STUDIES ON THE EFFECT OF AZOTOBACTER AND NANO MICRONUTRIENTS APPLICATION ON GROWTH, YIELD AND QUALITY OF KINNOW MANDARIN

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

In

Fruit Science

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PUNJAB, 2023

DECLARATION

I, hereby declared that the presented work in the thesis entitled **"Studies on the effect of *Azotobacter* and nano micronutrients application on growth, yield and quality of Kinnow mandarin"** in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of Dr. Manish Bakshi, working as Associate Professor, in the Department of Horticulture, School of Agriculture of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE-I

This is to certify that the work reported in the Ph. D. thesis entitled **"Studies on the effect of *Azotobacter* and nano micronutrients application on growth, yield and quality of Kinnow mandarin"** submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Horticulture, School of Agriculture, is a research work carried out by Mr. Rupinder Singh, 11919661, is bonafide record of his original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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CERTIFICATE-II

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Place: LPU, Phagwara (**Rupinder Singh**)

Date: (**Reg No. 11919661**)

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LIST OF ABBREVIATIONS

Abbreviations		Description
%	:	Percentage
@	:	at the rate
°C	:	Degree celcius
C.D.	:	Critical difference
CV	:	Co-efficient of Variation
cm	:	Centimeter
cm^2	:	centimeter square
DPPH	:	2,2-diphenylpicrylhydrazyl
et al.	:	et *alii* (Co-workers)
RBD	:	Randomized Block Design
Fig.	:	Figure
g or gm	:	Gram
ha	:	Hectare
i.e;	:	That is
kg	:	Kilogram
L.	:	Linneous
m	:	Meter
mg	:	Milligram
mg/g	:	milligram per gram
No.	:	Number
NS	:	Non-significant
ppm	:	Parts per million

SE(d)	:	Standard error deviation
SE(m)	:	Standard error mean
TSS	:	Total soluble solids
T	:	Tonne
Zn	:	Zinc
B	:	Boron
nZn	:	Nano Zinc
nB	:	Nano Boron
N	:	Nitrogen
P	:	Phosphorous
K	:	Potassium
Cu	:	Copper
RH	:	Relative Humidity

Title	:	Studies on the effect of *Azotobacter* and nano micronutrients application on growth, yield and quality of Kinnow mandarin
Name of Student	:	Rupinder Singh
Registration No.	:	11919661
Year of Admission	:	2020
Name of Research Guide and Designation	:	Dr. Manish Bakshi Associate Professor, School of Agriculture Lovely Professional University, Phagwara, Punjab

Abstract

The present research study entitled "Studies on the effect of *Azotobacter* and nano micronutrients application on growth, yield and quality of Kinnow mandarin" was carried out at Kinnow orchard of Lovely Professional University, Phagwara, Punjab, for the two consecutive years during 2021 and 2022. Nano Boron and Nano Zinc were applied to the Kinnow mandarin plants to study their effect on growth, yield and quality. A total of 12 treatment combinations were undertaken in the experiment with 3 replications. Among the vegetative parameters, maximum increase in plant height (5.41%), canopy volume (22.82%) was recorded under treatment T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)]. Maximum leaves perflush (178.79) were recorded under treatment T_6 [RDF + *Azotobacter* + nB (20 ppm) + nZn (200 ppm)]. Maximum fruit weight (153.73g), fruit length (5.84cm), fruit size (38.01 cm^2), weight of seeds (3.73g), peel weight (48.78g), juice content (57.83%), number of fruits per tree (542.36) and fruit yield (83.39 kg/plant) was recorded under treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)]. However, maximum fruit width was observed under treatment T_7 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)] and maximum pulp weight (105.01 g) was recorded under treatment T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)].

Among the quality parameters of Kinnow mandarin, maximum TSS (11.31 ^{o}Brix), titratable acidity (0.82%), ascorbic acid (26.07 mg/100 ml of juice), total sugars (5.95%), reducing sugars (2.83%), non-reducing sugars (3.12%), and minimum polyphenols (54.32) was recorded under treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

Leaf nutrient status of Kinnow mandarin leaves was also estimated for the various treatments undertaken in the experimentation. It was found that the boron and zinc have a

synergistic interaction with N, P, and K. Treatment T_8 recorded the maximum levels of nitrogen, phosphorous, boron, and zinc.

Economics of Kinnow mandarin cultivation for different treatments was worked out and highest cost benefit ratio 1:3.10 during year 2021 and 1:3.24 during year 2022 was recorded under treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

From the present investigation, vegetative parameters were found to be better with application of treatment T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)] as compared to other treatments. Treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] was found to be effective for improving the fruit quality and yield of Kinnow mandarin. Also, the cost benefit ratio was recorded maximum in T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] during 2021 and 2022. It can be concluded that for profitable Kinnow mandarin production, application of recommended dose of chemical fertilizers and *azotobacter* @100 g per plant conjugated with foliar application of nano boron @ 40 mg per plant and nano zinc 150 mg per plant is recommended.

Key words: Kinnow mandarin, *Azotobacter*, boron, zinc and nano-micronutrients.

Chapter 1

INTRODUCTION

Citrus, including oranges (*Citrus* × *sinensis* (L.) Osbeck), lemons (*C.* × *limon* (L.) Osbeck), limes (*C. aurantiifolia* (Christman.) Swingle), pummelos (*C. maxima* (Burm.) Merr.), grapefruits (*C.* × *paradisi* Macfad.), mandarins (*C. reticulata* Blanco), and other fruits, are among the most widely grown fruit crops on a global scale. Citrus is produced in sub-tropical, semi-tropical, and tropical regions around the world, with most commercial production between 20° and 40° latitude in the Northern and Southern hemispheres. Oranges represent the largest global harvested area, global production (in tons), and value, followed by mandarins, lemons/limes, and pummelos/grapefruits (Volk et al., 2023).

Citrus is globally recognized as a crucial fruit tree, with a total production of around 116 million tons (Shani et al., 2023). Citrus, guava, mango, litchi, pear, peach, and ber are the major fruit crops grown in Punjab, with Kinnow being the dominant citrus fruit. The total fruit production in Punjab in 2020-21 was 11,77,543 million tons from an area of 44,751 hectares. Average yield in kg/hectare is 26,313. The south-west belt in Punjab is ideal for Kinnow cultivation in sandy loam soils, with Fazilka (34018 hectares) and Hoshiarpur (1995 hectares) being the leading districts in Kinnow production (Anonymous, 2021).

Kinnow is an introduction from California and was first planted in Abohar, Punjab. Kinnow's success is attributed to its beautiful golden yellow color, abundant juice, excellent aroma, taste preferred by the Indian palate, and highly productive trees. Proper cultivation methods can yield higher returns from well-maintained Kinnow orchards than most other fruit crops (Anonymous, 2017).

It is important to note that the nutritional composition of kinnow fruit is not only limited to its sugar content. Kinnow is also a good source of vitamins and minerals. For instance, it is rich in vitamin C, containing up to 80-200 mg/100 g of juice (Lado et al., 2016). Additionally, kinnow fruit is a good source of dietary fiber, potassium, calcium, and folate (Shen et al., 2013; Ladaniya, 2011). The health benefits associated with kinnow consumption are numerous, including antioxidant properties, anti-inflammatory effects, and protection against various chronic diseases (Shen et al., 2013; Ladaniya, 2011). Overall, Kinnow is a highly nutritious and tasty fruit.

Kinnow juice has been found to possess several health benefits. The limonoids present in kinnow juice have been shown to have anti-cancer properties (Jayaprakasha et al., 2006; Lado et al., 2016). Flavonoids and phenolic compounds present in kinnow juice have been found to have antioxidant and anti-inflammatory properties, which could help in preventing or managing chronic diseases such as cardiovascular disease, diabetes, and cancer (Kamiloglu et al., 2021). Furthermore, the high ascorbic acid content of kinnow juice makes it effective in boosting the immune system and preventing scurvy (Lado et al., 2016). Kinnow juice has also been found to have potential as a natural preservative due to its antimicrobial properties (Kamel et al., 2022). Overall, the health benefits of kinnow juice make it a promising functional food that could contribute to the prevention and management of various health conditions.

Most of the Kinnow fruit in northwestern India is grown in the southwestern districts of Punjab. However, growers in this region often neglect micro-nutrient application and instead rely on macro nutrients such as N, P and K. This practice is complicated by the calcareous soil and high pH in the region, which limits the availability of micronutrients applied to the soil. As a result, Kinnow trees grown in this region often exhibit zinc, manganese, and iron deficiency, showing symptoms like curling of leaves, reduced young shoots growth and chlorosis (Sharma et al., 1990).

Micronutrients play role in growth of citrus trees and also in improving their yield and fruit quality. Agricultural scientists have highlighted the importance of micronutrients in correcting deficiencies that can hinder the growth of citrus trees. In recent years, there has been a growing realization of the importance of micronutrients in the agriculture sector. The adequate supply of micronutrients can help overcome deficiency symptoms and improve the overall health of citrus plants. Plant nutrients, including both macro and micronutrients, are important factors that affect profitable citrus production (Nandita et al., 2020).

Arid regions often suffer from nutrient deficiencies in their soils, which can limit plant growth and ultimately reduce fruit production. In particular, micronutrient availability can be limited due to the presence of calcium carbonate concretions in subsoil. Deficiency symptoms of micronutrients are common in orchards and can directly or indirectly impact fruit production. In such cases, foliar feeding of micronutrients can be an effective and convenient solution to save on chemical inputs and ensure nutrient availability for plants (Lazare et al., 2021).

Micronutrient application is recognized as a crucial plant and soil management practice for improving citrus productivity (Zoremtluangi et al., 2019). The availability of micronutrients at the proper time in reasonable quantities is essential for healthy growth and fruit production of citrus plants (Kumari, 2022). Citrus fruits grown on sandy, calcareous, shallow soils with high water table and previously uncultivated soils are highly depleted of micronutrients.

Zinc and boron are indeed important micronutrients for citrus cultivation in Punjab. Zinc is involved in various physiological and biochemical processes such as photosynthesis, hormone synthesis, and protein synthesis, while B is vital for cell wall formation, sugar transport, & hormone regulation in plants (Rohoma, 2020). Deficiencies of these micronutrients can lead to reduced growth, poor fruit quality, and other negative effects on plant health (Uthman et al., 2022). Therefore, adequate application of zinc and boron is important for optimal citrus growth and production in Punjab.

According to Ashraf et al. (2013), the quality of citrus fruits and yield can be improved with the zinc application. Zinc is also essential for various physiological and biochemical processes, such as photosynthesis, enzyme system activation, synthesis of protein and translocation of carbohydrate (Tsonev & Lidon, 2012). It can enhance the photochemical activity in the thylakoid apparatus, increase the electron transport through PSII, and improve the photosynthetic efficiency. Zinc is also crucial for chlorophyll and carotenoids, which are essential for the proper functioning of the -

photosynthetic mechanism. Application of Zn can increase the chlorophyll content and carotenoid synthesis, leading to improved yield and quality in crops (Razzaq et al., 2013).

Zinc is a part of various metabolic processes in plants, including starch metabolism, enzyme activities, carbon metabolism, photosynthetic activities, and chlorophyll production (Alloway, 2008). Zn is a component to synthesis of IAA precursor tryptophan required for plant growth (Alloway, 2008). Zinc deficiency can result in stunted growth, chlorosis, and reduced photosynthetic capacity in plants. Therefore, the application of zinc is important for maintaining healthy plant and improving crop yield.

Boron (B) is essential for various physiological processes in plants, including enzyme activities, protein synthesis, and the development of reproductive structures such as pollen tubes and grains, which ultimately leads to improved fruit setting and yield (Marschner, 2011). The lack of B can result in reduction of growth in young fruits, roots, and shoots due to its role in cell division, which leads to growth retardation. In citrus, B deficiency is the most noticable deficiency (Papadakis et al., 2003).

Application of boron (B) can enhance the fruit setting in plants and improve yield by facilitating pollen tube germination and elongation (Abd-Allah, 2006). Boron plays role in promoting growth and flowering in tomatoes. Moreover, the application of both Zn and B has been found to significantly improve fruit yield, quality, juice content, TSS, vitamin C, and sugars (Asad et al., 2003).

Biofertilizers refer to living microorganisms that multiply in rhizosphere or plant interior, promoting growth of plants by making the availability of minerals for plants (Das, 2019). Unlike chemical fertilizers, which directly add nutrients to the soil, biofertilizers contain symbiotic or non-symbiotic microorganisms that stimulate plant growth and enhance soil fertility in a more sustainable way.

In agriculture, the chemical fertilizers application has been shown to improve yields, however it also leads to soil and environmental pollution, as well as depletion of essential nutrients (Mitter et al., 2021). On the other hand, biofertilizers can enhance plant resistance to diseases, stimulate the production of phytohormones and water-soluble vitamins, and increase plant growth rates.

Studies have shown that the use of biofertilizers can lead to significant improvements in crop yields and soil health. For instance, Kumar et al. (2001) found that the application of biofertilizers to rice crops led to a 25% increase in grain yield, while Sumbul et al. (2020) reported biofertilizers application increased the nutrient content of crops and also resulted in improving the soil fertility.

The *Azotobacter* genus was first discovered by the Dutch microbiologist and botanist Beijerinck, 1901, who is considered the founder of environmental microbiology. Among different species of *azotobacter*, *Azotobacter chroococcum* is the most commonly found species and was the first aerobic free-living nitrogen fixer reported by Beijerinck et al. (1901).

Azotobacter is a Gram-negative bacterium that exhibits polymorphism. The young cells possess peritrichous flagella for locomotion, while old cells develop encapsulated forms that are more resistant to heat, desiccation, and adverse conditions. The cysts germinate under favourable conditions to give rise to vegetative cells. Additionally, *Azotobacter* spp. can produce polysaccharides. However, they are sensitive to low pH, high salts, and temperatures above 35°C.

Azotobacter spp. are free-living bacteria that grow well on nitrogen-free media. These bacteria rely on atmospheric nitrogen for protein synthesis, which is then mineralized in the soil after their death, thereby contributing towards nitrogen availability for crop plants.

Azotobacter spp. are non-symbiotic, heterotrophic bacteria that can fix up to 20 kg N/ha/per year (Kizilkaya, 2009). These bacteria are commonly found in the rhizosphere and phyllosphere of plants and are effective in improving soil fertility and crop productivity. They fix nitrogen directly from the atmosphere, which helps plants produce better grains. *Azotobacter* also plays an important part in the nitrogen cycle.

In addition to nitrogen fixation, *Azotobacter* also produces growth hormones such as thiamine, riboflavin, nicotine, indole acetic acid, and gibberellins. It synthesizes biologically active substances, including phytohormones like auxins, ethylene, cytokinins, and gibberellins, which stimulate plant growth. *Azotobacter* inoculation has been observed to improve seed germination, vigor of young plants, and other growth parameters (Mishustin and Naumova, 1962; Shende et al., 1984; Bagal et al., 1985).

Nanotechnology is an emerging technology that has found applications in various fields, including agriculture. Nanoparticles have been utilized in industries, medicine, and engineering, and their potential in agriculture is being explored (Biswas and Wu, 2005). Using nanotechnology in crop production has been shown to enhance growth and yield. Nano-fertilizers have been developed as an alternative to traditional fertilizers, which can release nutrients gradually and in a controlled manner (Tripathi et al., 2018). These nano-fertilizers can provide nutrients to the plants, leading to improved growth and yield, or enhance the performance of conventional fertilizers (Naderi and Danesh, 2013; Liu and Lal, 2015). Additionally, nanoparticles have higher reactivity and absorption capacity, which can benefit plant growth and development. Nanotechnology has the potential to design more soluble and diffusible sources of zinc fertilizers to increase plant productivity (Adhikari et al., 2015).

Nanoparticles (NPs) are aggregates of molecules with a size range of 1-100 nm, which alters their physico-chemical properties compared to bulk materials (Tarafdar et al., 2014). At the nanoscale, matter displays unique properties that differ significantly from those observed at the macroscopic level, resulting from reduced molecular size and changed interactions between molecules. Nanotechnology offers high reactivity, enhanced bioavailability and bioactivity, adherence effects, and surface effects of nanoparticles, which hold great promise for revolutionizing agriculture. The properties and possibilities of nanotechnology are rooted in the arrangement of atoms, enabling the production of customized manufactured products (De Volder et al., 2013).

Nanofertilizers that are encapsulated are utilized to improve fertilizer formulations for better absorption in plant cells and to reduce nutrient loss. The encapsulation of nanofertilizers is done in three ways, which include the following: 1) nutrients can be enclosed inside nanoporous materials, 2) they can be coated with thin polymer films, or 3) they can be delivered as particles or emulsions of nanoparticles (Rai and Ingle 2012). Furthermore, surface-modified nanomaterials such as nanocomposites consisting of macronutrients (N, P, K) and micronutrients have been shown to prevent undesirable nutrient losses to soil, water, and air during their uptake by tomato plants through direct internalization by crops and avoiding the interaction of nutrients with soil, microorganisms, water, and air (Misra et al., 2016).

Horticultural applications of nanofertilizers have been found to increase vegetative growth, pollination, and fertility of flowers, resulting in enhanced yield and improved product quality for fruit trees (Zagzog et al., 2017; Zahedi et al., 2020). For instance, exogenous supplementation of nano-Ca to blueberries under saline stress conditions has been found to increase vegetative growth and chlorophyll in leaf (Sabir et al., 2014). Similarly, nano-boron and nano-zinc applications to mango trees have shown positive effects on the overall yield and chemical properties of fruits, which may be attributed to the enhancement of chlorophyll and essential nutrient element contents in the leaves, such as nitrogen, phosphorus, potassium, manganese, magnesium, boron, zinc, and iron (Abdelaziz et al., 2019; Zagzog et al., 2017; Zahedi et al., 2020). In addition, application of nano-boron and nano-zinc fertilizers resulted in improving quality of fruit, increase the number of fruits, total soluble sugars (TSS) and maturity index, and concentrations of total sugars and total phenols in pomegranates (Davarpanah et al., 2016).

Objectives

Following are the objectives for the research work entitled **'Studies on the effect of azotobacter and nano micronutrients application on growth, yield and quality of Kinnow mandarin'** are:

1. To study the effect of *azotobacter* and nano-micronutrients on growth, yield and quality of Kinnow mandarin.

2. To study the effect of *azotobacter* and nano-micronutrients on leaf nutrient status in Kinnow mandarin
3. To workout the economics of Kinnow mandarin cultivation under different treatments.

Chapter 2

REVIEW OF LITERATURE

This section presents comprehensive detail of the studies conducted on the application of *Azotobacter* and nano micro nutrients in Kinnow mandarin. The review is organized under the following headings:

I. STUDIES ON GROWTH, YIELD AND QUALITY OF KINNOW MANDARIN

II. STUDIES ON LEAF NUTRIENT STATUS IN KINNOW MANDARIN

III. ECONOMICS FOR KINNOW MANDARIN CULTIVATION

2.1 STUDIES ON GROWTH, YIELD AND QUALITY OF KINNOW MANDARIN

Saini et al. (2021) performed an investigation to find out difference in utilization of nano & conventional zinc fertilizer in strawberries. The researchers examined various parameters for vegetative growth and yield throughout the duration of the study. Notably, when nano-Zn was applied through foliar application at a rate of 200 ppm, the strawberries exhibited enhanced vegetative growth characteristics, earlier flowering, increased fruit set, and higher yield. Additionally, foliar application of nano Zn @ 200 ppm resulted in a reduced number of days required for flowering, an extended flowering duration, and increased no. of flowers in strawberries. Application of nano zinc oxide @ 200 ppm also led to an increase in height of plant, leaves number, leaf area, no. of crowns, and no. of runners in strawberry cv. Sweet Charlie.

Elsheery et al. (2020) performed a study to examine how nano Zn and nano Si impact the various parameters of mango trees in saline conditions. Researchers applied foliar sprays containing different concentrations of nano zinc (50, 100, and 150 ppm) and nano silicon (150 and 300 ppm) to the plants. Among the various treatments, the combination of 100 pmm nano Zn and 150 ppm nano Si was determined to be the most effective in enhancing the mango tree's resistance to salinity, promoting an optimal annual crop load, and improving the quality of the fruits grown under saline conditions.

