82.50^{cd}	18.87	19.23	19.05^b
T ₆	71.00	74.00	72.50^{fg}	11.25	12.36	11.81^f
T ₇	72.00	75.00	73.50^{fg}	12.54	12.89	12.72^e
T ₈	83.00	86.00	84.50^{bc}	15.27	16.36	15.82^c
T ₉	86.00	89.00	87.50^b	16.25	16.85	16.55^c
T ₁₀	108.00	109.00	108.50^a	19.25	19.37	19.31^b
T ₁₁	110.00	112.00	111.00^a	20.76	20.81	20.79^a
CD (p≤0.05)	2.91	4.45		0.74	0.82	
SE±(m)	0.98	1.50		0.25	0.27	

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉ - NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5%+ 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

4.3.1.7.5 Leaf and fruit Zinc (mg/100g) content:

Data shown in Table 4.26 that in first year and second year trial the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest leaf Zinc content (8.20 and 8.60 mg/100g) and having at par values with the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) and the minimum leaf Zinc content was observed in control treatment (T_1) which was (5.00 and 5.20 mg/100g). Same trend followed in pooled data, application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest leaf Zinc content that was (8.40 mg/100g) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (8.10 mg/100g) and the lowest leaf Zinc content (5.09 mg/100g) was observed in control (T_1) treatment.

Data shown in Table 4.11 that in first year and second year trial the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit Zinc content (0.63 and 0.65 mg/100g) and having at par values with the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) and the lowest Zinc content in fruits was seen in control treatment (T_1) which was (0.33 and 0.35 mg/100g). Same trend followed in pooled data, application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (40 ppm + 0.5% + 300 ppm- T_{11}) recorded highest fruit Zinc content that was (0.64 mg/100g) followed by the application of $\text{GA}_3 + \text{ZnSO}_4 + \text{Salicylic acid}$ (30 ppm + 0.5% + 300 ppm- T_{10}) that was (0.61 mg/100g) and the lowest fruit Zinc content (0.34 mg/100g) was seen in control (T_1) treatment.

Table 4.26: Effect of PGRs and ZnSO₄ on Leaf and Fruit Zinc content of ber

Treatments	Leaf Zinc (mg/100g)			Fruit Zinc (mg/100g)		
	2022-2023	2023-2024	Pooled	2022-2023	2023-2024	Pooled
T ₁	5.00	5.20	5.09ⁱ	0.33	0.35	0.33^h
T ₂	5.60	5.80	5.70^g	0.50	0.53	0.51^e
T ₃	6.10	6.20	6.14^f	0.53	0.56	0.54^d
T ₄	6.50	6.80	6.64^e	0.57	0.60	0.58^c
T ₅	6.80	7.20	7.00^d	0.61	0.64	0.62^{bc}
T ₆	5.30	5.40	5.35^{hi}	0.42	0.44	0.43^g
T ₇	5.50	5.61	5.55^{gh}	0.45	0.48	0.46^f
T ₈	7.50	7.56	7.53^d	0.54	0.55	0.54^d
T ₉	7.94	7.96	7.95^c	0.57	0.59	0.57^c
T ₁₀	8.00	8.20	8.10^b	0.65	0.70	0.61^b
T ₁₁	8.20	8.60	8.40^a	0.72	0.77	0.65^a
CD (p≤0.05)	0.29	0.37		0.03	0.02	
SE±(m)	0.09	0.12		0.01	0.01	

Whereas, T₁ control (Water spray), T₂- NAA (20 ppm), T₃- NAA (30 ppm), T₄- GA₃ (30 ppm), T₅- GA₃ (40 ppm), T₆- Salicylic acid 300 ppm, T₇- ZnSO₄ (0.5%), T₈ - NAA + ZnSO₄ + Salicylic acid (20 ppm + 0.5% + 300 ppm), T₉ - NAA + ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₀ - GA₃+ZnSO₄ + Salicylic acid (30 ppm + 0.5% + 300 ppm), T₁₁- GA₃+ZnSO₄ + Salicylic acid (40 ppm + 0.5% + 300 ppm)