Rossi et al. (2019) validated that the Zn content in leaves treated with ZnO NPs was higher in comparison to plants treated with ZnSO4, as observed during application of ZnSO4 and nano Zn in *Coffea arabica* plants, specifically in the cvs. Anacafe 14 and Nemaya cultivars. Foliar sprays of 10 mg/L of zinc sulphate monohydrate and zinc oxide nanoparticles were administered to the coffee plants, and superior outcomes were observed with zinc oxide nanoparticles in terms of the fresh and dry weight of roots and leaves. The findings suggest that the utilization of nano Zn could be advantageous for coffee production systems, particularly in regions where Zn deficiency is prevalent, as it has the potential to enhance fruit set and improve overall fruit quality.

Pippal et al. (2019) claimed that application of zinc, boron, and magnesium through foliar made improvements in various yield attributing traits of guava. Yield reached 75.04 kg plant-1, 71.94 kg plant-1, and 74.9 kg plant-1, respectively, compared to 46.75 kg plant-1 in the control. Additionally, the application of Zn (0.75%), B (0.3%), and Mg (0.60%) led to the maximum number of fruits plant-1 (682.05, 648.82, and 681.53, respectively), surpassing the control count of 458.48. Furthermore, the maximum fruit diameter was reported as 7.07 cm, 6.85 cm, and 7.07 cm in the Zn (0.75%), B (0.3%), and Mg (0.60%) treatments, respectively, compared to 5.83 cm in the control.

El-Hak et al. (2019) examined the impact of nano zinc applied at concentrations of 0.4 ppm, 0.8 ppm, and 1.2 ppm on Flame Seedless grapes. The highest bunch weight was observed when nano zinc was applied at a concentration of 0.4 ppm on the grape plants. A reduced number of leaves were recorded in plants of Flame Seedless grapes that were supplemented with nano Zn@1.2ppm. Application of 0.4 ppm of nano-zinc resulted in increased leaf area and fresh weight, while @1.2 ppm significantly elevated total carbohydrate content, leaf concentration of Fe, cluster number, and cluster weight. Furthermore, the data indicated that nano-zinc at concentrations of 0.4 ppm, 0.8 ppm, and 1.2 ppm significantly increased the yield in comparison with traditional fertilizers.

Sourabh et al. (2018) conducted a study on guava cv. Hisar Surkha to investigate the effects of various treatments of biofertilizers and organic fertilizers. The research findings demonstrated that various treatments made significant increase in both the height and the no. of branches. Vermicompost and Farm Yard Manure (FYM) were utilized either alone or in combination with biofertilizers at three recommended dose of fertilizer (RDF) levels, namely 50%, 75%, and 100%. The combination of *Azotobacter* + PSB with 100% RDF + Vermicompost exhibited the highest values for plant height, flowers per branch, fruit set, no. of fruits, average size of fruit, and the yield. Moreover, this particular treatment also showed a significant reduction in fruit drop.

Carlesso et al. (2018) explored the impact of nano zinc on strawberries. Nano ZnO was applied at both 50% and 100% of the recommended dose. Surprisingly, the application of nanoparticles at 100% of the recommended dose exhibited greater effectiveness compared to zinc oxide in its conventional form, particularly in enhancing the soluble solids values. The researchers observed a remarkable increase in the total soluble solids (TSS) content when nano zinc was applied at a concentration of 0.01%, in contrast to the effects of ZnO in strawberry cv. San Andreas.

Zagzog and Gad (2017), in their investigation, the impact of nano zinc at concentrations of 0.5 g/L and 1 g/L on Mango plants was studied. Notably, foliar application of nano zinc at 1 g/L in mango cv. Ewasy showed increase in leaf length & higher number of flower panicles. Furthermore, the application of nano zinc at both 0.5 g/L and 1 g/L resulted in the highest weight of fruit and highest yield in mango. These findings highlight potential of nano zinc for promoting growth and enhancing fruit production in Mango plants.

Mohamed et al. (2017) documented a prominent rise in sugars (total and reducing) and also in the TSS content in addition to an increased number of flowers in date palm cv. Zaghloul through the application of nano zinc at a concentration of 10 ppm. Similarly, the utilization of nano zinc (10 ppm) resulted in increased fruit weight, length, breadth, improved fruit set, and a higher number of fruits. These findings showcase the potential of nano zinc at 10 ppm to enhance both the physiological and yield-related attributes of date palm.

Kumar et al. (2017) showcased nano zinc application at a concentration of 150 ppm, combined with iron oxide nanoparticles (NPs) at the same concentration, in strawberry cv. Chandler, yielded remarkable results. This treatment exhibited the highest benefit ratio and positively influenced various yield-related traits, including the duration to first flowering and first harvesting, fruits, wt. of fruit, fruit diameter, & fruit yield/plant. Additionally, the supplementation of zinc oxide nanoparticles (NPs) at 150 ppm led to increase in height of plant, no. of leaves, petiole length, weight of fruit, fruit diameter, and maximum fruit number. These findings highlight that NPs Zn at 150 ppm to significantly enhance growth and productivity of strawberry.

Kumar et al. (2017) showcased foliar application containing nitrogen, potassium, Zn on flowers & yield of guava cv. Taiwan Pink. Notably, the plants treated with nitrogen exhibited prominent outcomes, including the maximum no. of flowers/shoot (7.20), per cent fruit set (74.88%), no. of fruits/shoot (3.82), fruit yield (16.20 kg per plant), fruit retention, and reducing fruit drop. Additionally, nitrogen-treated plants displayed superior fruit characteristics, such as highest fruit volume, size and weight. These findings underscore the significant influence of nitrogen application on enhancing both flowers & yield related attributes of guava cv. Taiwan Pink.

Chander et al. (2017) documented a significant increase in guava yield (kg/tree) through the supplementation of boron, zinc, and urea in two varieties examined, surpassing the control group. The highest yields were observed in var. Lalit (17.78 kg/tree), (18.92 kg/tree), (19.59 kg/tree) and var. Shweta (16.55 kg/tree), (17.73 kg/tree), (18.32 kg/tree) with treatments boron and zinc @ 0.6 per cent each, and urea applied at conc. of 1% respectively. Conversely, lower retention of the fruits was observed in the control group. Notably, application of boron, zinc, and urea significantly increased the retention of fruits in both guava varieties studied. The highest fruit retention percentages were recorded in variety Lalit recording 61.76, 62.25, 62.51 and in var. Shweta 59.70, 60.15, 60.50 with treatments boron and zinc @ 0.6 per cent each, and urea applied at conc. of 1%, respectively, while the control group exhibited the lowest fruit retention.

Maurya et al. (2016) presented findings indicating a substantial improvement in fruit characteristics and yield in aonla cv. NA-6 through the synergistic application of calcium nitrate, potassium sulphate, and $ZnSO_4$. Notably, this combined treatment (Ca+Zn+K) led to increased fruit volume, measuring 41.4 cm^3, as well as enhanced fruit weight, measuring 44.3 g. Moreover, a remarkable yield of 61.8 kg/tree was observed, indicating the positive response combined sprays of these specific nutrients on productivity and quality of aonla.

Gurung et al. (2016) conducted research on Darjeeling Mandarin and examined the effects of foliar application of micronutrients and growth regulators. They found GA_3 (15 ppm) + Zn (0.5%) + boron (0.1%) resulted in significant improvements across various performance parameters. Notably, this treatment led to increased plant height (3.82 m), trunk girth (33.95 cm), canopy area (455.31 m2), shoot length (4.51 cm), flowering intensity (83.89), and fruit set (21.31%), while also reducing the incidence of fruit drop (23.66%). Additionally, the fruits from this treatment exhibited superior physical and chemical attributes, including increased fruit weight (66.24 g), segment number (10.33), juice content (33.83%), TSS (10.36 °B), total sugars (10.15%), reducing sugar (4.11%), ascorbic acid (29.94 mg/100 gram), and lower value of titrable acidity (0.66%) in mandarins. These results highlight the positive impact of the specific combination of GA_3, and secondary nutrients on various parameters Darjeeling mandarin.

Davarpanah et al. (2016) studied the impact of nano B and nano Zn on yield traits and quality parameters of Pomegranate. The spray of nano B & nano Zn, particularly at higher doses, resulted in significant enhancements in fruit quality. Notably, there were increases in total soluble solids (TSS), decreases in titratable acidity, increases in the maturity index, and pH of juice. However, the physical characteristics of the fruit remained unaffected. Furthermore, zinc nanoparticles at

120 mg/L resulted in an increased the fruits and yield, while foliar application of zinc NPs at 636 mg/tree led to higher total soluble sugars (TSS) and reduced fruit acidity. Additionally, a foliar spray of zinc nano fertilizers prior to full bloom at a rate of 5.3 l/tree resulted in an increased number of flowers in Pomegranate cv. Ardestani. These findings demonstrate the potential of nano B and nano Zn applications improve the quality traits and yield of Pomegranate.

Bhoyar and Ramdevputra (2016) conducted a study on impact of application of micronutrients through foliar mode on the number of fruits per shoot. They found that the application of specific micronutrient combinations made positive impact on fruit production. Maximum fruits/shoot (3.6) was recorded by application of 0.5% Zn sulphate, 0.5% ferrous sulphate, and 0.3% borax. In contrast, the lowest fruit drop percentage (53.6%) was recorded in treatment which included 0.5% ferrous sulphate and 0.3% borax. These findings highlight the importance of micronutrient foliar sprays in optimizing fruit yield and reducing the count for fruit drop.

Balaji et al. (2016) made a study on banana cv. Poovan, focusing on micronutrient application. Yield per hectare showed a increase in the high-density plant population, which was accompanied by higher plant height, increased leaf count and improved flowering rate. These positive effects were observed using foliar sprays containing zinc at a concentration of 0.5% and boron at a concentration of 0.1%. The benefits were seen by the application of micro nutrients on growth and yield of banana plants, especially in planting density, height, flowers and leaves no.

Singh et al. (2015) discovered that application of Zn @ 0.4% through foliar mode after fruit set stage on mango had a positive impact on fruit retention rate, no. of fruits per shoot, and reduced fruit drop. The Zn application at the specified concentration resulted in an increased fruit retention rate of 10.27%, an increased number of fruits per shoot (7.60), and a significantly reduced fruit drop rate of 89.73%. These findings highlight the effectiveness of foliar application of $ZnSO_4$ in promoting fruit retention and reducing fruit drop in mango trees.

A study was conducted by Singh et al. (2015) on strawberries to examine response of various treatments on crop growth and yield. Combination of vermicompost @10 tons/ha + *Azotobacter* applied at rate of 7 kg/ha + PSB at rate of 6 kilogram/ha + AM @5 kilogram/ha gave the highest strawberry yield, with an average yield of 311, 26g/plant. In contrast, the control plot had the lowest yield, averaging 136.59g/plant. Application of Vermicompost @10 tons/ha + *Azotobacter* at rate of 7 kilogram per ha + PSB at rate of 6 kilogram per ha + AM at rate of 5 kilogram per ha also resulted in significant improvements in tree height, canopy width, leaves no. and area of leaf per strawberry plant.

Khan et al. (2015) discovered that calcium, boron and zinc application @3.0%, 0.6% and0.6%, respectively, during the fruit set had significant effects on various fruit characteristics in Kinnow mandarin. This treatment was observed with highest diameter of fruit, weight, volume and fruits.

Gurjar et al. (2015) reached the conclusion that applying zinc and boron through foliar application on Kinnow mandarin, using a combination of 0.2% boric acid and zinc sulphate 0.5%, resulted in highest retention of fruit and the lowest fruit drop rates when compared to the control group. Furthermore, the treated group exhibited the highest fruit volume, diameter and fruit number/plant in comparison to the control group.

According to Gurjar et al. (2015), the application of a combination of $ZnSO_4$, $FeSO_4$, and borax through foliar spray made a noteworthy impact on the flowering characteristics of alphanso mango. This treatment exhibited the shortest duration to achieve 50% flowering, taking only 19.67 days, and resulted in an increased length of the panicles, measuring 40.33 cm.

According to a research conducted by Goswami et al. (2015), applying a combination of half the recommended fertilizer dose (225 g N_2O: 195 g P_2O_5: 150 g K_2O) and FYM @ 50 kg inoculated with *Azospirillum/*tree per year @ 250 g proved to be effective treatment in enhancing quality parameters of fruit such as TSS, vitamin C, percentage of total sugars, TSS/acid ratio, and pectin. These positive effects were observed consistently during both the rainy and winter seasons in guava.

Research conducted by Chandra and Singh in 2015, application of zinc, magnesium, and copper at a concentration of 0.5% resulted in significant improvements in various fruit quality parameters. This treatment led to increased fruit weight (32.5 g), pulp-to-stone ratio (19.70), and total yield (59.7 kg/tree). Additionally, higher levels of TSS, vitamin C, sugars (total, reducing and non-reducing) were observed. Furthermore, the treatment was associated with a lower titrable acidity level.

According to Yadav et al. (2014), $ZnSO_4$ and H_3BO_3 @0.4% each, and iron sulphate at rate of 0.2% had significant effects on various parameters in pomegranate cv. Sindhuri. The treatment resulted in increased plant height (11.52%), spread in the North-South direction (7.93%), fruit set (54.17%), fruits/plant (23.67), and leaf chlorophyll content (0.62 mg/g). Furthermore, the treatment with zinc sulphate and H_3BO_3@0.4% each made a maximum spread in East-West direction (7.83%) and total canopy volume (29.91%). Additionally, the application of $ZnSO_4$, boric acid, and iron sulphate with conc. of 0.4% each led to increased fruit weight, fruit volume, number of arils per fruit, and yield (5 kg/plant) in pomegranate.

Based on the research conducted by Venu et al. (2014), the micronutrients application had a significant impact on Acid lime (cv. Kagzi lime) in terms of flowering, fruiting, and yield. The findings demonstrated application of $FeSO_4$ (0.4%), $ZnSO_4$ (0.5%), and Borax (0.4%) resulted in various positive outcomes. These included an increased number of flowers (22.37), higher fruit set, greater number fruits/shoot (8.53), a higher fruits/plant (925), reduced fruit drop incidence (24.33%), increased fruit volume (29.67 ml), weight (42.67 g), length (4.80 cm), girth (13.20 cm), and enhanced fruit yield (27.07 kg per plant and 74.97 kg per hectare) in Acid lime.

During the years 2008-2010, Tripathi et al. (2014) performed an investigation to evaluate the effectiveness of *Azotobacter* and PSB individually & in combination on various parameters of strawberry. Researchers observed that PSB and the *Azotobacter* had a significant impact on various growth parameters of strawberry compared to the control group. Specifically, the combined treatment led to increased plant height, greater no. of leaves, an increased no. of crowns, and a higher number of runners in strawberry plants.

Nidhika and Thakur (2014) investigated effect of integrated practices of nutrients on plum (cv. Santa Rosa). They reported that 75% NPK (nitrogen-phosphorus-potassium) + biofertilizers @60 g per plant and green manuring (Sun hemp seeds at a rate of 25 g/tree basin) resulted in the shoot extension, plant height, and volume of tree in plum plants.

Srivastava et al. (2014) conducted comprehensive fertilizers experiment to evaluate the effects on various parameters of papaya (cv. CO-7). Among the treatments, the combination of FYM (farmyard manure) + 100% NPK (nitrogen-phosphorus-potassium) + *Azotobacter* + PSB (phosphate-solubilizing bacteria) resulted in the highest plant height, diameter of plant, and no. of leaves. Interestingly, FYM + NPK (100%) + *Azospirillum* + PSB showed comparable results. Additionally, these treatments significantly reduced the time taken to reach 1st flower, the tree height at which the 1st flower appeared, and the days taken to reach the maturity. Moreover, they also enhanced various fruit characteristics, including the highest fruit length, width, weight, fruits, yield/plant, and shelf life of the fruits. The increased level of TSS, ascorbic acid, and sugars, was also observed while acidity levels were minimized.

In their 2014 study, Sharma et al. studied effect of INM on various parameters of custard apple cv. Arka Sahan. The researchers reported that among various treatments involving different nutrient sources had a significant positive effect on growth traits of the plant. Particularly, RDF 50%, combined with vermicompost (50% of nitrogen) and *Azotobacter* + PSB @50 g each and VAM at rate of 20 g, yielded the most favorable results across all plant parameters. The parameters included height of plant, width of the rootstock, width of scion, plant spread, and no. of primary branches/plant.

A study by Rajkumar et al. (2014) on application of Zn & B @ 1 per cent each through foliar mode, made a significant impact on quality traits like TSS, sugars, pectin content, and vitamin C were observed with the maximum combined dose of

Zincn andBoron. These secondary nutrients reduced titratable acidity. It also had a significant impact on increased fruit volume (117.75 cm^3), fruit weight (148.75 g), higher fruit yield (135.10 kg/plant), fruit set, retention of fruit (72.55%) and less fruit drop (27.45%) in guava cv. Prabhat pants.

Meena et al. (2014) observed the Ca, B & Zn at conc. of 0.6%, 0.4%, and 0.8% spray on 6 years old Anola plants cv. NA-7 recorded the maximum of fruit retention, volume, length and diameter of fruit. Combined spray of calcium, boron, and zinc made a higher contribution in sugars, juice content, vitamin C and TSS. A combined spray of these nutrients reduced maximum plant height (0.95 m), canopy height (0.93 m), and east-west crown spread (0.89 m), north-south direction (0.86m), fruit drop reduction (32.60%), maximum fruit retention (67.40%), fruit length (4.2cm), diameter (4.46cm^2), fruit weight increase (45.2g), fruit thickness (1.41 cm), total yield (42.70 kg/tree), but with qualities such as reduced acidity, maximum TSS, ascorbic acid and juice content, was found to be significant using calcium nitrate+borax+zinc sulphate.

Kazemi (2014) studied the strawberry's reproductive development, yield, and quality parameters in response to calcium, zinc sulphate, and iron. Three concentrations of $ZnSO_4$, three concentrations of iron, two concentrations of calcium (5 and 10 mM), and distilled water served as treatments. The results showed that the fruits treated with zinc sulphate at 150 mg/L had the highest levels of TSS, titratable acidity, and vitamin C, while the control had the lowest.

Jat and Laxmidas (2014) observed that the zinc and urea fertilizers application on the leaves of guava (*Psidium guajaua*) recorded with the highest retained fruits, fruit weight, and maximum fruits/tree compared with 1.5 percent of urea and 0.6 percent of zinc were observed superior in most parameters compared to the other treatments.

Gurjar and Rana (2014) conducted a study to examine the impact of applying nutrients and growth regulators to Kinnow mandarin trees via foliar application. The results of their research unveiled findings regarding fruit drop, yield, fruit size, and quality. Remarkably, it was observed that the lowest fruit drop rate, measuring at

53.5%, was achieved through the application of $ZnSO_4$ (0.5%) in combination with 2,4-D.

In a study, Goswami et al. (2014) investigated the impact of different concentrations of calcium nitrate, boric acid, and zinc sulphate on guava cv. L-49. The researchers observed that applying 0.4% zinc through the leaves resulted in the highest levels of total soluble solids (TSS), vitamin C, reducing sugars, and total sugars, while also minimizing acidity.

In an investigation Gaur et al. (2014) found, application of nutrients and GA_3 through foliar mode made a positive impact on guava fruit in terms of yield and quality. Study disclosed that 0.4% borax resulted in the highest total soluble solids (TSS) value, measuring at 11.7 °Brix, was achieved with minimal acidity at 0.30%. Additionally, the foliar application of Borax at a concentration of 0.4% resulted in higher total sugar content and the highest vitamin C content in fruits of guava.

Dutta et al. (2014) investigated biofertilizers impact on the physical-chemical parameters of guava. Researchers examined various treatments and found that the combination of *Azospirillum*, *Azotobacter*, and VAM (vesicular arbuscular mycorrhiza) was the most effective in enhancing fruit quality. Following closely, the treatment involving *Azotobacter* and VAM also showed positive effects. Notably, the *Azospirillum*, *Azotobacter*, and VAM treatment resulted in the highest content of leaf minerals, including NPK.

Yadav et al. (2013) to investigate impact of foliar spray treatments involving boron, zinc, and iron, as well as their combinations, on the growth pattern and yield attributes of the low chilling peach variety, cv. Sharabati. The researchers utilized nutrients like B, Zn, and Fe. Results revealed significant improvements in various fruit-related parameters. These included increased fruit retention (74.14%), enhanced diameter, volume, length and firmness of fruit, as well as higher average fruit weight and fruit yield for the peach plants cv. Sharabati.

Waskela et al. (2013) examined impact of application of $ZnSO_4$ through foliar mode at various concentrations on guava fruits. The researchers found that applying zinc sulphate at a rate of 0.75% resulted in significant improvements in multiple fruit-related parameters. Notably, this treatment led to increase in fruit wt., length, width, no. of fruits/plant, weight, yield/plant, and yield/hectare. Moreover, this treatment outperformed other levels of zinc sulphate as well as the control group. The second most effective concentration was observed at 0.50% of $ZnSO_4$.

Verma and Rao (2013) recorded the superior growth parameters in strawberry plants when treated with a combination of *Azotobacter,* PSB (phosphate-solubilizing bacteria), vermicompost, and 50% RDF of NPK. The researchers observed the maximum plant height, leaf area and also the plant spread under this combined treatment. These findings indicate the beneficial effects of utilizing *Azotobacter*, PSB, vermicompost, and a reduced amount of NPK fertilizer in promoting the growth and development of strawberry plants. The plants subjected to these treatments exhibited increased yield/plant, marketable yield/plant, and yield/hectare.

Umar et al. (2013) reached the conclusion that full dose of nitrogen, combined with *Azotobacter*, had significant impact on the growth of strawberry plants. This treatment led to the production of the highest number of leaves (20.88) and crowns (3.15). These findings highlight the effectiveness of utilizing a combination of nitrogen and *Azotobacter* in promoting the vegetative development of strawberry plants, resulting in increased leaf formation and crown development.

Singh et al. (2013) examined impact of INM on the qualitative attributes of papaya cv. Madhubindu. The researchers found that the applying ½ RDF in combination with *Azotobacter* at a rate of 50 g per plant and PSB (phosphate-solubilizing bacteria) at a rate of 2.5 g per square meter resulted in the highest levels of sugars and TSS.

A study by Singh and Varu (2013) conducted on effect of INM on papaya cv. Madhubindu. The results concluded that the ½ RDF (N:P:K 100:100:125 gram per plant) combined with the 50 gram of *Azotobacter* per plant and PSB (phosphate-solubilizing bacteria) at a rate of 2.5 g per square meter positively influenced various growth and yield parameters. Notably, this treatment exhibited the highest survival %, height of plant, width of stem during flowering stage and also during the harvesting stage. Leaves number was highest during the harvesting stage, days taken to reach the 1st flowering and 1st harvest of fruit, fruit length, width, weight, fruits, and yield. Furthermore, the same treatment also resulted in the highest levels of qualitative parameters such as TSS and sugars. In contrast, control group displayed poor performance across all evaluated parameters.

Sharma et al. (2013) reached the conclusion that the utilization of a specific fertilization approach had a significant impact on the physico-chemical and chemical attributes of guava. Specifically, applying 25% of nitrogen per tree through FYM (farmyard manure) combined with 75% of nitrogen/plant through inorganic fertilizers resulted in a notable improvement in the physico-chemical characteristics of guava. On the other hand, *Azotobacter*+50% of nitrogen/plant through FYM and 50% of nitrogen/plant through inorganic fertilizer exhibited the highest levels of quality parameters.

Razzaq et al. (2013) conducted a research to assess impact of foliar applications of Zn on the productivity, growth, and quality of fruit of Kinnow mandarin. The results indicated that trees treated with 0.6% zinc sulphate exhibited notable improvements in various parameters. These included increased fruit length (71.60 mm), fruit width (83.74 mm), peel content (32.50%), and rag content (26.05%). Furthermore, the treatment resulted in increased fruit weight (194.50 g), juice content (39.60%), and total yield (59.60 kg per tree). In terms of tree growth, the application of zinc sulphate led to enhanced plant height (43.50 cm), crown width (40.00 cm), and trunk diameter (4.31 cm) in 'Kinnow' mandarin trees. These findings highlight the positive impact of zinc on growth, and physio-chemical traits of fruits of Kinnow.

Rakesh et al. (2013) showcased application of a combination of zinc, borax, NAA, and GA_3 on guava cv. Chittidar exhibited the most favorable outcomes in terms of various quality parameters. These included increased levels of sugars (total, reducing, and non-reducing), and TSS, TSS:acid & the lowest titrable acidity in the fruit. Additionally, this treatment yielded positive results in terms of plant and yield parameters. It resulted in improved yield and chemical parameters. Furthermore, the treatment contributed to a reduction in fruit drop and seed percentage.

Study by Obaid et al. (2013) of Mn and Zn on the various tratis of pomegranate through foliar application. The results demonstrated that the application of Zn @3.00% combined with Mn @60 mg/L resulted in several positive outcomes. These included an increase in fruit set by 50.55%, a reduction in fruit cracking by 15.60%, an increase in yield to 26.77 kg per tree, and an enhancement in TSS (total soluble solids) to 13.77% in pomegranate cv. Salemey. These findings highlight the potential of the specific foliar application combination for improving productivity and quality attributes of pomegranate.

Meena et al. (2013) studied impact of different treatment combinations on guava plants. Results revealed that combination involving 2/3rd quantity of RDF (500:200:500 g NPK), along with the application of FYM at rate of 25 kg per tree, *Azospirillum* and *Azotobacter* at rate of 250 g each on plant, had significant positive effects. This treatment resulted in an increased fruits/plant, and enhanced yield on a pooled basis. Furthermore, it was found that this treatment also positively influenced the soil dehydrogenase activity, indicating an improvement condition of soil heath.

Lata et al. (2013) evaluated nutrient sources impact on vegetative traits on strawberry plants. Findings indicated that application of a specific treatment, comprising *Azotobacter* (50% @ 25 ml in 20 liters of water), *Azospirillum* (50% @ 25 ml in 20 liters of water), NPK (50% @ 45:37.2:30 kg/ha), FYM @ 50 t/ha, and DAP, had a significant influence on various growth parameters.

Kumar et al. (2013) conducted biofertilizers study on growth, fruit quality, & yield of pear cv. Gola. Various doses of *Azotobacter*, VAM, and PSB were applied. The findings demonstrated that the application of *Azotobacter* at a rate of 30 g resulted in improved vegetative growth of the trees, increased fruit yield, and enhanced physical quality of the fruits. Furthermore, incorporating 90 g of VAM into the soil significantly enhanced the chemical qualities of the fruits. Notably, the treatment with 60 g of *Azotobacter* proved to be particularly effective in enhancing the phosphorus content in the leaves. These results highlight the potential benefits of using biofertilizers to improve the growth, quality, and yield of pear trees.

Kumar et al. (2013) derived the conclusion that application of a combination of zinc, borax, and ferrous at rate of 0.6 percent each through foliar mode exhibited the most favorable results in terms of enhancing multiple fruit characteristics in guava cv. Chittidar. The treatment demonstrated significant improvements in fruit weight, volume, pulp thickness, fruit length, diameter, and fruit wt., while concurrently reducing the seed %, seed-to-pulp ratio, and no. of fruits/tree. These beneficial effects ultimately resulted in an increased yield per tree.

Godage et al. (2013) studied chemical and bio-fertilizers effect on flowering, growth, yield, and quality of guava. The results revealed that the 75% nitrogen, 75% phosphorus, 100% potassium oxide, *Azotobacter* (5 ml/plant), and PSB exhibited significant improvements in various parameters. This treatment resulted in the maximum tree height (3.80 m), excellent retention of fruit (92.96%), diameter of fruit (10.07 cm), increased weight of fruit (215.06 g), and higher weight of pulp (193.44 g). Furthermore, it also led to a greater fruit no. (144.33), enhanced yield of fruits per tree and fruits per hectare, and extended shelf life of the fruit (12.50 days).

Obaid et al. (2013) conducted a resaerch to explore the impact of Mn and Zn foliar sprays on pomegranate cv. Salemy. Zn solutions at three different levels: 0%, 1.5%, and 3% were applied to plants. The findings revealed that the treatment consisting of 60 mg/l manganese combined with 3% zinc demonstrated notable effects. This treatment resulted in the maximum chlorophyll, improved fruit set, and weight of fruit during the initial and 2^{nd} season.

Balesini et al. (2013) examined impact of different nutrient factors on fruit set, yield, and quality of apples. Findings demonstrated that the various treatments exerted distinct effects on yield and chemical traits of fruits. Notably, treatments incorporating B and Zn exhibited pronounced influence on fruit set compared to other treatments.

According to Bakshi et al. (2013), the application of 0.6% ZnSO4 to strawberry cv. Chandler plants resulted in significant outcomes. The treated plants exhibited the highest total soluble solids (TSS) content at 8.31^0B, highest amount of ascorbic acid. Additionally, the TSS:acid was notably elevated at 11.70, while the acidity level was the lowest at 0.716%.

Ashraf et al. (2013), found that 2,4-D, and salicylic acid @10 ppm each along with, K, and Zn @0.25% each through foliar mode resulted in significant enhancements in various fruit parameters of kinnow. The treated fruits exhibited a notable increase in juice %, TSS, vitamin C, and a decrease in titrable acidity. Furthermore, the TSS/acid ratio was substantially higher in the treated fruits.

Singh et al. (2012) findings revealed that vermicompost application @ 5 t/ha along with *Azotobacter*, *Azospirillum*, and PSB, in combination with NPK, yielded the highest levels of total soluble solids (TSS) at 10.34 ^{o}Brix and total sugars at 7.80% in strawberry fruits. The highest plant height and berry weight of strawberry was recorded under 100% NPK treatment followed by 50% NP (40: 8.8 kg/ha) + 100% K (33.2 kg/ha) + *Azotobacter* + PSB + AMF.

According to Singh et al. (2012), Zn application through $ZnSO_4$ at conc. of 0.6% demonstrated significant efficacy in promoting various fruit parameters of aonla cv. Banarasi. The treated fruits exhibited enhanced fruit weight, with an average of 48.64 g, as well as increased pulp weight at 46.46%. Additionally, the total yield per tree was notably improved, reaching 174.13 kg.

Sheikh and Manjula (2012) applied boric acid at a concentration of 0.2% yielded notable outcomes in terms of total yield, with an average of 34.05 kg per plant. This treatment demonstrated a substantial reduction in fruit cracking incidence, which was observed at 3.33%. However, when considering individual fruit weight, concentration of boric acid (0.4%) resulted in greater fruit weight.

Sarrwy et al. (2012) evaluated impact of foliar treatments involving B and Ca on fruit quality & yield of date palm. The results revealed that all treatments led to a significant increase in fruit length during the two seasons under study, compared to the control group. The highest fruit length, measuring 4 cm and 4.1 cm, was achieved by spraying a mixture of 500 ppm boric acid and 2% calcium nitrate. This was followed by a combination of 250 ppm boric acid with 2% calcium nitrate, resulting in fruit lengths of 3.9 cm and 4.03 cm in 1^{st} and 2^{nd} seasons. In contrast, control group exhibited lower fruit length, measuring 3.1 cm and 3.17 cm in the respective growing seasons.

Sajid et al. (2012) findings indicated that application of Zn and B had a substantial positive effect on the fruit juice, TSS, vitamin C, and non-reducing sugar levels of sweet orange fruits. Notably, the TSS, fruit juice, and vitamin C was recorded more when fruit was sprayed with concentration of Zn @1% and a low concentration of boron @0.02%.

Pandey et al. (2012) findings revealed that combination of $ZnSO_4$ @0.5% and H_3BO_3 @0.2% demonstrated significant efficacy in various fruit parameters. The treated fruits exhibited notable increases in fruit length (98.95 mm), fruit diameter (90.89 mm), fruit weight (349.92 g), fruit set (22.23%), fruit yield (13.92 kg per tree), juice content (75.81%), TSS (16.93%), TSS:acid (44.55), and a decrease in titrable acidity (0.38%).

Nitin et al. (2012) demonstrated that $ZnSO_4$ at conc. of 0.6 per cent and H_3BO_3 at conc. of 0.5% on guava, both before & after fruit set, yielded remarkable results in various fruit parameters. The treated fruits exhibited maximum fruit radial diameter at 7.52 cm, higher fruit weight at 162.01 g, increased fruit yield at 46.41 kg per tree, polar diameter at 7.91 cm, higher fruit volume at 195.27 cc, and specific gravity at 1.024 g/cc.

Modi et al. (2012) conducted an investigation to find micronutrients impact on growth, quality & yield of papaya cv. Madhu Bindu. The findings demonstrated that the individual application of $ZnSO_4$ at a concentration of 0.5% and borax at a concentration of 0.3% had significant effects on height of plant, width of stem, no. of leaves, and the initiation of flower buds, resulting in a shorter time from fruit setting to first harvest. Furthermore, $ZnSO_4$ at a concentration of 0.5% and borax at a concentration of 0.5% yielded the highest weight of fruit, no. of fruits, and overall yield in papaya. In terms of quality, the different levels of $ZnSO_4$ and borax significantly influenced various quality parameters of papaya fruits, including ascorbic acid content, TSS, sugars content.

Mir et al. (2012) findings indicated application of nutrients Zn, Mn, and B exhibited superiority in terms of biochemical characteristics, specifically TSS (15.85 °B), total sugars (9.78%), vitamin C (13.48 mg/100ml), and anthocyanin content (20.36 mg/100ml) in pomegranate fruits.

Study by Khan et al. (2012) revealed that sprays of H_3BO_3 at conc. 0.3 per cent and $ZnSO_4$ at conc. 0.5 per cent yielded significant improvements in various parameters of Feutrell's early mandarin trees. The treated trees exhibited increased tree height at 43.80 cm and stem girth at 4.82 cm. Additionally, the fruits showed increased fruit length at 53.34 mm, diameter at 64.57 mm, and fruit weight at 145.30 g. Moreover, the leaf size was notably larger at 318 cm^2 in the treated trees.

Research conducted by Hasani et al. (2012) on impact of Zn on fruit yield and chemical traits of pomegranate. Zn applications were carried out twice, utilizing concentrations of 0%, 0.3%, and 0.6%. The effects of zinc were found to be significant in parameters such as juice content, total soluble solids, ratio of TSS/TA, and leaf area. Most suitable combination for these characteristics, given the prevailing conditions, was the spray of Zn at rate of 0.3%. Moreover, foliar spray of manganese and zinc demonstrated positive and significant effects on various fruit-related attributes, including fruit yield (8.1 kg/tree), weight of 100 arils (33.5 g), fruit diameter (8.20 cm), leaf area (592.4 mm^2), arils per peel ratio (1.88%), TSS (15.73 °B), juice content of arils (68.2%), and anthocyanin index (0.328).

Gupta and Tripathi (2012) conducted trials from 2009 to 2011 to investigate the application of biofertilizers on strawberry plants. The results showed that *Azotobacter* @7kg/ha & vermicompost@30tonnes/ha had significant effects on various characteristics. The treated plants exhibited maximum berry length, width, weight, volume at 6.12 cc and 5.82 cc, total soluble solids (TSS) at 10.31 ^{o}Brix and 9.29 ^{o}Brix, total sugars at 9.73% and 8.74%, and ascorbic acid content at 56.52 mg/100gpulp and 54.53 mg/100gpulp, with minimum titratable acidity at 0.52% and 0.47%, respectively. Application of *Azotobacter* and vermicompost on the quality and growth of strawberry plants, compared to untreated plants.

Goswami et al. (2012) conducted a study on effect of calcium nitrate, boric acid, and zinc sulphate through foliar application on guava cv. Sardar. The treatments were sprayed twice, 45 and 25 days before the harvest. The results showed that among the different doses, zinc sulphate @0.6 per cent yielded the maximum fruit length at 6.18 cm, diameter at 5.46 cm, and fruit volume at 120.28 cc.

Goswami et al. (2012) studied the impact of calcium, B, and Zn on the physical and chemical traits and storage behaviour of guava fruits cv. L-49. The findings revealed that the foliar spray of zinc sulphate at a concentration of 0.4% resulted in the maximum fruit length, diameter, and volume. However, the maximum weight of fruit was observed when boric acid @0.4 per cent was applied. These results highlight the importance of these treatments in influencing the physical characteristics of guava fruits, providing valuable insights for fruit quality improvement and storage considerations.

Goswami et al. (2012) conducted a research from 2007 to 2009 to investigate the impact of biofertilizers enriched in farmyard manure along with ½ RDF on 5 year old plants of guava cv. Pant Parbhat. The study aimed to assess the growth parameters of the plants under different treatments. The researchers found plants grown with a combination of recommended dose of fertilizers (NPK 250:195:150 gram) and FYM @50 kg enriched with *Azospirillum* @250 g/tree per year exhibited the highest increase in various growth parameters. Specifically, during the 2007-08 and 2008-09 seasons, this treatment resulted in the maximum increase in height of tree, tree spread, diameter of trunk, and volume of plant.

Godage (2012) conducted a study to find impact of various nutrient combinations and biofertilizer applications on various parameters of guava fruit. The researcher observed significant effects on different aspects of guava fruit quality and yield under different treatments. The treatment consisting of NPK 100:75:100, *Azotobacter* and PSB each at 5 ml per plant found to increase the TSS of guava fruits. On the other hand, the treatment with NPK 75:75:100, *Azotobacter* and PSB each at conc. of 5 ml per plant exhibited significant improvements in the no. of fruits, yield, retention, diameter, weight, and pulp wt. Additionally, the treatment with NPK

75:75:100, *Azotobacter* and PSB each at rate of 5 ml per plant resulted in highest height of plant, width of the primary branch, plant spread. These findings highlight the significance of nutrient combinations and biofertilizer applications in enhancing guava fruit quality, yield, and tree growth parameters, providing valuable insights for optimizing guava cultivation practices.

Research carried by Devi et al. (2012) on 4-year-old guava trees of the Sardar variety. The study aimed to assess the effects of different organic sources (FYM, neem cake and vermicompost) and various combinations of biofertilizers (*Azotobacter*, PSB, *Azospirillum*, and Potash mobilizers) on guava fruit production. The results revealed that the treatment combining poultry manure, PSB, and Potash mobilizers resulted in the maximum fruit yield/plant, with an average of 623.3 fruits. Additionally, the combination of FYM, *Azotobacter,* PSB, and Potash mobilizers led to increased fruit weight. Based on these findings, it can be concluded that organic cultivation of guava by applying FYM @26 kg per tree with the *Azotobacter* @100 gm per plant, PSB @100 gm per plant, and Potash mobilizers @100 gm per plant is economically profitable. This research provides valuable insights into the use of organic sources and biofertilizers for maximizing guava fruit production, promoting sustainable and economically viable cultivation practices for guava farmers.

Arvind et al. (2012) outbased response of potassium, boron, calcium & zinc on fruits of mango. It was found that trees sprayed borax @0.5percent showed maximum fruit yield, TSS, sugars and vitamin C in mango. Other quality traits like sugar and ascorbic acid content were best maintained by borax, calcium and potassium treatments. The findings indicated that the application of 0.5% borax through foliar spray resulted in the highest fruit yield in mango trees. Additionally, borax treatment exhibited significant improvements in sugars, TSS and vitamin C in mango fruits. Moreover, the treatments involving borax, calcium, and potassium were found to be effective in maintaining sugar and ascorbic acid levels, contributing to overall fruit quality and fruit yield.

Anees et al. (2012) experimented impact of micronutrients: iron, boron, and zinc on mango trees of the Desehri variety. The study aimed to assess the effects of

$FeSO_4$, H_3BO_3, and $ZnSO_4$ applied at 2 different stages. Findings of the study indicated that applied treatments resulted in reduced fruit acidity in comparison to the control group. Furthermore, treatments demonstrated a significant increase in TSS and vitamin C in mango fruits compared to the control group. These research results highlight the positive response of secondary nutrient application, specifically Fe, B, and Zn, on the quality of Desehri mangoes. The treatments effectively reduced fruit acidity and enhanced important attributes such as TSS and vitamin C content.