Foliar application enables direct nutrient absorption through the leaves, resulting in faster and more efficient uptake than soil application. Salicylic acid can enhance the permeability of leaf tissues, facilitating the absorption of nutrients such as zinc and other micronutrients from the foliar spray. Foliar sprays of SA and ZnSO₄ significantly increased the micronutrient content in the fruits of treated plants, suggesting that foliar applications enhance nutrient availability and uptake (Khan *et al.*, 2023). The mixture of GA₃ and SA enhanced chlorophyll content and photosynthetic efficiency, which was positively associated with increased micronutrient levels in the fruit. (Verma *et al.*, 2023). The combined application of salicylic acid, gibberellic acid, and zinc sulfate results in a significant increase in the nutrient content of ber fruits through improved photosynthesis, enhanced nutrient uptake, increased enzymatic activity, strengthened cell walls, and better moisture retention. Recent studies confirm these findings and highlight the importance of these compounds in enhancing the nutritional quality of ber fruit. The interaction of SA, GA₃ and ZnSO₄ creates a synergistic effect that optimizes growth conditions, enhancing the physiological processes necessary for nutrient accumulation in fruits. Application of these compounds led to significant improvements in the nutrient content of ber fruits, underscoring the benefits of using these treatments in combination (Patel *et al.*, 2023).

4.3.1.7.6 To study the correlation between foliar and fruit nutrients status with quality and yield attributes:

4.3.1.7.6.1 Leaf nutrient correlation with yield parameters:

The data represented in fig 4.12 revealed that nitrogen has positive and significant correlation with yield efficiency ($r=0.70$), fruit weight ($r=0.89$), fruit diameter ($r=0.83$), fruit length ($r=0.90$), fruit firmness ($r=0.84$) and fruit volume ($r=0.89$) but nitrogen had negative correlation with fruit drop ($r= -0.37$). Likewise, P, K, Cu, Ca and Zn were having negative correlation with fruit drop but positive correlation with initial fruit set, yield, yield efficiency, fruit weight, fruit diameter, fruit length, fruit firmness and fruit volume. At the same time Fe was positively correlated with fruit drop and having negative correlation with yield ($r=-0.15$). Mn had positive correlation with initial fruit set, fruit retention, yield, yield efficiency, fruit length, fruit firmness but had negative correlation with fruit drop, weight, diameter and volume. Boron had negative correlation with fruit drop, yield but

positive correlation with all other yielding parameters like initial fruit drop, fruit retention, weight, diameter, length, firmness and volume. The results corroborate with the findings (Zhou *et al.*, 2021), (Huang *et al.*, 2022), (Kumar *et al.*, 2023) and (Singh *et al.*, 2023). The positive correlation of nitrogen with initial fruit set, fruit retention, yield, yield efficiency, and various fruit quality metrics (fruit weight, fruit diameter, fruit length, fruit firmness, and fruit volume) under-scores its critical role in enhancing fruit production. Nitrogen is a vital component of amino acids and proteins, which are essential for plant growth and development. Recent studies confirm that adequate nitrogen supply significantly boosts fruit quality and yield (Zhou *et al.*, 2021). Conversely, nitrogen deficiency can lead to reduced fruit development and lower yields, highlighting the importance of balanced fertilization in achieving optimal results (Kumar *et al.*, 2023). Boron's negative correlation with fruit drop and yield, coupled with its positive association with other yielding parameters, indicates that boron is essential for cellular wall structure and reproductive development, its imbalance can lead to adverse effects on fruit quality (Singh *et al.*, 2023).

	N	P	K	Fe	Cu	Mn	Ca	B	Zn	ini fruit s	t retentio	Fruitdrop	Yield	Y.E	Weight	Diameter	Length	Firmness	Volume
N	1.00																		
P	0.90	1.00																	
K	0.83	0.94	1.00																1.00
Fe	0.83	0.90	0.85	1.00															0.80
Cu	0.88	0.94	0.92	0.98	1.00														0.60
Mn	0.22	-0.04	0.16	-0.12	-0.02	1.00													0.40
Ca	0.88	0.91	0.92	0.91	0.93	0.19	1.00												0.20
B	0.85	0.89	0.86	0.98	0.97	0.03	0.96	1.00											0.00
Zn	0.87	0.93	0.96	0.84	0.90	0.24	0.97	0.89	1.00										-0.20
ini fruit s	0.55	0.37	0.47	0.10	0.24	0.81	0.41	0.21	0.52	1.00									-0.40
Frtretent	0.40	0.31	0.49	0.07	0.20	0.84	0.43	0.20	0.55	0.92	1.00								-0.60
Fruit drop	-0.37	-0.21	-0.38	0.01	-0.13	-0.90	-0.37	-0.14	0.47	-0.90	-0.98	1.00							-0.80
Yield	0.22	0.03	0.23	-0.15	0.00	0.90	0.16	-0.03	0.25	0.85	0.86	-0.89	1.00						-1.00
Y.E	0.70	0.51	0.61	0.32	0.45	0.80	0.60	0.43	0.67	0.94	0.89	-0.90	0.81	1.00					
Weight	0.89	0.94	0.82	0.86	0.90	-0.16	0.79	0.82	0.79	0.29	0.13	-0.04	-0.06	0.41	1.00				
Diameter	0.83	0.93	0.83	0.96	0.94	-0.24	0.88	0.92	0.83	0.08	0.03	0.06	0.2	0.26	0.90	1.00			
Length	0.90	0.92	0.87	0.92	0.91	0.09	0.95	0.95	0.92	0.36	0.32	-0.25	0.00	0.52	0.83	0.90	1.00		
Firmness	0.84	0.80	0.84	0.78	0.82	0.41	0.96	0.87	0.94	0.56	0.60	-0.57	0.34	0.74	0.66	0.72	0.89	1.00	
Volume	0.89	0.95	0.87	0.86	0.90	-0.10	0.79	0.81	0.80	0.33	0.18	-0.08	-0.02	0.44	0.96	0.90	0.84	0.64	1.00

Fig: 4.12 Graphical representation of leaf nutrients with yield attributes

Here, data between 0.37-0.47 significant (*), 0.5-0.6 significant (**) and 0.6-0.9 highly significant (***) Leaf nutrient correlation with biochemical parameters:

From the data showed in fig 4.13 revealed that nitrogen had positive and significant correlation with chlorophyll content ($r=0.91$), fruit TSS ($r=0.88$), TSS: acid ratio ($r=0.92$), total sugar ($r=0.93$) fruit reducing sugar ($r=0.93$), non-reducing sugar ($r=0.68$), vitamin c ($r=0.96$) and phenols ($r=0.94$) and had negative correlation with acidity ($r= -0.91$). Same trend has followed in rest of the nutrients P, K, Fe, Cu, Mn, Ca, B and Zn had positive and significant correlation with chlorophyll content, fruit Tss, TSS: acid ratio, fruit total sugar, fruit reducing sugar, non- reducing sugar, fruit vitamin c and phenols. The results corroborate with the findings of Kumar and Chandel (2004), Fallahi *et al.* (2010) and Dar *et al.* (2012). Analysis of correlation matrix reveal significant and positive relation between leaf with fruit length, diameter, volume, SSC, total sugar. This could be due to its role as essential constituent in cell and its organelles and in plant metabolism. Similar findings were earlier reported by Kumar and Chandel (2004); and Kumar *et al.* (2015). Phosphorus participates in some of the vital metabolic processes by supplying energy, increasing acid neutralization and sugar synthesis, resulting in less acidic but more sugary fruits (Kader, 2008). The leaf potassium revealed positive and significant correlation with fruit length, weight, volume and total sugar. Being a quality nutrient, its role is indicated by increased enzyme activation, translocation of photosynthates for efficient utilization, promoting cell division and development of meristematic tissues. These lines corroborate with the results of Farooqui *et al.* (2004) and Kumar *et al.* (2015). Stino (2011) determined that potassium directly influences fruit growth, maintains cell turgidity and is associated with good equilibrium between acid and sugar contents, good ripening and good eating quality. The leaf calcium revealed significant and positive correlation with fruit length, diameter, weight, volume. This is because calcium plays a central role on cell functioning and essential for formation pectin substances which enhance the fruit firmness (Dar *et al.*, 2014) and Kumar (2015). High Calcium level in apple is associated with slower degradation of cellular structure. Magnesium content showed positive and significant correlation with fruit quality and yield. It may be because of the role of magnesium in chlorophyll and many physiological and biochemical processes. It is also an essential element for plant growth and development (Cakmak and Kirkby, 2008). The leaf boron exhibited significant and positive correlation with

fruit length, diameter and yield indicates its role in cell division and activation; of several enzymes and as constituent of many amino acids (Mansour *et al.*, 2008 and Fallahi *et al.*, 2010).