Abd El-Rhman and Shadia (2012) investigated the impact of varying concentrations of urea and zinc on yield and physio-chemical traits of ber. The researchers observed significant increases in fruit weight, volume, diameter, and yield when urea was applied at a concentration of 2.0% in combination with zinc sulphate at a concentration of 0.6%.

Yadav et al. (2011) discovered that when utilizing recommended combination of NPK fertilizers, vermicompost, *Azotobacter*, phosphate-solubilizing bacteria (PSB), zinc (Zn), iron (Fe), and paclobutrazol on mango cv. Amrapali, significant improvements were observed in various parameters. The researchers noted a higher fruits per plant, increased yield, elevated total soluble solids (TSS) levels, improved TSS:acid, enhanced vitamin C, higher carotenoid levels, augmented reducing sugars, non-reducing sugars content, elevated total sugar content, and reduced acidity. In terms of physical fruit characteristics, the recommended treatment resulted in a greater fruit set per panicle, longer fruit length, wider fruit width, higher fruit weight, increased pulp weight, heavier stone weight, and improved pulp:stone. These observations were consistent over the course of both years of experimentation.

Shukla (2011) investigated influence of Ca and B on the growth and quality of Aonla. The application of calcium carbonate along with borax at a concentration of 0.4% resulted in the highest yield recorded (158.6 kg/tree), whereas the control group yielded the lowest (105.2 kg/tree). Additionally, the combination of calcium carbonate and borax at 0.4% led to the high juice in fruits (78.5%) and vitamin C (626.49 mg/100g). Furthermore, the fruits treated with calcium carbonate and borax at

0.4% exhibited larger sizes and slightly higher total soluble solids (TSS) levels (16.5%) at the time of harvest compared to the fruits in the control group (15.1%).

Pathak et al. (2011) studied application of $FeSO_4$ @0.5% + $ZnSO_4$ @0.5% at 3rd, 5th, and 7th month after planting had notable effects on various parameters in banana cv. Martaman. This combination showed improvements in quality parameters such as sugar to acid ratio (47.70), non-reducing sugar content (10.04%), and minimum titratable acidity (0.36%). However, when FeSO4 (0.5%) was applied alone, significant improvements were observed in total soluble solids (25.53°B), reducing sugar content (6.57%), and total sugar content (17.24%) of the fruits.

Baviskar (2011) performed a research on sapota plants during the year 2010-2011. Effects of various treatments on fruit yield and quality were studied. Among the various treatments tested, the trees treated with NPK 1125:750:375 g along with vermicompost @15kg, *Azotobacter* @250g, and PSB (phosphate-solubilizing bacteria) @250 g per plant displayed the highest yield in terms of both harvested fruits/tree & the overall weight of fruit (kg/plant). Additionally, this particular treatment also resulted in superior fruit quality, as indicated by higher levels of TSS and sugars accompanied by low titrable acidity. Moreover, plants treated with this specific combination exhibited maximum fruit set, retention percentage, weight, volume, size as well as peel and pulp weight compared to the other treatments.

Barne (2011) conducted an experimental study on guava during the period of 2010-11. The aim was to find the impact of different treatments on various parameters of guava plants. The application of NPK (nitrogen, phosphorus, and potassium) with of FYM (50kg), 250g of *Azotobacter*, and 250 g of PSB (phosphate-solubilizing bacteria) per plant recorded highest fruit set and a significant reduction in fruit drop percentage. Additionally, this treatment led to increase in plant height, spread, & volume (measured in cubic meters). The same treatment also resulted in the more fruits and yield. Moreover, the fruits treated with this specific combination exhibited higher TSS, total sugar content, and lower acidity levels compared to control group.

Research conducted by Anees et al. (2011) made an observation on iron, boron and zinc on mango fruit cv. Dashehari. The results indicated that this particular treatment resulted in the highest levels of total soluble solids (TSS) at 27.90°Brix, ascorbic acid content at 150.3 mg/100ml, reducing sugar at 19.92%, non-reducing sugar at 8.83%, total sugar at 49.92%, and the lowest acidity level at 0.178%. These findings were in comparison to the control group, suggesting the application of 0.4% iron, 0.8% boron and 0.8% zinc had positive impact on the quality attributes of mango.

Singh et al. (2010) examined the impact of varying levels of B and Zn & combined effect on the yield of papaya cv. Ranchi. The application of 0.50% borax combined with 0.25% Zn was determined to be the most effective treatment. This particular treatment resulted in the highest fruit yield of 37.20 kg per plant and exhibited elevated levels of TSS, sugars, vitamin C, beta carotene, & high TSS:acid in papaya compared to the other treatments.

A study by Chandra et al. (2010) on impact of secondary nutrients on yield and growth traits of Washington cv. of papaya was experimented. Research findings revealed that a combination of copper sulphate manganese sulphate and borax exerted a significant influence on various growth parameters. These parameters included plant height, plant girth, fruit length, fruit width, fruits, yield (40.40kg/tree), total sugar content (9.72%), vitamin C content (58.32 mg/100 g), and TSS at 9.60°Brix. Application of this specific combination of micronutrients played a vital role in enhancing the growth and yield characteristics of papaya plants, along with improving the nutritional composition of the fruits.

Rawat et al. (2010) applied the foliar application of Zn, Cu, and B at different concentrations (0.2%, 0.3%, and 0.4%) both individually and in various combinations. The results indicated that application of zinc @0.4% had a significant impact on several parameters. It notably improved the total soluble solids (TSS) at 11.78°Brix, total sugar content at 6.36%, sugar-acid ratio at 15.91, and seed weight at 2.02 mg. On the other hand, the application of boron (0.4%) demonstrated notable effects on vitamin C content, which increased to 137.56 mg/100 g pulp, and pectin content, which increased to 1.65%, in the L-49 guava fruits. These findings highlight the specific benefits associated with the foliar application of zinc and boron, respectively, in enhancing the quality and nutritional composition of guava fruits.

As per Pilania et al. (2010), the application of NPK combined with vermicompost @5kg mixed with the *Azotobacter* and *Aspergillus* found to be beneficial on guava plants. It was observed that this treatment led to maximum leaf area, measuring 57.19 cm^2, as well as the highest fruit set at 45.79% and fruit retention at 44.76%. Additionally, when 75% pruning intensity was applied along with 50 g NPK, 20 g NPK, and 50 g NPK combined with vermicompost enriched with *Azotobacter+Aspergillus*, the guava fruits exhibited the largest diameter. Furthermore, this treatment resulted in increased fruit weight at 158.06 g, pulp weight at 154.19 g, and pulp seed ratio at 39.93. Notably, the highest fruit yield and when NPK 50:20:50 g were combined with vermicompost @5 kg enriched with *Azotobacter* and *Aspergillus niger*, accompanied by a 50% pruning intensity. These findings highlight the effectiveness of this particular combination in promoting the growth and productivity of guava during the period 2007-08.

According to Patel et al. (2010), their study aimed to investigate the impact of secondary nutrients on banana. The findings revealed that the Zn application @0.5 per cent combined with Fe @0.5 per cent through foliar spraying resulted in several positive outcomes. The treatment showed significant improvements in various parameters, including maximum bunch weight at 23.85 kg, increased bunch length measuring 93.50 cm, and greater bunch girth reaching 114 cm. Additionally, this treatment led to a higher number of hands per bunch, averaging at 11.70, and an increased total yield of 149.078 tonnes per hectare for the Basrai banana cultivar. Notably, the Zn and Fe each applied at rate of 0.5 per cent also effectively enhanced the ascorbic acid content in the fruit, which reached 25 mg per 100 g of pulp. Furthermore, the treatment resulted in an elevated level of total soluble solids, measuring 22.03 °B, in the banana fruits. These findings highlight the positive effect of foliar feeding with micronutrients on the growth, yield, and nutritional quality of the Basrai banana variety.

In their 2010 study, Mitra et al. examined how various organic substances, inorganic fertilizers, and biofertilizers influenced the fruit quality & yield of guava cv. Sardar. They concluded that application of NPK 50:40:50 gm/tree/year + neem cake @5 kg/tree/year, resulted in the highest and yield.

Lal et al. (2010) had done application of micronutrients on litchi which resulted in enhanced fruit yield and quality parameters such as TSS, vitamin C, total sugars, & juice percentage. Among the micronutrients tested, 1.0% borax resulted in the highest improvement in these quality attributes. Additionally, the treatment with 400 ppm SADH led to the highest percentage of edible fruits and the lowest percentage of non-edible fruits. Furthermore, trees that were sprayed with 1.5% potassium nitrate and 2.0% calcium nitrate exhibited the maximum weight of fruit, measuring 20.41 g and 20.37 g, respectively.

Dayal et al. (2010) investigated the impact of N, P, and Zn on the ber cultivar 'Gola' in arid and semi-arid conditions. The results indicated, Zn when applied at 0.6 percent recorded in the highest measurements for fruit length (3.13 cm), diameter of fruit (3.18 cm), fruit wt. (21.55 g), fruit volume (20.67 ml), and yield (38.05 kg/tree). Conversely, the control group exhibited the lowest values for these parameters.

Abdollahi et al. (2010) noted rise in the vitamin C content in strawberries from 111.9 mg per 100 g in the control group to 123.3 mg per 100 g in the fruits treated with $ZnSO_4$ at a concentration of 200 mg per liter.

Mitra et al. (2010) discovered that employing a combination of nutrients and organic matter resulted in the highest fruit setting on 'Sardar' guava trees under a HDP. Specifically, they applied 50 grams of nitrogen (N), 40 grams of phosphorus (P_2O_5), and 50 grams of potassium (K_2O) per plant/year, along with FYM @10 kilograms and *Azotobacter* @20 kilograms per tree/year.

Khan et al. (2009) concluded that $ZnSO_4$ and Thiourea proved to be highly effective in improving various growth and yield parameters in the aonla cultivar 'Narendra Aonla-6'. This treatment resulted in increased height of plant (6.5 cm), spread of plant (6.8 cm), and trunk girth (7.22 cm). Moreover, it led to maximum fruit retention (26.07%), as well as longer length of fruit (4.1 cm) and greater breadth of fruit (4.54 cm). The combined spray also enhanced fruit yield (46.54 kg/tree) and improved quality attributes, such as higher total soluble solids (TSS) content (12.7°B), increased ascorbic acid levels (680 mg/100 g pulp), elevated phenolic content (168.4), higher sugars content (5.97%), and lower titratable acidity (1.75%). Furthermore, $ZnSO_4$ (0.5%) specifically resulted in high initial fruit set (75.05%) in the 'Narendra Aonla-6' cultivar.

Ghosh et al. (2009) found that $ZnSO_4$ @0.5% resulted in increased fruit weight (31.3 g), higher pulp content (95.2%), elevated TSS (8.4°B), greater total sugar content (4.9%), and enhanced vitamin C levels (540 mg/100 g) in the study. Additionally, the application of borax at 0.4% significantly improved the total yield (36.2 kg/plant). The study found a positive impact of $ZnSO_4$ on fruit quality attributes, while borax application had a significant effect on total yield.

Dutta et al. (2008) examined bio-fertilizers impact on papaya cv. Ranchi. Various treatments investigated, the combination of *Azotobacter*, *Azospirillum*, vesicular-arbuscular mycorrhizae (VAM), and 2 kg of farmyard manure (FYM) exhibited the highest plant height, width, and no. of fruits. The treatment consisting of *Azotobacter*, VAM, and 2 kg FYM also showed favorable growth characteristics. In contrast, the control group exhibited the least growth parameters. Furthermore, the treatment with *Azotobacter*, *Azospirillum*, VAM, and 2 kg FYM resulted in the highest fruit weight. The application of bio-fertilizers also influenced the bio-chemical constituents of the papaya fruit. The treatment with *Azotobacter*, *Azospirillum*, VAM, and 2 kg FYM recorded the highest levels of TSS, total sugars, and beta-carotene content, while exhibiting the lowest acidity.

Singh et al. (2008) observed zinc @0.5%, copper @0.4%, and NAA @10 ppm resulted in the highest measurements of plant height, spread, and plant width in the Narendra Aonla-10 cultivar.

Jeyabaskaran and Pandey (2008) documented that the spray of zinc and boron through foliar mode yielded more favourable results in terms of increasing pseudostem girth (101 cm), total leaf count (35), leaf length (132.2 cm), and overall leaf area (14.6 m2) compared to the application of Zn and B through soil under high pH conditions.

Chauhan (2008) conducted an experiment where plum plants were treated with 80% of the RDF of NPK along with the supplementation of vermicompost @20 kilogram/tree. Additionally, biofertilizers consisting of 60 grams per tree each of VAM and *Azotobacter* were used. The results demonstrated increase in shoot extension growth and leaf area compared to other treatments.

In the study by Wassel et al. (2007) investigated micronutrients and growth regulators impact on various parameters of cv. white banaty seedless grapes. Zn, Fe, and Mn led to significant improvements in various growth parameters. These included enhanced leaf area, increased cane thickness, higher pruning weight, heavier berry weight, and longer bunch length.

Singh et al. (2007) discovered that application of a mixture containing zinc (0.5%), copper (0.4%), and NAA @10 ppm resulted in maximum fruit weight, pulp weight, and yield in the 'Narendra Aonla 10' variety of aonla. Additionally, this treatment combination significantly improved various quality attributes of the fruit, including reduced acidity, increased TSS, elevated levels of vitamin C, reducing sugars, non-reducing sugars, total sugars, total phenols, juice content, and fiber content.

In study by Medhi et al. (2007) found that ½ the recommended amount of NP, along with 20 grams of *Azotobacter* and 20 grams of PSB per plant/year, in addition to K at rate of 600grams/plant and 7.5 kg of mustard oil cake, led to significantly higher levels of TSS, total sugar, and vitamin C in citrus crops. Moreover, this treatment combination resulted in the highest yield and economic return (5.75).

Saraswat et al. (2006) evaluated the effects of NAA (naphthalene acetic acid) and zinc sulphate on various aspects of litchi cv. Calcuttia, including fruit set, fruit drop, cracking, fruit size, and yield. The findings clearly demonstrated that the treatment combination of NAA at a concentration of 20 parts per million (ppm) and

$ZnSO_4$ at conc. of 0.6% resulted in highest no. of inflorescences/tree (414.00), fruit set/panicle (238.00), and fruit retention (7.43%).

2.2 STUDIES ON LEAF NUTRIENT STATUS IN KINNOW MANDARIN

Saini et al. (2021) performed study to compare effects of nano & conventional zinc fertilizers on strawberry plants. The researchers aimed to observe the differences between these two types of zinc fertilizers. The results showed that spraying of nano-Zn fertilizer resulted in the maximum recorded levels of leaf nitrogen, leaf phosphorus, leaf potassium, fruit nitrogen, fruit phosphorus and fruit potassium compared to other zinc analogues. Additionally, the study found a direct correlation between zinc content and nano-Zn fertilization in both leaf and fruit samples. This suggests that the use of nano-Zn fertilizers can effectively increase the zinc content in strawberries, promoting improved nutrient levels in both leaves and fruits.

Rossi et al. (2019) conducted a study on *Coffea arabica* plants, on cvs. Anacafe 14 and Nemaya cultivars, to compare impact of $ZnSO_4$ and zinc oxide nanoparticles on zinc content. The researchers found that leaves treated with ZnO NPs had higher levels of zinc compared to plants treated with ZnSO4. Application of nano Zn resulted better in fresh and dry weight of roots & leaves. These findings suggest that the use of nano Zn could be beneficial for coffee production systems, particularly in areas where zinc deficiency is prevalent, as it can enhance fruit set and improve overall fruit quality.

El-Hak et al. (2019) examined impacts of nano Zn at concentrations of 0.4 ppm, 0.8 ppm, and 1.2 ppm on Flame Seedless grapes. The study revealed that the application of nano zinc at a concentration of 0.4 ppm led to an increase in leaf zinc content in Flame Seedless grapes.

Zagzog et al. (2017) observed impact of nano Zn @ 0.5 and 1 g/L on increase of leaf mineral content in mango cultivars Ewasy and Zebda. The application of nano zinc treatments resulted in a significant increase in leaf mineral content compared to the control treatment. Conversely, the interaction between cultivar types and nano zinc treatments did not showed a significant impact on leaf minerals.

Dutta et al. (2014) investigated the biofertilizers impact on the physicochemical qualities and leaf mineral composition of guava cultivar L-4. Researchers compared different treatments and found that the combination of *Azospirillum*, *Azotobacter*, and VAM (vesicular-arbuscular mycorrhiza) was particularly effective in enhancing the fruit quality. Following closely was the treatment of *Azotobacter* and VAM, which also showed positive effects on fruit quality improvement. Furthermore, the treatment with *Azospirillum*, *Azotobacter*, and VAM resulted in the highest content of leaf minerals, specifically nitrogen, phosphorus, and potassium. These findings suggest that the application of the biofertilizers combination, *Azospirillum*, *Azotobacter*, and VAM, holds promise for enhancing the production of high-quality guava fruits.

In their study, Kumar et al. (2013) evaluated the impact of biofertilizers on the development, quality, and production of Gola pears was studied. Azotobacter, vesicular-arbuscular mycorrhiza, and phosphate-solubilizing bacteria (PSB) were tested in a range of concentrations. The results of the investigation showed that using Azotobacter @ 60 grams effectively improved the phosphorus content in the leaves.

According to Sharma et al. (2013) findings, the treatments combining *Azotobacter* inoculation with 25 per cent of nitrogen provided through farmyard manure and nitrogen 75% supplied through urea resulted in the maximum leaf nitrogen content of 1.76% and phosphorous content of 0.26%. Similarly, the treatments also exhibited the highest leaf calcium content of 2.01% and magnesium content of 0.86%.

As per study conducted on apricot by Singh et al. (2012), biofertilizers application+vermicompost+cow urine and 50% of RDF of NPK chemical fertilizers resulted in significant improvements in the total contents of macro and micro nutrients in leaves compared to traditional orchard practices.

According to Shashi et al. (2011) ¾ of the recommended application of NPK fertilizer, along of farmyard manure (FYM) @100 kg and the inclusion of *Azotobacter*, *Azospirillum*, and PSB, resulted in the highest levels of available nitrogen (N) and phosphorus (P) in the soil during both years. Additionally, the leaf contents of N, P, K, and Cu were also highest when 3/4th of the NPK fertilizer was used in combination with *Azotobacter*, *Azospirillum*, and PSB. On the other hand, the highest leaf contents of zinc (Zn) and boron (B) were observed when 1/2 of the NPK rates were applied in combination with *Azotobacter*, *Azospirillum*, and PSB.

According to the research by Sharma et al. (2011) on bio-organic nutrient sources and their impact on crop performance, soil characteristics, and chemical traits of apricot fruits, it was observed 50 kg of vermicompost per plant, 60 g of biofertilizers/tree, cow urine at a concentration of 12.5% in water, and vermiwash at a concentration of 12.5% in water resulted in the highest content of NPK in the leaves. The leaf nitrogen content was recorded as 2.64%, leaf phosphorus content as 0.34%, and leaf potassium content as 3.71%.

As per the Dutta et al. (2010), that highest nitrogen content and potassium content in leaves was achieved by applying farmyard manure (FYM)@50kg/tree, along with 150g*Azotobacter*, 100gvesicular arbuscular mycorrhiza (VAM), and a combination of NPK 500:250:500 g.

2.3 ECONOMICS FOR KINNOW MANDARIN CULTIVATION

As per Mitra et al. (2012), applying neem cake with *Azotobacter* observed with significant rise in yield and achieved the highest B:C ratio of 3.18 in guava cultivar 'Sardar' within HDP system in West Bengal, India.

According to the findings of Godage (2012), the application of NPK @75:75:100 along with *Azotobacter* at a rate of 5 ml per tree, and phosphorus-solubilizing bacteria (PSB) at a rate of 5 ml/tree in guava cultivar Allahabad Safeda recorded highest net realization and the highest CBR of 1:8.99.