	N	P	K	Fe	Cu	Mn	Ca	B	Zn	Chlorophyll	TSS	Acidity	Tss:Acid	Total sugar	Reducing sugar	Non-reducing sugar	Vit c	Phenols
N	1.00																	
P	0.90	1.00																
K	0.83	0.94	1.00															
Fe	0.83	0.90	0.85	1.00														1.0
Cu	0.88	0.94	0.92	0.98	1.00													0.8
Mn	0.22	-0.04	0.16	-0.12	-0.02	1.00												0.6
Ca	0.88	0.91	0.92	0.91	0.93	0.19	1.00											0.4
B	0.85	0.89	0.86	0.98	0.97	0.03	0.96	1.00										0.2
Zn	0.87	0.93	0.96	0.84	0.90	0.24	0.97	0.89	1.00									0.0
Chlorophyll	0.91	0.84	0.79	0.69	0.77	0.22	0.70	0.68	0.73	1.00								-0.2
TSS	0.88	0.93	0.97	0.80	0.89	0.24	0.87	0.81	0.93	0.88	1.00							-0.4
Acidity	-0.91	-0.94	-0.92	-0.87	-0.91	-0.18	-0.98	-0.91	-0.98	-0.74	-0.89	1.00						-0.6
Tss:Acid	0.92	0.95	0.95	0.91	0.96	0.18	0.98	0.94	0.98	0.79	0.94	-0.98	1.00					-0.8
Total sugar	0.93	0.86	0.74	0.83	0.85	0.08	0.88	0.87	0.85	0.73	0.76	-0.91	0.88	1.00				-1.0
Reducing	0.93	0.86	0.75	0.85	0.87	0.08	0.89	0.89	0.85	0.72	0.76	-0.91	0.89	1.00	1.00			
Non-reducing	0.68	0.70	0.71	0.60	0.70	0.13	0.63	0.60	0.68	0.66	0.75	-0.68	0.72	0.59	0.60	1.00		
Vit c	0.96	0.87	0.82	0.81	0.88	0.19	0.80	0.80	0.79	0.95	0.90	-0.82	0.88	0.83	0.83	0.70	1.00	
Phenols	0.94	0.93	0.86	0.86	0.91	0.14	0.94	0.89	0.93	0.79	0.88	-0.96	0.96	0.93	0.94	0.66	0.88	1.0

Fig: 4.13. Graphical representation of leaf nutrients with bio-chemical parameters

Here, data between 0.37-0.47 significant (*), 0.5-0.6 significant (**) and 0.6-0.9 highly significant (***)

4.3.1.7.6.2 Leaf nutrient correlation with proximate parameters:

Based on the correlation data presented in fig 4.14, nitrogen (N) shows strong positive correlations with several leaf nutritional components with fat, fiber and protein content,. However, it also exhibits a negative correlation with ash content. The positive correlation with fat content ($r=0.89$), fiber content ($r=0.81$) and protein ($r=0.89$). Increased nitrogen levels can enhance lipid synthesis in plants, which may lead to higher fat content. Furthermore, nitrogen fertilization can promote plant growth and development, potentially leading to higher yields of fibrous plant parts, which are important for dietary fiber intake (Fageria & Baligar, 2005; Saini *et al.*, 2013). The negative correlation with ash content ($r=-0.15$) suggests that as nitrogen levels increase, the ash content (which is a measure of the total mineral content) may decrease. This could be attributed to the dilution effect; as nitrogen promotes increased biomass and growth, the relative concentration of minerals may decrease if they do not accumulate at the same rate. This observation could have implications for the mineral density of crops, potentially affecting their overall nutritional value.

	N	P	K	Fe	Cu	Mn	Ca	B	Zn	Fat	Fiber	Ash	
N	1												
P	0.90	1.00											1.00
K	0.83	0.94	1.00										0.80
Fe	0.83	0.90	0.85	1.00									0.60
Cu	0.88	0.94	0.92	0.98	1.00								0.40
Mn	0.22	-0.04	0.16	-0.12	-0.02	1.00							0.20
Ca	0.88	0.91	0.92	0.91	0.93	0.19	1.00						0.00
B	0.85	0.89	0.86	0.98	0.97	0.03	0.96	1.00					-0.20
Zn	0.87	0.93	0.96	0.84	0.90	0.24	0.97	0.89	1.00				-0.40
Fat	0.89	0.91	0.93	0.87	0.92	0.26	0.99	0.93	0.99	1.00			-0.60
Fiber	0.81	0.95	0.93	0.92	0.93	-0.08	0.90	0.91	0.89	0.87	1.00		-0.80
Ash	0.15	-0.09	-0.23	-0.09	-0.02	-0.02	-0.10	-0.07	-0.13	-0.07	-0.28	1.00	-1.00
Protein	0.93	0.98	0.94	0.90	0.95	0.05	0.93	0.90	0.94	0.93	0.92	-0.01	1.00

Fig: 4.14 Graphical representation of leaf nutrients with proximate parameters

Here, data between 0.37-0.47 significant (*), 0.5-0.6 significant (**), and 0.6-0.9 highly significant (***)