Devi et al. (2012) on four-year-old guava trees of the Sardar cultivar, various organic sources including farmyard manure (FYM) at a rate of 10 kg per plant, vermicompost at 19 kg per plant, and neem cake at 9 kg per plant were tested. Additionally, different combinations of biofertilizers, namely *Azotobacter*, *Azospirillum*, phosphorus-solubilizing bacteria (PSB), and potash mobilizers, each applied at a rate of 100 grams per plant, were investigated. The results revealed that the organic cultivation of guava cv. 'Sardar' using a combination of FYM@26kg per tree, *Azotobacter*@100grams per tree, PSB@100grams per tree, and potash mobilizers @100 grams per tree proved to be economically profitable.

In 2012, Devi et al. found that applying FYM at a rate of 26 kg per tree per year, along with Azotobacter at 100g per treeperyear, phosphorussolubilizers at 100 g per tree peryear, and potashmobilizers at 100g pertree peryear in two separate intervals (January and August), proved to be a beneficial and economically viable treatment for promotinggrowth, fruiting, andyield of guava.

As per findings of Pilania et al. (2010), the highest fruit yield in guava was achieved through the application of a specific combination of nutrients and cultural practices. By using 50 grams of nitrogen (N), 20 grams of phosphorus (P), and 50 grams of potassium (K) along with 5 kilograms of vermicompost enriched with *Azotobacter* and *Aspergillus niger*, combined with a 50% pruning intensity, the researchers observed the highest fruit yield during the 2007-08 season. This treatment resulted in a significant fruit yield increase, showcasing its effectiveness in enhancing guava production. Furthermore, same treatment exhibited the maximum benefit-to-cost (B:C) ratio of 4.33. The high B:C ratio underscores the potential profitability of adopting these practices in guava orchards.

As per the findings of Shukla et al. (2009), applying 50% RDF of NPK combined with farmyard manure (FYM) @50 kg and *Azotobacter* @250 g had significant positive impact on the fruit yield of 8 yearold guavaplants, specifically the Sardar cultivar, grown under HDP conditions. The treatment resulted in a substantial increase in fruit yield, reaching 28.95 kg per plant. Moreover, it also led to a higher benefit-cost (B:C) ratio of 2.53:1, indicating a favorable economic outcome for guava cultivation. These results highlight the effectiveness of utilizing a combination of NPK, FYM, and *Azotobacter* in optimizing fruit production and profitability in guava orchards planted with high-density techniques.

Chapter 3

Materials and Methodology

The present studies were conducted at the Kinnow orchard situated within the premises of Lovely Professional University, Phagwara, Distt. Kapurthala, Punjab, during the period from 2021 to 2022. Details of this chapter employed in the research are elaborated in this section. This chapter consists of brief description of the experimental site's geographical coordinates, atmospheric conditions featuring meteorological records, soil properties, experimental framework, and various practices, categorized under the subsequent subheadings.

3.1 EXPERIMENTAL SITE DESCRIPTION

3.1.1 Location of Experimental site:

Research trial was executed at the Kinnow orchard, situated within premises of Lovely Professional University, Phagwara, Kapurthala district, during the period from year 2020 to 2021. The orchard's geographical coordinates are 31º22'31.81" North latitude and 75º23'03.02" East long., with an average elevation 252 meters above MSL. Orchard is positioned in Punjab, approximately 350 kilometers away from Delhi, the capital city of India. Moreover, it falls within the sub-tropical region of the central plains agroclimatic zone.

3.1.2 Climatic and weather condition:

The research site, situated within the sub-tropical region, exhibits distinct climatic characteristics, featuring cool winters and hot summers. Rainfall is primarily observed during the months of July, August, and September, attributed to the South-West monsoon. Although the temperature never reaches sub-zero levels, the winter months of December and January experience extreme cold conditions. Conversely, the summer months of April, May, and June witness soaring temperatures, with the highest recorded temperature nearing 46°C. The onset of monsoon showers typically commences in the latter half of July, persisting until the conclusion of September, unless delayed by the South-West monsoon. Notably, frequent rainfall is prevalent during July and August.

3.1.3 Soil sample collection

Prior to commencing the investigation, a series of random soil samples were procured from the orchard site. To ensure an accurate representation, the surface layer was delicately scraped off, followed by the creation of V-shaped incisions reaching a depth of 6 inches. A soil slice, approximately 1 inch thick, was carefully extracted from one side of each incision. This sampling process was carried out in a zigzag pattern across the orchard, resulting in the collection of 10 to 12 distinct samples. These individual soil samples were thoroughly mixed together through the quartering method, yielding a homogenous composite weighing around 500 grams. This composite sample served as the basis for assessing the physical and chemical characteristics of the soil. The initial fertility status of the experimental site's soil is presented in Tables 3.1 and 3.2. Furthermore, subsequent to the harvest, additional soil samples were obtained and subjected to analysis to gauge any changes.

Table no.3.1 Physical properties of soil at experimental site

Characteristics	Percentage (%)
Sand content	70
Silt content	14.3
Clay content	15.7
Soil texture	Sandy Loam

Table no. 3.2 Chemical properties of soil at experimental site

S.no.	**Particulars**	**Result**	**Method Followed**
1	pH	7.6	pH meter
2	EC	0.31	EC meter
3	Organic carbon	0.45%	Walkley and black`s method
4	Available Nitrogen	145kg/ha	Alkaline potassium permanganate
5	Available phosphorus	13.8 kg/ha	Olsen method

6	Available potassium	168 kg/ha	Flame photometery method
7	Boron	0.45 ppm	
8	Zinc	0.45 ppm	

3.3 EXPERIMENTAL DETAILS

The study was conducted at Kinnow orchard, Lovely Professional University, Phagwara. A total of 12 treatments were implemented during the experiment, with each treatment replicated 3 times. Two plants were selected for each replication, resulting in a total of 72 plants. The following treatments were applied:

Treatment	**Treatment details**
T_1	RDF + B (0.25%) + Zn (1000 ppm)
T_2	RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)
T_3	RDF + *Azotobacter*
T_4	RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)
T_5	RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm)
T_6	RDF + *Azotobacter* + nB (20 ppm) + nZn (200 ppm)
T_7	RDF + *Azotobacter* + nB (40 ppm) + nZn (100 ppm)
T_8	RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)
T_9	RDF + *Azotobacter* + nB (40 ppm) + nZn (200 ppm)
T_{10}	RDF + *Azotobacter* + nB (60 ppm) + nZn (100 ppm)
T_{11}	RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)
T_{12}	RDF + *Azotobacter* + nB (60 ppm) + nZn (200 ppm)

RDF = Recommended dose of NPK (as per recommendations of PAU)

Azotobacter = 100 g/tree

B = Sodium Boron (0.25% borate solution)

Zn = Zinc (1000 ppm) 4.7g Zinc sulphate/L

nB = Nano Boron

nZn = Nano Zinc

3.4 METHODOLOGY OF THE EXPERIMENTS

3.4.1 Selection of trees

Total of seventy-two 13-year-old Kinnow mandarin plants, exhibiting consistent vigor, size, and productivity, were chosen from the kinnow orchard as subjects for the present research study conducted during the years 2021 and 2022. With the exception of treatment applications, consistent cultural practices were implemented across all selected plants.

3.4.2 Time and mode of application of Nutrients

The prescribed dosage of N_2O, P_2O_5 and K_2O was uniformly administered across all treatments. Inorganic fertilizers, specifically nitrogen and phosphorus, were applied around the periphery of the tree basins, while potassium and micronutrients were applied through foliar application. The nitrogen was delivered through urea, utilizing a split-dose approach, with the first half administered in February and the second half in April. Full phosphorus supplementation was provided alongside the initial nitrogen dose, utilizing single superphosphate (SSP). Potassium was supplied through foliar application of a 1% potassium nitrate solution at the conclusion of May, June, and July. Boron, including its nano form, was applied twice, with the initial application in the first week of March, followed by the second dose 20 days after full bloom. Similarly, zinc, along with its nano form, was applied via foliar application on two occasions: firstly, towards the end of March and secondly during mid-August.

3.4.3 Application of biofertilizer

For the application of biofertilizer (Azotobacter), a uniform dose of 100 grams per plant of Azotobacter culture was thoroughly blended with a 10 percent solution of jaggery (gur slurry), which was prepared individually for each tree. Following the specific treatment guidelines, this mixture was then administered to the roots of the plants after a span of 20 days from the initial application of urea and SSP.

3.5 OBSERVATIONS RECORDED

3.5.1 Vegetative Parameters

3.5.1.1 Increase in plant height (%)

The measurement of plant height was conducted using a designated bamboo stick, marked to denote the distance from the ground surface to the plant's maximum height prior to fertilizer application (BFA) and following fruit harvest (AFH). The recorded values were expressed in meters (m) and subsequently used to calculate the percentage increase in plant height, employing the following formula:

$$\text{Percent increase in plant height} = \frac{\text{Plant height (AFH) - Plant height (BFA)}}{\text{Plant height (BFA)}} \times 100$$

3.5.1.2 Increase in canopy volume (%)

Canopy volume (m^3) of the respective trees for each treatment was calculated as per the formula given by Westwood (1963)

Canopy volume = $4/3\pi\, a^2b$ (where a=1/2 of plant height, b= average of east-west and north-south spread of plant)

Per cent increase in canopy volume was worked out using the formula

$$\text{\% increase in canopy volume} = \frac{\text{Canopy volume (AFH) – Canopy volume (BFA)}}{\text{Canopy volume (BFA)}} \times 100$$

3.5.1.3 Leaves per flush (no.)

New leaves per flush were counted manually at legth of 1m from apex from the tagged branches in the month of March. The data was averaged out and presented as average number of leaves per flush.

3.5.2 Yield Parameters

3.5.2.1 Fruit weight (g)

Using an electronic balance, the average weight of ten fruits representative of each treatment across replicates was recorded and the data was presented as average fruit weight (g) per treatment.

3.5.2.2 Fruit length (cm)

A random sample comprising ten (10) healthy fruits from each treatment was collected, and the length of each fruit was recorded using a Digital Vernier's Caliper. The mean value of the recorded fruit lengths was expressed in centimetres (cm).

3.5.2.3 Fruit breadth (cm)

A random selection of ten (10) viable and healthy fruits was acquired from each treatment group, and the breadth of each individual fruit was measured using a Digital Vernier Caliper. The resulting measurements were used to calculate the mean value, which was expressed in centimetres (cm).

3.5.2.4 Fruit size (cm^2)

It is calculated by multiplying fruit length with fruit width. It is expressed in cm^2.

3.5.2.5 Specific gravity

The specific gravity was determined using following formula: wt. of fruit/Vol. of water displaced by fruit.

3.5.2.6 Rind thickness (mm)

The peel thickness of ten fruits, randomly chosen from each treatment within each replication, was measured using a Digital Vernier Caliper. The recorded values were expressed in centimetres (mm).

3.5.2.7 Weight of seeds (g)

The weight of seeds collected from the representative samples was carefully recorded by using weighing balance, and resulted measurements were expressed in grams (g).

3.5.2.8 Peel weight (g)

Selected healthy fruit representative samples were peeled and the peel was weighed using a digital weighing balance, and the recorded value was averaged and expressed in grams (g).

3.5.2.9 Pulp weight (g)

The weight of the fruit without the peel was obtained by subtracting the weight of the peel from the total fruit weight. This calculated value was measured in grams.

3.5.2.10 Juice content (%)

The fruit was sliced in half crosswise, and the juice was extracted by thoroughly squeezing each half. Alternatively, a juice extractor could be utilized for this purpose. The extracted juice was then filtered using fine filter paper or a strainer. The resulting measurement was expressed as a percentage.

$$\text{Juice content (\%)} = (\text{Juice weight} \div \text{Fruit weight}) \times 100$$

3.5.2.11 Fruit drop (%)

Pre-harvest drop was determined by subtracting the number of fruits retained in the month of December from the number of fruits retained in the month of July.

$$\text{Fruit drop (\%)} = \frac{\text{No. of fruits dropped}}{\text{Total no. of fruits on the tree}} \times 100$$

3.5.2.12 Number of fruits per tree (no.)

During harvesting, the total no. of fruits was recorded in each replication, and the average number of fruits per tree were counted and expressed in numbers.

3.5.2.13 Fruit Yield (Kg/plant)

The yield/plant in kilograms was determined by considering the total fruits harvested per plant and the average of fruit weight.

3.5.3 Fruit Quality Parameters

3.5.3.1 Total soluble solids (^{O}Brix)

The measurement of total soluble solids (TSS) in the fruit pulp was conducted using an Erma hand refractometer (0-32 °B), following the standard procedure outlined in A.O.A.C (1995). TSS content was noted in terms of degrees Brix (°B) at room temperature. In cases where the readings were taken at temperatures other than 20°C, a temperature correction was applied. Prior to usage, the refractometer was calibrated using distilled water.

3.5.3.2 Titratable acidity (%)

A.O.A.C. (1995) guidelines were used to calculate the titratable acidity of raw fruits. The pulp from 25 grammes of fruit was mixed and homogenised in 250 millilitres of distilled water. Next, Whatman no. 1 filter paper was used to remove any remaining particles from the homogenised solution. Filtered sol. is then titrated against 0.1 N NaOH using phenolphthalein as the indicator, starting with a 25 ml sample. According to the formula 1 mL of NaOH = 0.0064 g of anhydrous citric acid, the total titratable acidity was determined. The results were reported as a percentage of the total acidity that could be measured.

3.5.3.4 Ascorbic acid (mg/100ml of juice)

The analysis was conducted following the standard protocol using 2,6-Dichlorophenol indophenols (0.04%). A measured quantity of the sample (10 ml) was diluted to 100 ml with 0.4% oxalic acid and subsequently filtered. A specific volume of the resulting aliquot (10 ml) was mixed with 15 ml of 0.4% oxalic acid, and a few drops of 0.1% phenolphthalein indicator were added. The mixture was then titrated against the standardized dye until a light pink color persisted for a minimum of 15 seconds, as outlined by Ruck (1969).

3.5.3.5 Polyphenols (mg GAE/100g fresh weight)

The assessment of the total phenol content in the fruit juices was carried out utilizing the Folin-Ciocalteu colorimetric method, as described by Singleton and Rossi (1965). The juices were subjected to centrifugation at 2000 x g for 5 minutes at

4°C. Subsequently, the juices were diluted ten-fold with distilled water, and the optical density of the samples was measured using a UV spectrophotometer (SHIMAZDU) at a wavelength of 765nm. The results were expressed as milligrams of gallic acid equivalents (mg GAE per 100 milliliters of juice).

3.5.3.6 Total Sugars

We used 25 grammes of fruit pulp and homogenised it with a lot of distilled water. A precipitate formed after adding 2 ml lead acetate sol. to the mixture, and this was filtered in flask holding 5 ml of potassium oxalate solution. After filtering, the liquid was vigorously agitated and filtered again. For overnight hydrolysis, 5 ml of strong HCl was added to 100 ml of this cleared and deleaded solution. The resulting excess HCl was neutralised with a strong sodium hydroxide solution. Titration of a boiling combination containing 5 ml of Fehling A and 5 ml Fehling B sol. against a hydrolyzed aliquot with methylene blue (indicator) allowed for measurement of total sugars. The titration was complete when the solution turned brick red. Following the protocol provided by A.O.A.C. (1995), total sugars were determined by measuring the volume of the aliquot used.

3.5.3.7 Reducing sugars

Methylene blue was used as an indicator to titrate a boiling solution of Fehling A and B reagents against a sample that had not been hydrolyzed, deleaded, or cleared. The titration was complete when the solution turned brick red. Following the method described by A.O.A.C. (1995), reducing sugars were determined by measuring the volume of the aliquot used.

3.5.3.8 Non-reducing sugars

The total sugars were subtracted from reducing sugars, and the difference was multiplied by the standard factor of 0.95 to obtain the non-reducing sugars. The calculation was carried out using the procedures described in A.O.A.C (1995).

3.5.4 NUTRIENT STATUS

3.5.4.1 Leaf nutrients

Fifty fully mature leaves were selectively harvested from 7-month-old non-fruiting terminals of the spring flush in the month of July, following the methodology described by Chahill et al. (1988). The leaves were collected from points facing north, east, south, and west on the periphery of the tree. Each treatment was sampled around the entire tree. The collected leaves were thoroughly washed with running tap water, followed by rinsing with 0.1 percent HCl and two additional rinses with distilled water. Subsequently, the leaf samples were dried and subjected to oven drying at a temperature of 70°C for duration of 48 hours. The washing, cleaning, grinding, & storage of the leaf samples were conducted in accordance with the procedures outlined by Chapman (1964).

3.5.3.1.1 Digestion of leaf sample

For the digestion of various elements (excluding nitrogen), one gram of leaf sample was utilized. The digestion process was conducted using a diacid solution composed of HNO_3 and $HClO_4$ in a volumetric ratio of 4:1. All necessary precautions recommended by Piper (1966) were carefully followed during the digestion procedure. Additionally, a separate digestion procedure was employed specifically for nitrogen estimation, utilizing concentrated sulphuric acid and a digestion mixture as described by Jackson (1973).

3.5.7 STATISTICAL ANALYSIS

The data collected during the course of study was subjected to analysis of variance (ANOVA) and Duncan's multiple-ranged test was performed using SPSS v. 23 software to identify the homogeneous type of the data sets among different treatments for different plant parameters.

Chapter 4

RESULTS AND DISCUSSION

4.1 Vegetative parameters

4.1.1 Increase in Plant height (%)

Table 4.1 shows the data pertaining to the variation in plant height during the two years of the experiment (2021 and 2022) along with the pooled data and is represented in Fig. 4.1. Keen perusal of the data indicates there was a significant effect of different micro nutrient treatments on plant height in Kinnow mandarin during both the years of the experiment. The data has been presented as per cent increase in the height of the plant.

In the initial year of the experiment (2021), observations were made regarding the maximum percentage increase in plant height. Treatment T_{11} [RDF + *Azotobacter* + nB (60 ppm) + nZn (150ppm)] exhibited the maximum increase of 5.26% which was significantly higher than T_3. Among remaining treatments, significant percentage increase in plant height was observed. However, treatment T_3 (RDF + *Azotobacter*) recorded the minimum percentage increase in plant height of 4.29%, which was at par with treatment T_4.

In the second trial (2022), maximum plant height (5.56%) was in T_{11} [RDF +*Azotobacter* + nB (60 ppm) + nZn (150 ppm)], that was non-significant with treatment T_2 and T_1 recording an increase in plant height of 5.46% and 5.44% respectively but it was significantly higher than T_3. Minimum increase (4.24%) in plant height was under treatment T_3 (RDF + *Azotobacter*).

The combined data from both years (2021 & 2022) revealed that treatment T_{11} RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm) exhibited the maximum percentage increase in plant height of 5.41% which was significantly higher than T_3. On the other hand, treatment T_3 (RDF + *Azotobacter*) resulted in the minimum plant height increase of 4.27%.

Urea and zinc fertilization made positive impact on plant height and growth rate. As nitrogen is an important component of chlorophyll. Chlorophyll is responsible for absorbing the light energy needed for photosynthesis, and higher photosynthetic efficiency can contribute to better plant growth. These observations are consistent with the findings of Malik et al. (2000), who said urea promoted the growth of Kinnow oranges and tangerines. The increase in height of plant may be due to the enlargement of individual cells in both the core and the bark. These results also coincide with the study of Rathore and Chandra (2003), who noted that nitrogen fertilization led to citrus growth.

The observed height increase in trees could potentially be attributed to of zinc involvement in tryptophan synthesis, which serves as a precursor for the synthesis of IAA. This, in turn, promotes tissue growth and development, as noted by Swietlik (2010). Additionally, adequate level of zinc in plants promotes various important processes such as photosynthesis, nucleic acid metabolism, and protein biosynthesis. These findings align with the research conducted by Dawood et al. (2001), also on Washington Navel oranges with zinc application.

The increase in both plant height and canopy spread observed with the application of zinc sulphate can be attributed to the higher concentration of auxin, which leads to enhanced apical growth. This connection is explained by the requirement of zinc for tryptophan synthesis, which serves as a precursor for auxin, as highlighted by Kumar et al. (2015). Furthermore, Bowler et al. (1994) indicate that zinc plays a crucial role in the functioning, structure, and regulation of numerous enzymes. Moreover, Singh et al. (1989) have reported that zinc is believed to facilitate cell division, meristematic growth in apical tissues, cell enlargement, and actively participate in the synthesis of new cell walls. These findings collectively support the understanding that the positive effects of zinc on plant growth are attributed to its involvement in auxin concentration, enzymatic processes, and cellular development.