4.3.1.7.6.3 To study the correlation between fruit nutrient status with quality and yield attributes

4.3.1.7.6.3.1 To study the correlation between fruit nutrient status with yield attributes

According to the correlation data illustrated in fig 4.15, fruit nitrogen (N) exhibits strong positive correlations with several fruit characteristics, including weight ($r=0.88$), diameter ($r=0.97$), length ($r=0.84$), and volume ($r=0.88$). Manganese (Mn) demonstrates a positive correlation with initial fruit set ($r=0.89$), fruit retention ($r=0.80$), yield ($r=0.86$), yield efficiency ($r=0.88$) and weight ($r=0.09$), while negatively correlating with fruit drop ($r=-0.86$). Additionally, phosphorus (P), potassium (K), iron (Fe), copper (Cu), calcium (Ca), boron (B), and zinc (Zn) exhibit negative correlations with fruit drop but show positive and significant correlations with other parameters, such as weight, length, diameter, volume, and firmness. This aligns with findings from recent studies indicating that nitrogen is a vital macronutrient that influences various aspects of plant growth and fruit quality, promoting cellular expansion and weight accumulation (He et al., 2021). However, the negative correlation of nitrogen and zinc with yield ($r=-0.31$) and ($r=-0.06$), respectively raises concerns about the interplay between these nutrients and overall fruit productivity. This may indicate that while nitrogen enhances fruit size and growth parameters, excessive nitrogen may lead to poor fruit set or retention, ultimately reducing yield. Previous research has suggested that high nitrogen levels can sometimes result in vegetative growth at the expense of reproductive growth, which could explain the observed negative relationship with yield (Khan *et al.*, 2020). Manganese demonstrates a strong positive correlation with initial fruit set ($r=0.89$), fruit retention ($r=0.80$), yield ($r=0.86$), and yield efficiency ($r=0.88$), highlighting its critical role in enhancing fruit productivity and quality. Mn is known to be involved in several physiological processes, including photosynthesis and enzyme activation, which can directly impact fruit development (García-Sánchez et al., 2019). The negative correlation of manganese with fruit drop ($r=-0.86$) indicates that adequate levels of this micronutrient are essential for minimizing premature fruit drop, thus improving overall yield. The relationships observed for other nutrients such as phosphorus (P), potassium (K), iron (Fe), copper (Cu), calcium (Ca), boron (B), and zinc (Zn) also provide valuable insights. While these nutrients exhibit negative

correlations with fruit drop, their positive and significant correlations with weight, length, diameter, volume, and firmness suggest their importance in enhancing fruit quality attributes. For instance, potassium is well- documented for its role in fruit quality, impacting sugar accumulation and firmness, which are crucial for marketability (Kumar *et al.*, 2021).

	N	P	K	Fe	Cu	Mn	Ca	B	Zn	nifruitse	rtretentia	Fruitdrop	Yield	Y.E	Weight	Diameter	Length	Firmness	Volume
N	1																		
P	0.76	1.00																	
K	0.88	0.93	1.00																1.00
Fe	0.87	0.91	0.95	1.00															0.80
Cu	0.77	0.95	0.91	0.90	1.00														0.60
Mn	-0.21	0.29	0.20	0.23	0.21	1.00													0.40
Ca	0.83	0.96	0.94	0.97	0.90	0.26	1.00												0.20
B	0.91	0.92	0.93	0.89	0.94	-0.03	0.90	1.00											0.00
Zn	0.82	0.95	0.94	0.87	0.94	0.17	0.89	0.96	1.00										-0.20
Ini fruitse	-0.04	0.53	0.38	0.39	0.49	0.89	0.45	0.24	0.43	1.00									-0.40
Frtretentia	-0.08	0.51	0.27	0.37	0.47	0.80	0.43	0.21	0.35	0.92	1.00								-0.60
Fruitdrop	0.19	-0.42	-0.19	-0.28	-0.38	-0.86	-0.34	-0.09	-0.23	-0.90	-0.98	1.00							-0.80
Yield	-0.31	0.29	0.06	0.07	0.17	0.86	0.18	-0.06	0.16	0.85	0.86	-0.89	1.00						-1.00
Y.E	0.14	0.67	0.54	0.56	0.61	0.88	0.62	0.37	0.54	0.94	0.89	-0.90	0.81	1.00					
Weight	0.88	0.83	0.95	0.88	0.86	0.09	0.84	0.89	0.91	0.29	0.13	-0.04	-0.06	0.41	1.00				
Diameter	0.97	0.78	0.90	0.91	0.81	-0.05	0.86	0.90	0.82	0.08	0.03	0.06	-0.22	0.26	0.90	1.00			
Length	0.84	0.82	0.90	0.98	0.82	0.24	0.92	0.82	0.78	0.36	0.32	-0.25	0.00	0.52	0.83	0.90	1.00		
Firmness	0.63	0.83	0.79	0.90	0.79	0.48	0.90	0.68	0.67	0.56	0.60	-0.57	0.34	0.74	0.66	0.72	0.89	1.00	
Volume	0.88	0.87	0.96	0.88	0.88	0.12	0.86	0.93	0.95	0.33	0.18	-0.08	-0.02	0.44	0.96	0.90	0.84	0.64	1.00

Fig: 4.15 Graphical representation of fruit nutrients with yield attributes

Here, data between 0.37-0.47 significant (*), 0.5-0.6 significant (**), and 0.6-0.9 highly significant (***)

4.3.1.7.6.3.2 Correlation of fruit nutrients with bio-chemical parameters

The data presented in fig 4.16 indicates that the nutrient content of fruit like nitrogen had positive correlation with TSS: acid ratio ($r=0.83$), vitamin c ($r=0.73$), carotenoid ($r= 0.71$), reducing sugar ($r=0.77$) and antioxidant ($r= 0.81$). And same trend has followed in phosphorus, potassium, iron, calcium, boron and zinc. The results corroborate with the findings of (Berkelmans *et al.*, 2022), (Zhang *et al.*, 2023) and (Ali *et al.*, 2023). Nitrogen is Vital for amino acid synthesis and chlorophyll formation, nitrogen directly influences photosynthesis, resulting in higher chlorophyll content and overall plant vigor. This enhanced photosynthesis can lead to increased production of sugars and organic compounds that improve fruit quality. The positive correlations observed with antioxidants, including vitamin C and phenolic compounds, are also noteworthy. These compounds not only enhance the nutritional value of the fruit but also improve its shelf life and resistance to diseases. Adequate nutrient levels have been associated with higher antioxidant capacities, which are critical for fruit health and consumer appeal (Zhang *et al.*, 2023). The relationship between nutrient levels and parameters such as the TSS: acid ratio is particularly important, as it influences the overall taste and marketability of the fruit. A higher TSS: acid ratio is generally preferred in many fruits, indicating a balance between sweetness and acidity that enhances flavor (Ali *et al.*, 2023).

Conversely, these nutrient levels exhibit a negative correlation with fruit acidity. The results corroborate with the findings of (Ali *et al.*, 2023). The observed negative correlation between nutrient levels and fruit acidity can be attributed to the metabolic shifts caused by increased nutrient availability. High nutrient levels often promote the accumulation of sugars, leading to a dilution of organic acids in the fruit. This phenomenon is particularly notable in fruits where sweetness is a desirable trait, indicating a balance between sugar and acid for optimal fruit flavor.

	N	P	K	Fe	Cu	Mn	Ca	B	Zn	Chlorophyll	TSS	Acidity	TSS:Acid	Total sugar	Reducing sugar	Non reducing	Vit c	Phenols	Carotenoid	Antioxidant
N	1																			
P	0.76	1																		
K	0.88	0.93	1																	
Fe	0.87	0.91	0.95	1																
Cu		0.95		0.90	1															
Mn	-0.21	0.29	0.20	0.23		1														0.80
Ca	0.83	0.96	0.94		0.90	0.26	1													0.60
B	0.91	0.92	0.93	0.89	0.94	-0.03	0.90	1												
Zn	0.82	0.95	0.94	0.87	0.94		0.89	0.96	1											0.20
Chlorophyll	0.64	0.82	0.89	0.78	0.80		0.80		0.89	1										0.00
TSS		0.99	0.94	0.90	0.95	0.35	0.95	0.90	0.96	0.88	1									-0.20
Acidity	-0.79	-0.89	-0.89	-0.97	-0.90	-0.33	-0.94	-0.85	-0.82	-0.74	-0.89	1								-0.40
TSS:Acid	0.83	0.94	0.94	0.98		0.31		0.89	0.88			-0.98	1							-0.60
Total sug			0.87	0.90	0.80	0.30	0.82				0.76	-0.91	0.88	1						-0.80
Reducing			0.87	0.90	0.78	0.30	0.83				0.76	-0.91	0.89		1					-1.00
Non reducing	0.62	0.67	0.67	0.64		0.26	0.62	0.66		0.66		-0.68		0.59	0.60	1				
Vit c		0.87	0.95	0.85	0.83		0.86	0.80	0.90	0.95	0.90	-0.82	0.88	0.83	0.83		1			
Phenols		0.86	0.91	0.94	0.88	0.35	0.90	0.82	0.83	0.79	0.88	-0.96	0.96	0.93	0.94	0.66	0.88	1		
Carotenoid		0.94	0.89	0.87	0.94	0.32	0.88	0.86	0.89	0.74	0.94	-0.89	0.92		0.80	0.76	0.85	0.89	1	
Antioxidant	0.81	0.86	0.94	0.93		0.31	0.88	0.85	0.86	0.84	0.89	-0.95	0.95	0.95	0.95			0.96	0.90	1