The observed increase in vegetative growth parameters in the current study, resulting from the boron and zinc foliar spray, that is consistent with the findings of previous research. Similarly Khan et al. (2012) reported outcomes in citrus, Meena et al. (2021) observed comparable results in aonla, and Dhurve et al. (2018) noted similar effects in pomegranate. These studies collectively support the notion that the application of boron and zinc can positively influence vegetative growth parameters in various plant species.

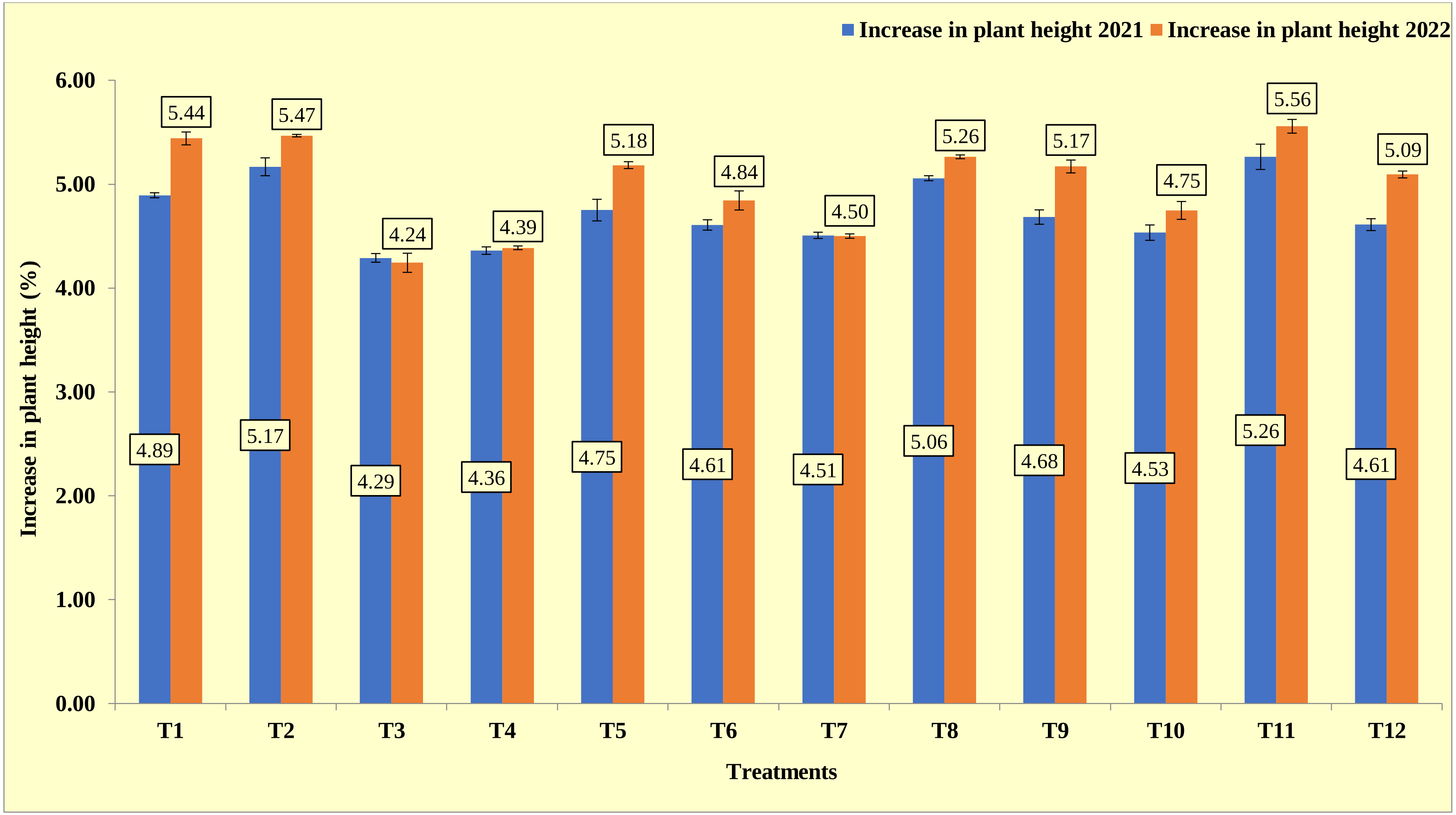

Fig. 1: Effect of *Azotobacter* and nano-micronutrients on increase in plant height in Kinnow mandarin

4.1.2 Increase in canopy volume (%)

Table 4.1 presents the data related to the increase in canopy spread over the course of the two-year experiment (2021 and 2022), and the combined data is graphically represented in Figure 4.2. Various micronutrient treatments had significant impact on increasing the canopy volume of Kinnow mandarin plants throughout the duration of the experiment. The data is presented as % increase in canopy volume.

In the primary year of the experiment (2021), % increase in canopy volume observed during the study. Treatment T_{11} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)] showed the highest increase of 22.82 per cent, which was at par with treatments T_2 (RDF + *Azotobacter* + B + Zn) and T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] with recorded increases of 22.50 per cent and 22.07 per cent, respectively. This was found to be significantly higher than T_3. On the other hand, treatment T_3 (RDF + *Azotobacter*) exhibited the lowest increase in canopy spread of 19.31 per cent.

In second year of experimentation (2022), study revealed findings about the increase in canopy volume. Treatment T_9 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (200 ppm)] showed the maximum increase of 22.73%. This was at par with treatments T_{12}, T_{11}, T_5, T_2 and T_1, ranging from 22.10 to 22.71 per cent. On the other hand, treatment T_7 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the minimum increase in canopy volume (20.31%).

The combined data from the two years (2021 & 2022) of experimentation showed that, treatment T_{11} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (200 ppm)] had the maximum per cent increase in canopy volume (22.46%) which was significantly higher than T_3. On the other hand, treatment T_3 (RDF + *Azotobacter*) recorded the lowest increase in canopy volume of 19.91%, which was found to be at par with T_7, T_6, and $T_{4.}$

The enhancement in the vegetative growth of trees through the application of macro and micronutrients may be attributed to the increase in their endogenous levels.

These nutrients play a crucial role in the activities of photosynthetic enzymes, leading to an overall improvement in tree growth (Alloway, 2008). Previous observations have indicated that reduced levels of photosynthesis result in lower food reserves and subsequently hinder the growth of citrus trees (Alloway, 2008; Ashraf et al., 2010). Similarly, research studies have reported that macro nutrients and application of secondary nutrients can effectively promote the growth of mandarin and sweet orange fruits (Khan et al., 2015). These findings underscore the significance of nutrient availability and their role in supporting photosynthetic processes and overall tree growth.

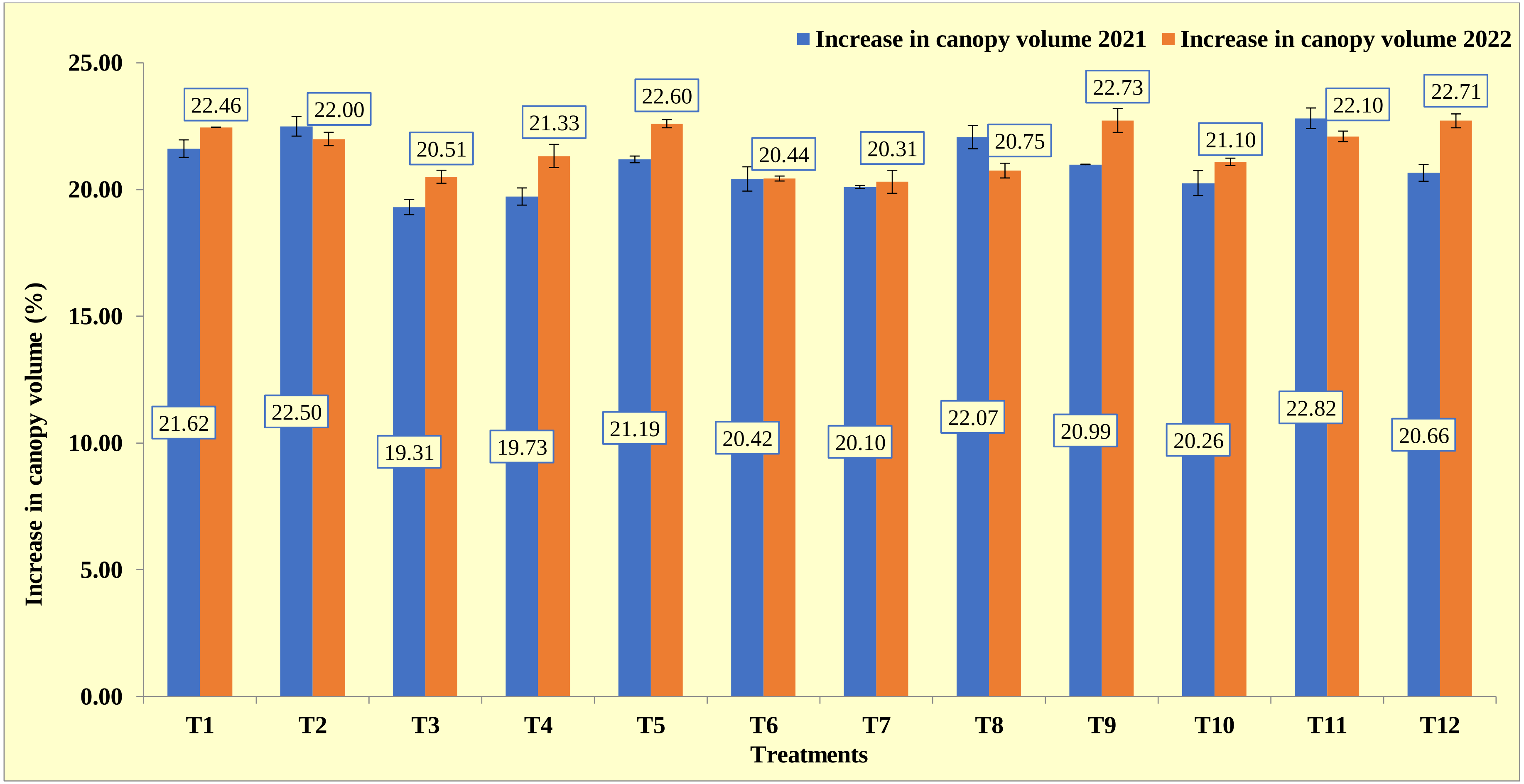

Fig. 2: Effect of *Azotobacter* and nano-micronutrients on increase in canopy volume in Kinnow mandarin

4.1.3 Leaves per flush (no.)

Data presented in table 4.1 shows the variation in the number of leaves per flush throughout the two-year experiment (2021 and 2022), and the combined data is presented in Figure 4.3. A thorough examination of the data reveals a remarkable influence of various micronutrient treatments on the leaves per flush of the Kinnow mandarin plant during both years of the experiment.

In the experimental year of 2021, treatment T_6 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (200 ppm)] resulted in the maximum count, with 180.74 leaves per flush, treatments T_{10}, T_5, and T_9 which had leaf counts of 177.17, 174.59, and 173.58, respectively. Statistically, there was a significant difference in the number of leaves between the treatments. On the other hand, treatment T_3 (RDF + *Azotobacter*) recorded the lowest count of leaves per flush, with 153.54, where as T_{12}, T_7, T_1, and T_{11}, which recorded leaf counts of 155.44, 155.79, 159.51, and 160.48, respectively.

During 2022 trail, the treatment T_9, which included the application of RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm), resulted in the maximum number of leaves per flush, with a count of 181.33. This was at par with treatment T_{12} and T_6, which had leaf counts of 178.22 and 176.84, respectively. In contrast, the treatment T_3 (RDF + *Azotobacter*) had the lowest number of leaves per flush, with a count of 149.31.

The pooled data from the two years (2021 & 2022) of the experiment showed that treatment T_6 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (200 ppm)] recorded the maximum number of leaves per flush, with 178.79 leaves, which was at par with leaf count in treatment T_9. This was found to be significantly higher than T_3. Whereas, treatment T_3 (RDF + *Azotobacter*) had the lowest number of leaves per flush, with 151.43 leaves.

The application of combined Zn and B spray on trees resulted in maximum leaf numbers, indicating an enhancement in vegetative growth. Previous studies have reported that a decrease in carbonic anhydrase activity can lead to a significant reduction of photosynthesis, resulting in decreased food reserves and negatively impacting plant growth (Alloway, 2008). Moreover, Zn or B in previous research promoted the growth of plants, as reported by Dawood et al. (2001), Razzaq et al. (2013), and Ullah et al. (2012).

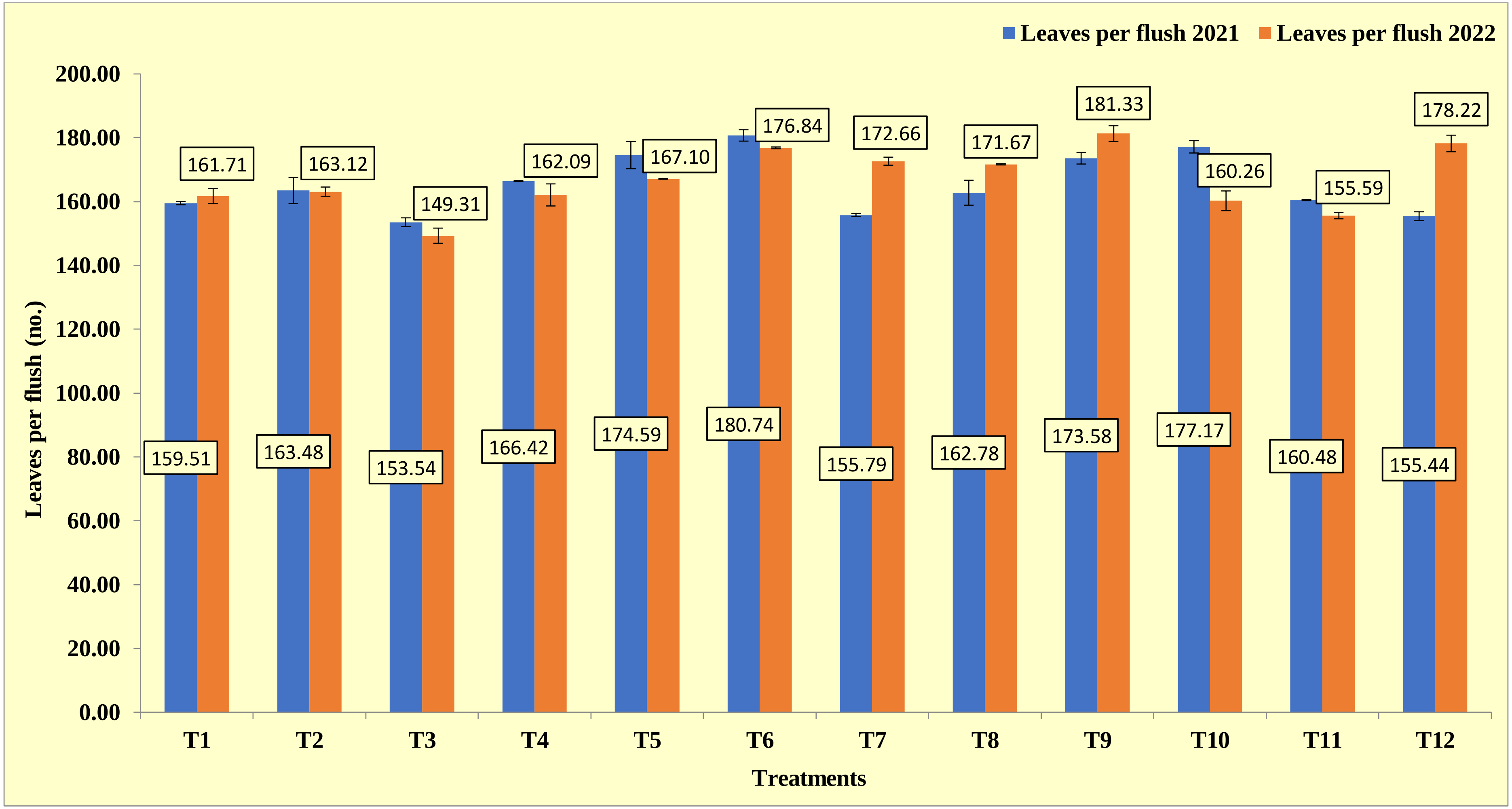

Fig. 3: Effect of *Azotobacter* and nano-micronutrients on leaves per flush in Kinnow mandarin

Table no. 4.1: Effect of *Azotobacter* and nano micro nutrients on increase in plant height, increase in canopy volume and leaves per flush of Kinnow mandarin.

Treatments	Increase in plant height (%)			Increase in canopy volume (%)			Leaves per flush (no.)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	4.89^{ef}	5.44^{e}	5.17^{f}	21.62^{def}	22.46^{d}	22.04^{cd}	159.51^{abc}	161.71^{bcd}	160.61^{bc}
T_2	5.17^{gh}	5.46^{e}	5.32^{g}	22.50^{fg}	22.00^{cd}	22.25^{d}	163.48^{c}	163.12^{cd}	163.30^{cd}
T_3	4.29^{a}	4.24^{a}	4.27^{a}	19.31^{a}	20.51^{ab}	19.91^{a}	153.54^{a}	149.31^{a}	151.43^{a}
T_4	4.36^{ab}	4.39^{ab}	4.37^{a}	19.73^{ab}	21.32^{bc}	20.52^{ab}	166.42^{c}	162.09^{cd}	164.26^{cde}
T_5	4.75^{de}	5.18^{d}	4.97^{e}	21.19^{cde}	22.60^{d}	21.90^{cd}	174.59^{d}	167.10^{de}	170.85^{f}
T_6	4.61^{cd}	4.84^{c}	4.73^{cd}	20.42^{abc}	20.44^{ab}	20.43^{ab}	180.74^{d}	176.84^{fgh}	178.79^{g}
T_7	4.51^{bc}	4.50^{b}	4.50^{b}	20.10^{abc}	20.31^{a}	20.20^{ab}	155.79^{ab}	172.66^{efg}	164.23^{cde}
T_8	5.06^{fg}	5.26^{d}	5.16^{f}	22.07^{efg}	20.75^{ab}	21.41^{c}	162.78^{bc}	171.67^{ef}	167.23^{def}
T_9	4.68^{cd}	5.17^{d}	4.93^{e}	20.99^{cde}	22.73^{d}	21.86^{cd}	173.58^{d}	181.33^{h}	177.46^{g}
T_{10}	4.53^{bcd}	4.75^{c}	4.64^{c}	20.26^{abc}	21.10^{ab}	20.68^{b}	177.17^{d}	160.26^{bc}	168.72^{ef}
T_{11}	5.26^{h}	5.56^{e}	5.41^{g}	22.82^{g}	22.10^{cd}	22.46^{d}	160.48^{abc}	155.59^{b}	158.04^{b}
T_{12}	4.61^{cd}	5.09^{d}	4.85^{de}	20.66^{bcd}	22.71^{d}	21.69^{cd}	155.44^{ab}	178.22^{gh}	166.83^{def}
S. Em (±)	0.068	0.06	0.046	0.362	0.296	0.241	2.358	2.132	1.592
C.D (5%)	0.202	0.177	0.135	1.068	0.874	0.712	6.959	6.293	4.7

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

4.2 Yield parameters

4.2.1 Fruit Weight (g)

Table 4.2 presents the data on the variation in fruit weight during the two-year experiment (2021 and 2022), along with combined data is represented in Figure 4.4. A detailed analysis of the data reveals a significant impact of various micronutrient treatments on the fruit weight of the Kinnow mandarin during both years of the experiment.

During the first year of the experiment (2021), treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded with highest fruit weight of 154.06 g. Minimum fruit weight (140.72 g) was recorded in T_3 (RDF + *Azotobacter*). Experiment conducted in 2021, shows that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] had the maximum fruit weight, measuring 154.06 g. This result was at par with treatments T_9, T_7, T_2, and T_1. Conversely, treatment T_3 (RDF + *Azotobacter*) recorded the lowest fruit weight of 140.72 g.

In the second-year trail (2022), the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the maximum fruit weight, which was 152.13 g which was significantly higher than T_3. All the other treatments showed significant differences in fruit weight, except for treatments T_3 and T_{12}. Treatment T_3 (RDF + *Azotobacter*) recorded the lowest fruit weight of 142.76 g, which was at par to the fruit weight of 143.35 g observed under treatment T_{12}.

Aggregate data for the two years (2021 & 2022), shows that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the maximum fruit weight, with a value of 153.73 g which was significantly higher than T_3. On the other hand, the treatment T_3 (RDF + *Azotobacter*) observed with the lowest fruit weight, measuring 141.74 g.

The integration of organic sources of nutrients resulted in an increase in average fruit weight. Hormones released or synthesized due to organic nutrient (Singh et al., 2012). The larger fruit size can be attributed to corresponding rise in fruit length & diameter. The application of bio-fertilizers increased the levels of plant growth regulators in plants, promoting cell enlargement (Bhatia et al., 2001; Singh et al., 2012). Zinc (Zn) plays a crucial role in the synthesis of tryptophan, a precursor of IAA involved in fruit growth and development. Consequently, higher Zn levels in leaves contribute to increased tryptophan production, leading to enhanced fruit growth. Zn is known to participate in various physiological functions of plants, influencing the crop's yield and quality (Hafeez et al., 2013; Goswami et al., 2012).

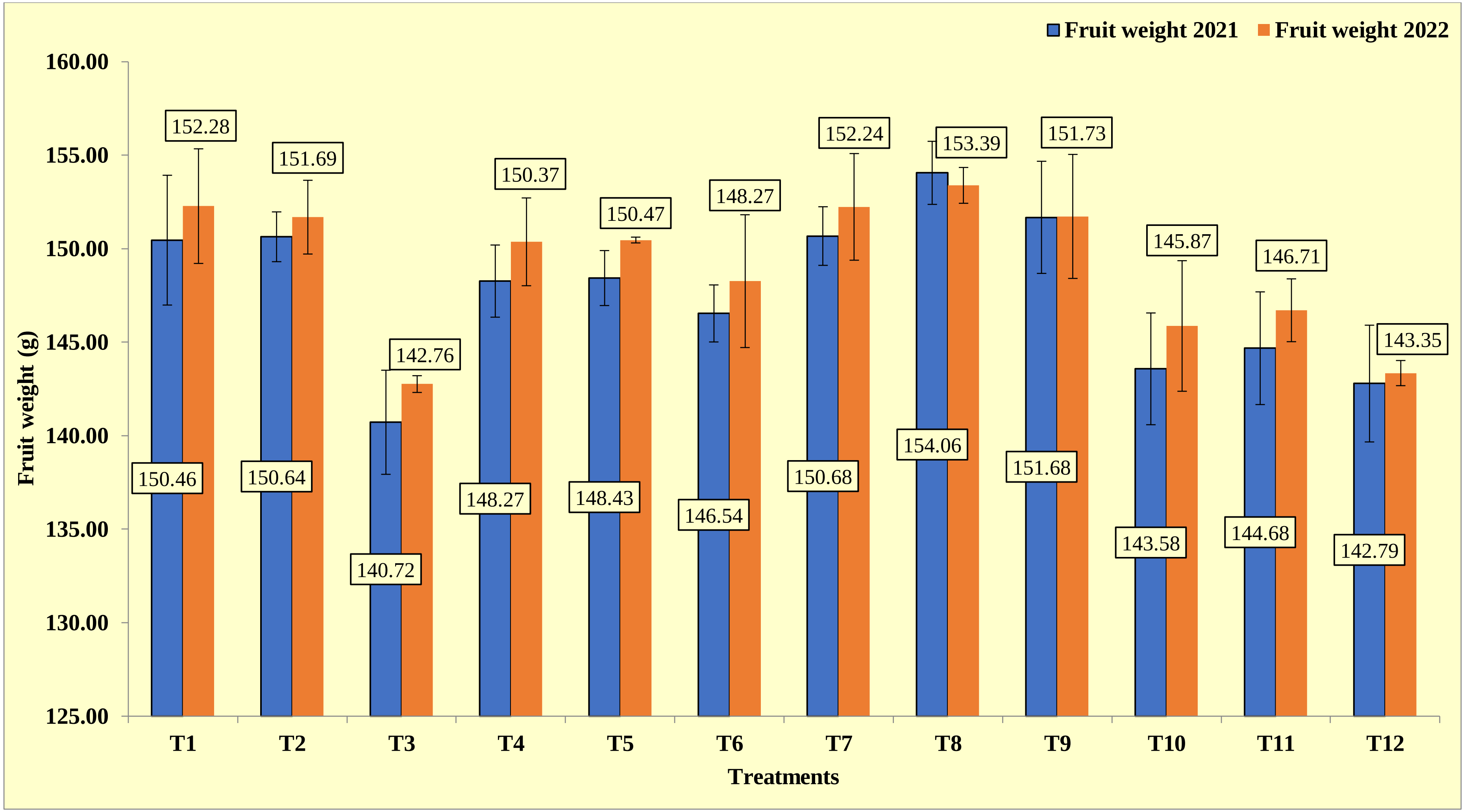

Fig. 4: Effect of *Azotobacter* and nano-micronutrients on fruit weight in Kinnow mandarin

4.2.2 Fruit Length (cm)

Table 4.2 showcases the empirical data regarding the fluctuation in fruit length throughout the course of the two-year experiment (2021 and 2022). The data is visually depicted in Figure 4.5.

In first trail (2021), T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum fruit length, measuring 5.84 cm which was significantly higher than T_3. All treatments made impact on the fruit length of Kinnow mandarin fruits, except for treatments T_3, T_{10}, and T_{12}. The treatment T_3 (RDF + *Azotobacter*) had the minimum fruit length, measuring 5.36 cm, which was at par with to the fruit lengths of 5.40 cm and 5.43 cm observed under treatments T_{12} and T_{10}, respectively.

During the second year of the trail conducted in 2022, the treatments T_8 and T_7, involving the application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) and RDF + *Azotobacter* + nB (40 ppm) + nZn (100 ppm), respectively, displayed the maximum fruit length of 5.83 cm which was significantly higher than T_3. Statistically, all treatments had impact on the fruit length of Kinnow fruits, except for treatments T_3, T_{10}, and T_{12}. The treatment T_3 (RDF + *Azotobacter*) had the minimum fruit length of 5.37 cm, which was at par to the fruit lengths of 5.42 cm and 5.45 cm observed under treatments T_{12} and T_{10}, respectively.

Pooled data for the two years registered the same trend as observed in the two years of the experimentation. The highest fruit length (5.84 cm) was in T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] which was significantly higher than T_3. Minimum fruit length (5.37 cm) was recorded in treatment T_3 (RDF + *Azotobacter*).

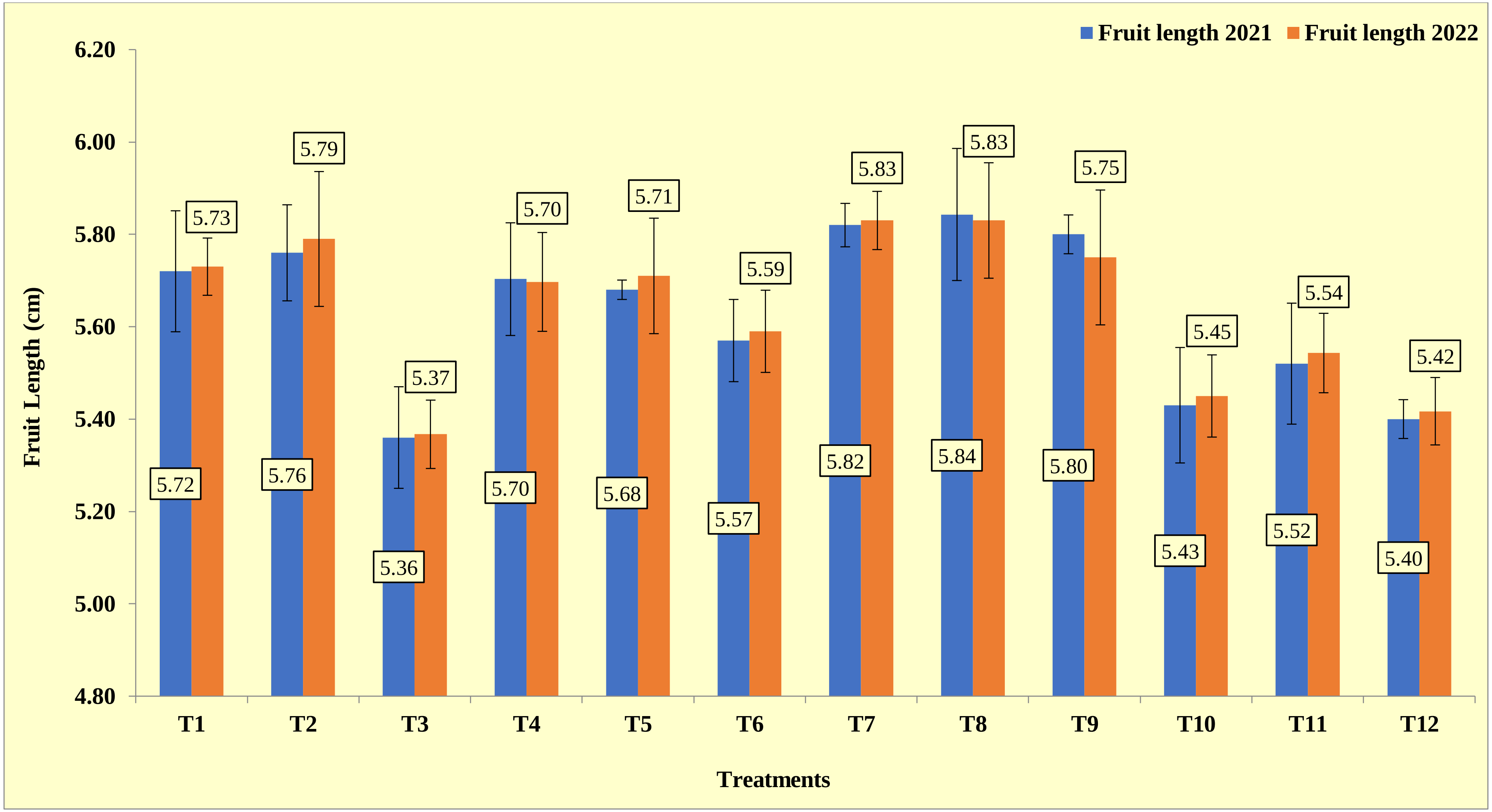

Fig. 5: Effect of *Azotobacter* and nano-micronutrients on fruit length in Kinnow mandarin

4.2.3 Fruit Width (cm)

Table 4.2 shows the data pertaining to the variation in fruit width during the two years of the experiment (2021 and 2022) along with the pooled data and is represented in Fig. 4.6. A keen perusal of the data indicates that there is a significant effect of different micro nutrient treatments on fruit width in Kinnow mandarin during both the years of the experiment.

During the study conducted in 2021, it was founded that the treatment T_7 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)] resulted in the maximum fruit width of 6.52 cm which was significantly higher than T_3. On the other hand, the treatment T_3 (RDF + *Azotobacter*) had the minimum fruit width of 5.68 cm.

In 2022 trail, the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the maximum fruit width of 6.55 cm, which was near to T_7, T_2, T_9 and T_1 recording fruit width of 6.53 cm, 6.42 cm, 6.31 cm, and 6.26 cm, respectively. On the other hand, the treatment T_3 (RDF + *Azotobacter*) had the minimum fruit width, measuring 5.70 cm, treatments T_{12}, T_{10} and T_{11} was at par, which measured fruit width of 5.79 cm, 5.85 cm, and 6.00 cm.

Observations from both years (2021 & 2022) of experiment, data revealed treatment T_7 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (100 ppm)] recorded in maximum fruit width, measuring 6.53 cm which was significantly higher than T_3. Conversely, the treatment T_3 (RDF + *Azotobacter*) recorded the minimum fruit width (5.69 cm).

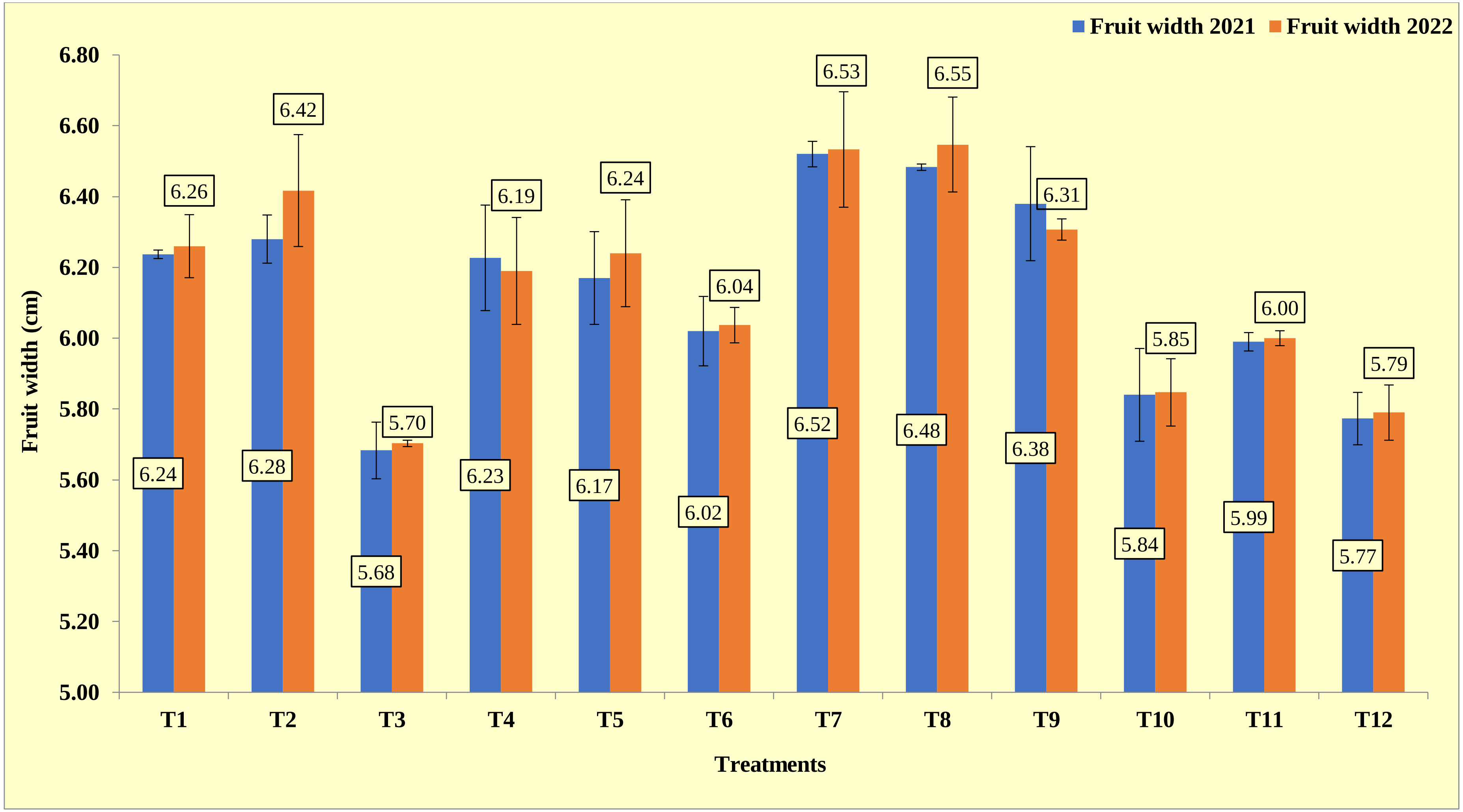

Fig. 6: Effect of *Azotobacter* and nano-micronutrients on fruit width in Kinnow mandarin

Table no. 4.2: Effect of *Azotobacter* and nano micro nutrients on fruit weight, fruit length and fruit width of Kinnow mandarin.

Treatments	Fruit weight (g)			Fruit length (cm)			Fruit width (cm)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	150.46^{bcd}	152.28^{b}	151.37^{de}	5.72^{bcd}	5.73^{bcd}	5.73^{de}	6.24^{cde}	6.26^{cd}	6.25^{ef}
T_2	150.64^{bcd}	151.69^{b}	151.17^{de}	5.76^{cd}	5.79^{d}	5.78^{e}	6.28^{cde}	6.42^{d}	6.35^{fg}
T_3	140.72^{a}	142.76^{a}	141.74^{a}	5.36^{a}	5.37^{a}	5.37^{a}	5.68^{a}	5.70^{a}	5.69^{a}
T_4	148.27^{abcd}	150.37^{ab}	149.32^{cde}	5.70^{bcd}	5.70^{bcd}	5.70^{cde}	6.23^{cde}	6.19^{bcd}	$6.21d^{ef}$
T_5	148.43^{abcd}	150.47^{ab}	149.45^{cde}	5.68^{abcd}	5.71^{bcd}	5.70^{cde}	6.17^{cd}	6.24^{cd}	$6.21d^{ef}$
T_6	146.54^{abcd}	148.27^{ab}	147.40^{bcd}	5.57^{abcd}	5.59^{abcd}	5.58^{bcd}	6.02^{bc}	6.04^{abc}	6.03^{cde}
T_7	150.68^{bcd}	152.24^{b}	151.46^{de}	5.82^{d}	5.83^{d}	5.83^{e}	6.52^{e}	6.53^{d}	6.53^{g}
T_8	154.06^{d}	153.39^{b}	153.73^{e}	$.84^{d}$	5.83^{d}	5.84^{e}	6.48^{de}	6.55^{d}	6.52^{g}
T_9	151.68^{cd}	151.73^{b}	151.71^{de}	55.80^{d}	5.75^{cd}	5.78^{e}	6.38^{de}	6.31^{cd}	6.35^{fg}
T_{10}	143.58^{abc}	145.87^{ab}	144.72^{abc}	5.43^{abc}	5.45^{abc}	5.44^{ab}	5.84^{ab}	5.85^{ab}	5.85^{abc}
T_{11}	144.68^{abc}	146.71^{ab}	145.70^{abc}	5.52^{abcd}	5.54^{abcd}	5.53^{abc}	5.99^{bc}	6.00^{abc}	6.00^{bcd}
T_{12}	142.79^{ab}	143.35^{a}	143.07^{ab}	5.40^{ab}	5.42^{ab}	5.41^{ab}	5.77^{ab}	5.79^{a}	5.78^{ab}
S. Em (±)	2.52	2.367	1.597	0.092	0.09	0.058	0.096	0.11	0.072
C.D (5%)	7.439	6.986	4.715	0.27	0.266	0.171	0.284	0.324	0.212

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

4.2.4 Fruit Size (cm^2)

Table 4.3 showcases the data encompassing the fluctuations in fruit size observed during the two-year experiment (2021 and 2022). The combined data is represented in Figure 4.7. An examination of the data indicates that there is a significant effect of micro nutrient treatments on the overall fruit size of Kinnow mandarins throughout both experimental years.

In an experiment performed in 2021, the treatment T_7 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (100 ppm)] exhibited the maximum fruit size (37.95 cm^2), treatments T_8, T_9, T_2 and T_1, was at par which ranged from 35.69 cm^2 to 37.84 cm^2. In contrast, the treatment T_3 (RDF + *Azotobacter*) resulted in the minimum fruit size, measuring 30.44 cm^2, it was at par with fruit sizes to treatments T_{12} and T_{10}, which measured 31.16 cm^2 and 31.71 cm^2.

During the experimental year of 2022, the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] had the maximum fruit size of 38.19 cm^2. Treatments T_7, T_2, T_9 and T_1 was at par, recording fruit size of 38.07 cm^2, 37.17 cm^2, 36.28 cm^2, and 35.87 cm^2, respectively. On the other hand, the treatment T_3 (RDF + *Azotobacter*) had the minimum fruit size of 30.61 cm^2, which was at par with fruit sizes to treatments T_{12}, $T_{10,}$ and T_{11}, recording a value of 31.38 cm^2, 31.88 cm^2, and 33.24 cm^2.