4.16 Graphical representation of fruit nutrients with bio-chemical parameters

4.3.2.4.10.4.3 Correlation of fruit nutrients with fruit proximate parameters

The data in fig 4.17 reveals that nitrogen showed a positive correlation of nitrogen with fat content ($r=0.77$), fiber content ($r=0.91$), and protein content ($r=0.86$), while it had a negative correlation with ash content ($r=-0.08$). This pattern was also observed for other nutrients such as phosphorus(P), potassium (K), iron (Fe), copper (Cu), calcium (Ca), boron (B), and zinc (Zn). However, for manganese (Mn), the correlation was positive with fat content, fiber content, ash content, and protein content. The data is consistent with findings in recent studies that indicate the role of nitrogen in enhancing the nutritional quality of crops. Nitrogen, a key macronutrient, is a crucial component of amino acids, proteins, and enzymes, which explains its strong positive association with protein content (Giri *et al.*, 2023). Nitrogen fertilization is also known to increase carbohydrate and lipid synthesis in plants, which may explain its positive correlation with fat and fiber content (Tariq *et al.*, 2021). The negative correlation with ash content ($r= -0.08$) suggests that higher nitrogen levels may dilute the mineral content in plant tissues, a trend that has been documented in various crops (Song *et al.*, 2020). Excessive nitrogen supply can lead to the accumulation of non-mineral nutrients while potentially reducing the concentration of certain minerals, leading to lower ash content. Similarly, the pattern of positive correlation between nitrogen and other essential nutrients like phosphorus (P), potassium (K), iron (Fe), copper (Cu), calcium (Ca), boron (B), and zinc (Zn) aligns with previous research suggesting that nitrogen can influence the uptake of other macro- and micronutrients in plants (Kadival *et al.*, 2023). This is due to the interdependent nature of nutrient uptake and assimilation, with nitrogen playing a pivotal role in nutrient absorption efficiency. The case of manganese (Mn), where positive correlations with fat, fiber, ash, and protein content were observed, is particularly intriguing. Manganese, a micronutrient involved in various enzymatic processes, can influence both metabolic and structural components of plants. Recent studies have shown that Mn availability and its interaction with nitrogen can enhance the nutritional profile of plants, particularly in terms of protein and fiber content (Tiwari *et al.*, 2023). The positive correlation between manganese and these nutrients may reflect its role in optimizing plant growth and nutrient assimilation processes under specific conditions of nitrogen application. In conclusion, the observed correlations highlight the complex relationships between nitrogen and the nutritional

composition of plants. Optimizing nitrogen levels can improve the yield and nutritional quality of crops, but the balance with other nutrients, including micronutrients like manganese, is critical for achieving desired outcomes in crop management. Ash has strongest negative correlation with fiber (−0.80) and fat (−0.60), both being organic fractions. During high-temperature dry ashing (typically 500–600 °C), organic nitrogen compounds are oxidized to gaseous forms such as NO_x and NH₃, so much of the N does not remain in the ash residue (Thy *et al.*, 2006). Ash is weakly or negatively correlated with almost all minerals, suggesting organic enrichment and inorganic depletion in tissues with higher nutrient-induced growth.

Boron and Other Volatile Elements: Elements like boron, potassium, chlorine, and sulfur are known to vaporize or sublime at ashing temperatures, resulting in their underrepresentation in the final ash weight (Shen *et al.*, 2015).

	N	P	K	Fe	Cu	Mn	Ca	B	Zn	Fat	Fiber	Ash	Protein	
N	1													
P	0.76	1.00												1.00
K	0.88	0.93	1.00											0.80
Fe	0.87	0.91	0.95	1.00										0.60
Cu	0.77	0.95	0.91	0.90	1.00									0.40
Mn	-0.21	0.29	0.20	0.23	0.21	1.00								0.20
Ca	0.83	0.96	0.94	0.97	0.90	0.26	1.00							0.00
B	0.91	0.92	0.93	0.89	0.94	-0.03	0.90	1.00						-0.20
Zn	0.82	0.95	0.94	0.87	0.94	0.17	0.89	0.96	1.00					-0.40
Fat	0.77	0.91	0.89	0.97	0.88	0.37	0.96	0.82	0.81	1.00				-0.60
Fiber	0.91	0.89	0.93	0.96	0.87	0.03	0.94	0.94	0.88	0.87	1.00			-0.80
Ash	-0.08	-0.19	-0.02	-0.10	-0.08	0.18	-0.23	-0.18	-0.13	-0.07	-0.28	1.00		-1.00
Protein	0.86	0.94	0.98	0.97	0.96	0.21	0.95	0.94	0.93	0.93	0.92	-0.01	1.00	

Fig: 4.17 Graphical representation of fruit nutrients with proximate parameters

Here, data between 0.37-0.47 significant (*), 0.5-0.6 significant (**) and 0.6-0.9 highly significant (***)

CHAPTER-V

SUMMARY AND CONCLUSION

SUMMARY

Current research “**Influence of PGRs and ZnSO₄ on Fruit drop and Chemo-metric Attributes of Ber (*Ziziphus mauritiana* L.)**” was conducted in the orchard of Lovely Professional University. The data were statistically analyzed. The behavior patterns of the ber crop under these different treatments are presented in tables and supported by relevant figures at appropriate points.

5.1 Vegetative parameters

T₁₁, consisting of (40 ppm GA₃ + 0.5% ZnSO₄ + 300 ppm Salicylic acid), determined to be the best as it has given the highest results in vegetative parameters and control (T₁) given minimum in resulting in both the incremental plant height and incremental plant spread.

5.2 Yield parameters:

In term of chlorophyll content T₁₁, consisting of (40 ppm GA₃ + 0.5% ZnSO₄ + 300 ppm Salicylic acid), was given the best result and control (T₁) has given minimum result.

In term of return bloom, fruit retention, fruit drop T₉, which includes (30 ppm NAA + 0.5% ZnSO₄ + 300 ppm Salicylic acid), was the most efficient for reducing fruit drop and enhancing both, initial fruit set and fruit retention compared to control (T₁).

In term of yield and yield efficiency T₉, which includes (30 ppm NAA + 0.5% ZnSO₄ + 300 ppm Salicylic acid), was the most effective for increasing yield and yield efficiency.

Treatment T₁₁, which included a combination of 40 ppm GA₃, 0.5% ZnSO₄ and 300 ppm Salicylic acid, was identified as the most effective for enhancing the fruit weight, diameter, length, volume, and firmness, all of which reached their highest levels. In contrast, the control group (T₁) recorded the lowest measurements for these attributes.

5.3 Biochemical parameters

The highest concentrations of bio-chemical components in ber fruit including total soluble solids (°Brix), acidity (mg/100g), TSS: acid ratio, reducing sugars (%), non-reducing sugars, total sugars (%), ascorbic acid content (mg per 100g of pulp), total phenol content (mg/100g), Total carotenoids (mg/100g) and antioxidant content (% inhibition) were found best under treatment T₁₁, which consisted of GA₃ at 40 ppm, salicylic acid at 300 ppm, and ZnSO₄ at 0.5%. In contrast, the lowest levels of these components were observed in the control (T₁).

In term of leaf and fruit nutrient content T₁₁, consisting of (40 ppm GA₃ + 0.5% ZnSO₄ + 300 ppm Salicylic acid), was determined to be the most effective and control (T₁) given minimum result.

In term of proximate parameters like ash content, crude fibre content (%), total protein content (%), total moisture content (%), total fat content (%) T₁₁ consisting of (40 ppm GA₃ + 0.5% ZnSO₄ + 300 ppm Salicylic acid), was most effective than the control (T₁) which has given minimum results.

Leaf and fruit nutrients had positive and significant correlation with yield and quality parameters of fruit except fruit drop and acidity content which were negatively correlated.

CONCLUSION

The use of PGRs and ZnSO₄ through foliar methods is more effective than the control treatment. The results from the current study on 10-years-old ber plants indicate that treatment T₉, which includes (30 ppm NAA + 0.5% ZnSO₄ + 300 ppm Salicylic acid), was the most effective for reducing fruit drop and improving initial fruit set percentage, return bloom and fruit retention and this combination also found to be best for enhancing yield and yield efficiency. Meanwhile, T₁₁, (40 ppm GA₃ + 0.5% ZnSO₄ + 300 ppm Salicylic acid), was seen best for maximizing plant height, plant spread, chlorophyll content, leaf and fruit nutrient content, fruit quality parameters and all proximate parameters of ber. After evaluating the effects of all treatments on various parameters, it is concluded that both treatment T₉ and treatment T₁₁ were the most effective as compare to control.

The findings indicate that T₉ is notably superior to all other treatments in terms of controlling fruit drop and enhancing initial fruit set, return bloom, fruit retention

percentage, yield and yield efficiency. While T₁₁ excels in improving the vegetative parameters, bio chemical parameters like leaf and fruit nutrient status, chlorophyll content, all the quality parameters and all proximate parameters. These treatments are effective for commercial use, offering valuable benefits to researchers and farmers. The combined application of NAA, GA₃, salicylic acid, and ZnSO₄ significantly reduces fruit drop and enhances the yield and quality of ber fruits in Punjab.

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