Two years data recorded maximum fruit size (38.01 cm^2) under the treatment T_8 and T_7. Minimum fruit size (30.53 cm^2) was recorded in T_3 (RDF + *Azotobacter*).

From the combined data of the two years (2021 & 2022), the experimental data revealed that the treatments T_8 and T_7 exhibited the maximum fruit size, measuring 38.01 cm^2 each which was significantly higher than T_3. In contrast, the treatment T_3 (RDF + *Azotobacter*) displayed the minimum fruit size of 30.53 cm^2.

Yield increase can be primarily attributed to the improved nutrients availability and enhanced solute uptake by plants. Findings align reported results by Korwar et al. (2006) and Sharma et al. (2022). The application of foliar Zn significantly improved various physical characteristics of the fruit, including weight, juice per cent. This improvement in quality may lead to higher prices in market, as yield is directly proportional to commodity prices. Previous studies have also demonstrated that the external application of Zn enhances physio-chemical traits of fruits such as 'Kinnow', 'Khasi', and 'Washington Navel'. IAA which plays a vital role in fruit growth and development. Therefore, increased zinc levels in the leaves promote the production of tryptophan. Zinc is involved in numerous physiological functions in tress, influencing both the quality and yield of crops. Notably, spray of Zn is highly effective for physicochemical quality-related parameters of guava fruit at harvest (Hafeez et al., 2013; Goswami et al., 2012). Additionally, the foliar application of zinc spray on trees may contribute to improved endogenous auxin levels, leading to enhanced fruit set. In the case of 'Kinnow' mandarin trees, higher yields were obtained through the application of exogenous Zn, resulting rise in both no. and weight of fruits/tree (Rawat et al., 2010).

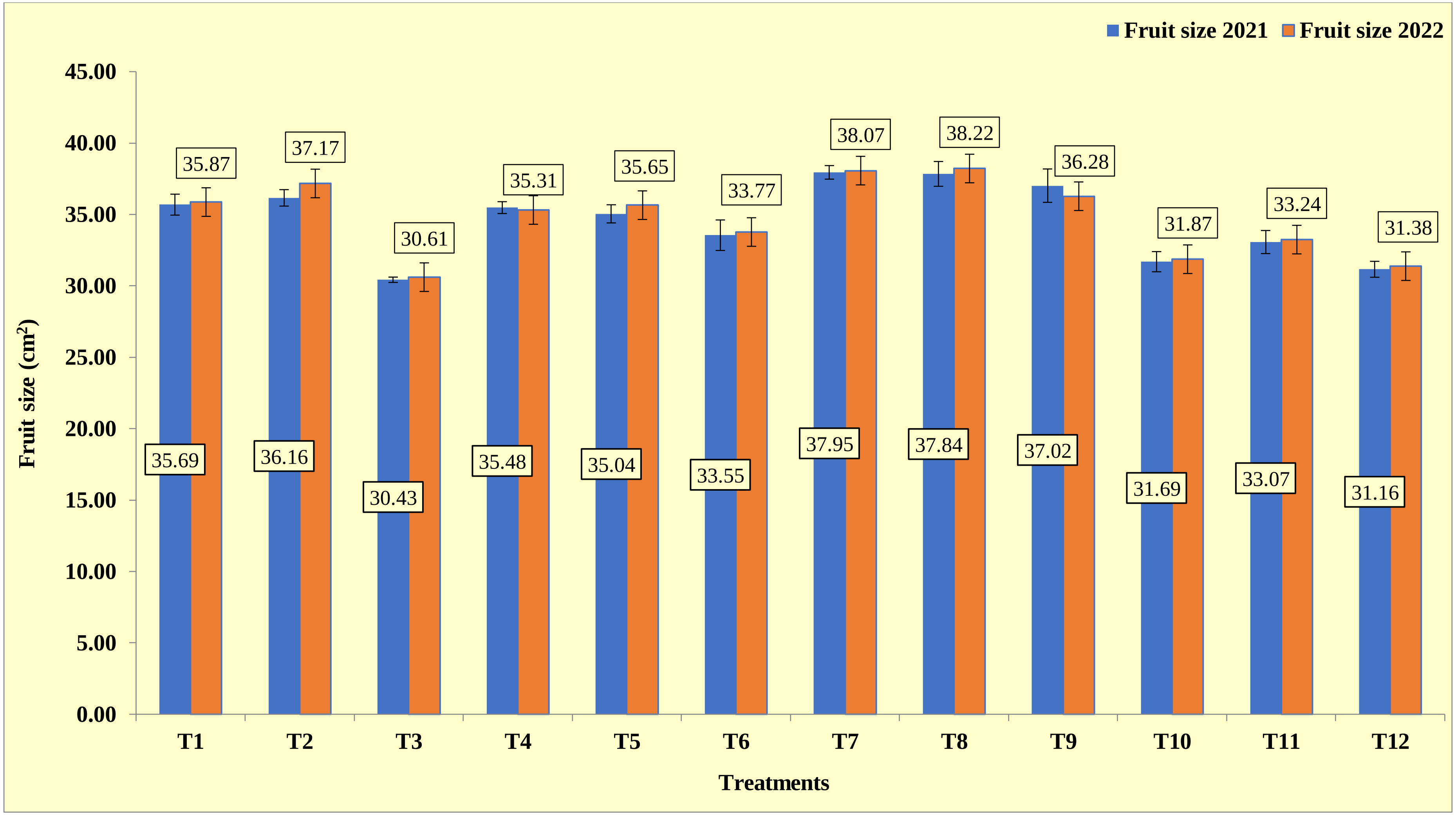

Fig. 7: Effect of *Azotobacter* and nano-micronutrients on fruit size in Kinnow mandarin

4.2.5 Specific Gravity

Table 4.3 presents the data regarding the variation in specific gravity observed during the two-year experiment (2021 and 2022). The pooled data is graphically represented in Figure 4.8. A keen perusal of the data indicates that there is non-significant effect of micro nutrient on specific gravity in Kinnow mandarin during both the years of the experiment.

In the first-year trail (2021), non-significant difference was observed in specific gravity among the treatments examined. However, treatments T_4, T_7, T_9, T_{10} and T_{11} exhibited the maximum specific gravity value (1.00). Statistically it was at par with the recommended application of the nutrients to the Kinnow plants i.e. 0.99 for treatment $T_{1.}$

During the second year of experimentation (2022), non-significant difference for specific gravity among treatments in consideration. Minimum specific gravity (0.99) was in treatment T_5, T_6, T_{11}, and T_{12}. Other treatments recorded specific gravity of 1.00.

Pooled data for the two years also registered non-significant difference for specific gravity among all the treatments in consideration. Maximum specific gravity recorded was 1.00 and minimum was 0.99.

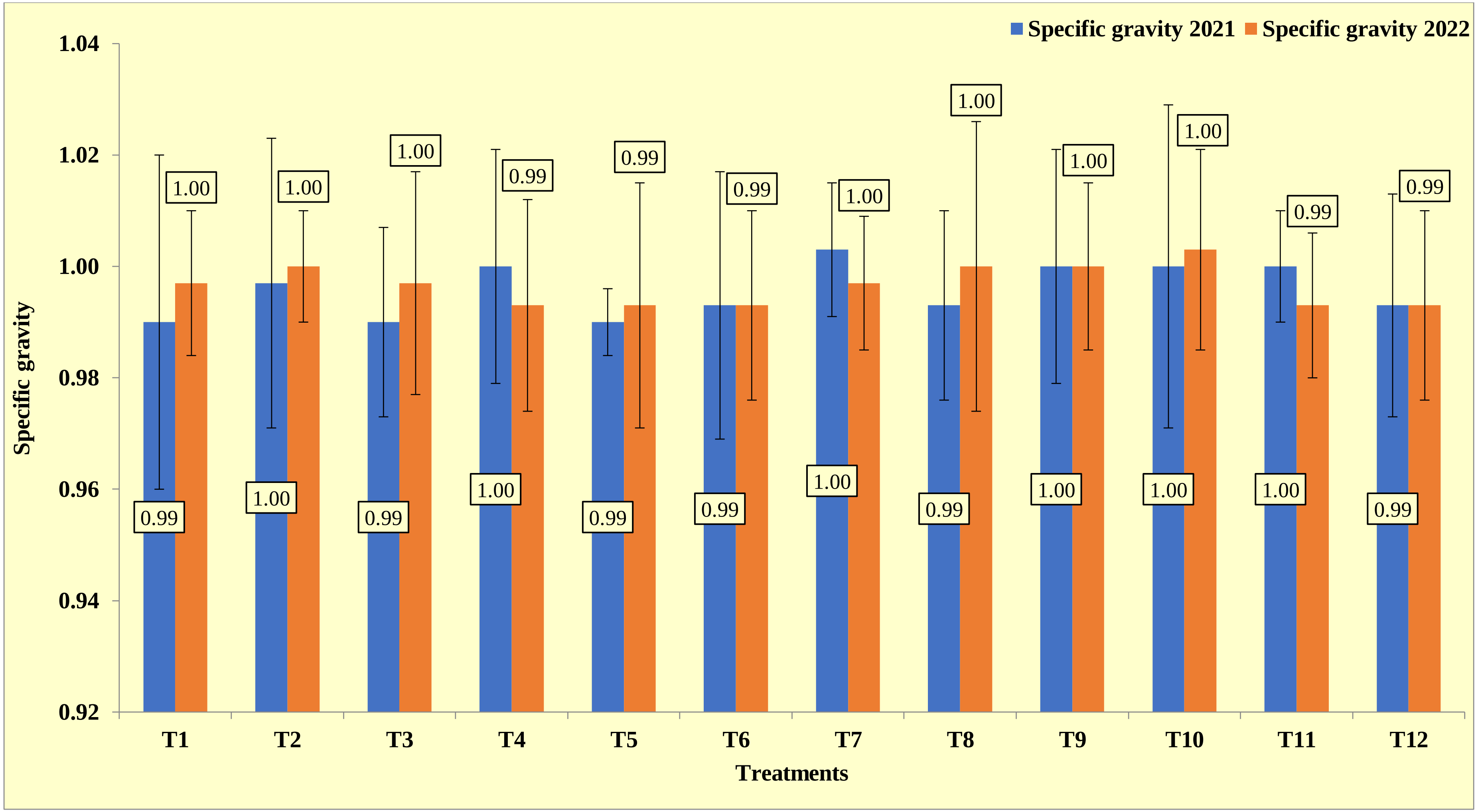

Fig. 8: Effect of *Azotobacter* and nano-micronutrients on specific gravity in Kinnow mandarin

4.2.6 Rind Thickness (mm)

Table 4.3 presents the data regarding the variation in rind thickness during the two years of the experiment (2021 and 2022), and the pooled data is depicted in Fig. 4.9. Examination of the data reveals a significant impact of micro nutrient treatments on the rind thickness of Kinnow mandarin during both years of the experiment.

In the primary year of the experiment (2021), the treatment T_7, T_8, and T_2 showed maximum rind thickness (0.52 mm). These outcomes were statistically at par with rind thickness observed under treatments T_1 and T_9, which demonstrated rind thickness of 0.51 mm. In contrast, the treatments T_3 (RDF + *Azotobacter*) and T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)] exhibited the most minimum rind thickness, measuring a mere 0.45 mm. These values are at par with the rind thickness recorded under treatments T_5 and T_6, both displaying a rind thickness of 0.47 mm.

In the second year of the experiment (2022), the treatment T_8, which involved the application of RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm), resulted in the maximum rind thickness of 0.53 mm. This was at par with the rind thickness observed under treatments T_7, T_2, T_1, T_{11}, T_9, T_{10}, and T_{12}. On the other hand, the treatment T_3 (RDF + *Azotobacter*) exhibited the lowest rind thickness of 0.44 mm.

Pooled data for the two years registered maximum rind thickness (0.53 mm) was recorded under the treatment T_8 [(RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)]. Minimum rind thickness (0.45 mm) was recorded in treatment T_3 (RDF + *Azotobacter*) and T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)].

Combined data for the two years (2021 and 2022) indicated that the treatment T_8 [(RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)] resulted in the maximum rind thickness of 0.53 mm. This value was statistically at par to the rind thickness observed under treatments T_7, T_2, T_1, T_9, and T_{11}. Conversely, the treatments T_3 (RDF + *Azotobacter*) and T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)] exhibited the minimum rind thickness of 0.45 mm.

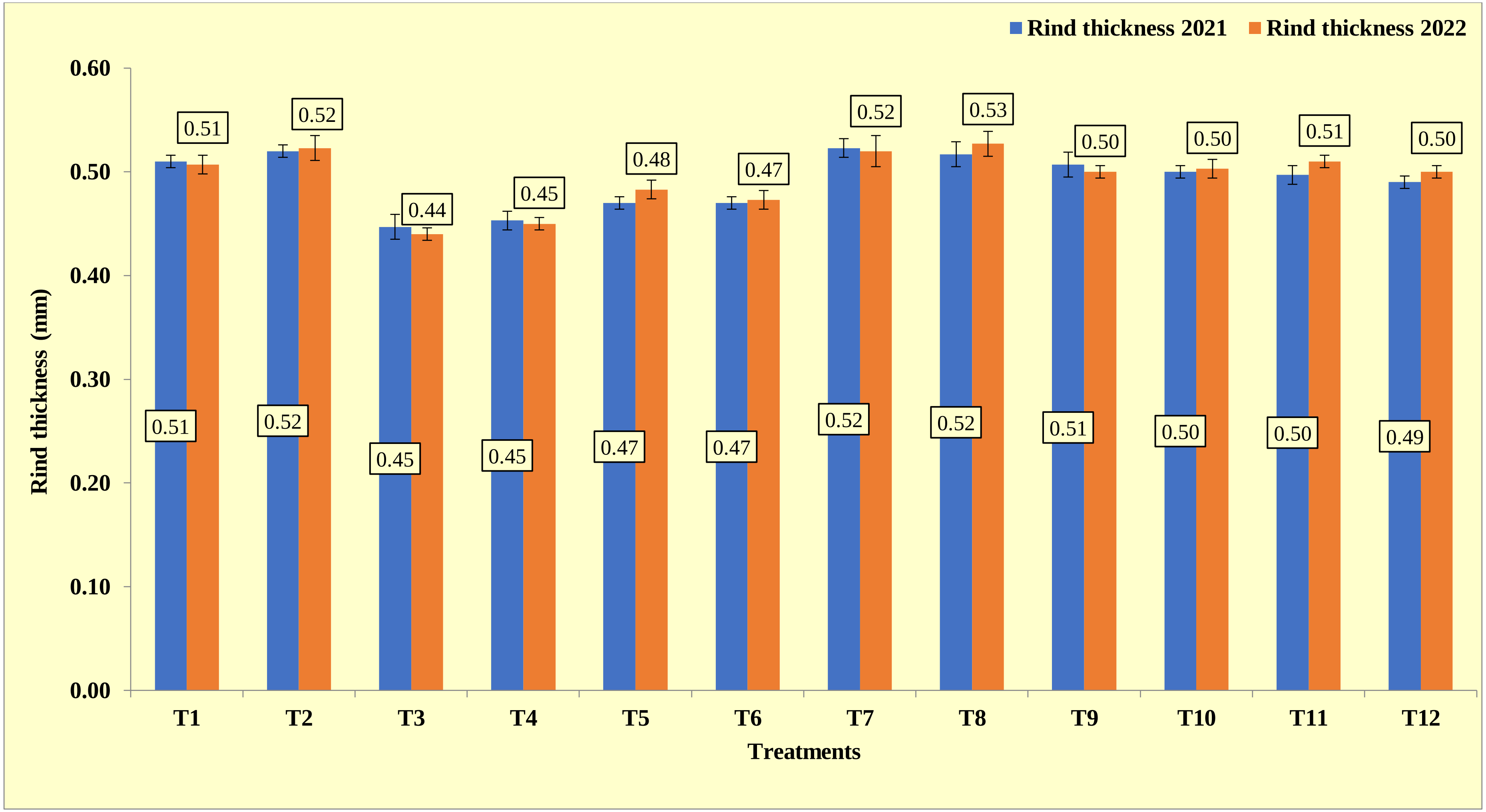

Fig. 9: Effect of *Azotobacter* and nano-micronutrients on rind thickness in Kinnow mandarin

Table no. 4.3: Effect of *Azotobacter* and nano micro nutrients on fruit size, specific gravity and rind thickness of Kinnow mandarin.

Treatments	Fruit size (cm^2)			Specific Gravity			Rind thickness (mm)		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_1	35.69^{efgh}	35.87^{bc}	35.78^{d}	0.99^{a}	1.00^{a}	0.99^{a}	0.51^{cd}	0.51^{de}	0.51^{cde}
T_2	36.17^{fgh}	37.17^{c}	36.67^{de}	0.99^{a}	1.00^{a}	1.00^{a}	0.52^{d}	0.52^{e}	0.52^{de}
T_3	30.44^{a}	30.61^{a}	30.53^{a}	0.99^{a}	1.00^{a}	0.99^{a}	0.45^{a}	0.44^{a}	0.45^{a}
T_4	35.51^{efg}	35.28^{bc}	35.40^{d}	1.00^{a}	1.00^{a}	1.00^{a}	0.45^{a}	0.45^{ab}	0.45^{a}
T_5	35.05^{def}	35.63^{bc}	35.34^{d}	0.99^{a}	0.99^{a}	0.99^{a}	0.47^{ab}	0.48^{cd}	0.48^{b}
T_6	33.53^{cde}	33.76^{ab}	33.65^{c}	0.99^{a}	0.99^{a}	0.99^{a}	0.47^{ab}	0.47^{bc}	0.47^{b}
T_7	37.95^{h}	38.07^{c}	38.01^{e}	1.00^{a}	1.00^{a}	1.00^{a}	0.52^{d}	0.52^{e}	0.52^{de}
T_8	37.84^{gh}	38.19^{c}	38.01^{e}	0.99^{a}	1.00^{a}	0.99^{a}	0.52^{cd}	0.53^{e}	0.53^{e}
T_9	37.00^{fgh}	36.28^{bc}	36.64^{de}	1.00^{a}	1.00^{a}	1.00^{a}	0.51^{cd}	0.50^{cde}	0.51^{cde}
T_{10}	31.71^{abc}	31.88^{a}	31.80^{ab}	1.00^{a}	1.00^{a}	1.00^{a}	0.50^{cd}	0.50^{de}	0.50^{cd}
T_{11}	33.06^{bc}	33.24^{ab}	33.15^{bc}	1.00^{a}	0.99^{a}	1.00^{a}	0.50^{cd}	0.51^{de}	0.51^{cde}
T_{12}	31.16^{ab}	31.38^{a}	31.27^{a}	0.99^{a}	0.99^{a}	0.99^{a}	0.49^{bc}	0.50^{cde}	0.50^{c}
S. Em (±)	0.685	0.923	0.509	0.021	0.018	0.014	0.008	0.008	0.006
C.D (5%)	2.021	2.724	1.503	N/A	N/A	N/A	0.024	0.023	0.017

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

4.2.7 Weight of seed (g)

Table 4.4 shows seed weight variation data and pooled data for two experimental years (2021 and 2022) and is shown in Figure 4.10. A closer examination of the data shows that micronutrient had a significant impact on Kinnow mandarin seed wt. in both years of the experiment.

During the first year of the trial (2021), the results in the weight of Kinnow mandarin seeds showed treatment T_{10} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (100 ppm)] had the maximum seed weight of 3.75 g. Seed weight was at par observed in the treatments T_5, T_8, T_{12}, T_1, T_7, and T_4, with values of 3.72 g, 3.69 g, 3.68 g, 3.65 g, 3.65 g and 3.61 g respectively. In contrast, treatment T_9 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (200 ppm)] recorded the minimum seed weight of 3.30 g. This result was at par to the seed weight recorded in treatments T_{11} and T_6, which is 3.33 g and 3.41 g, respectively.

In the second trial during year 2022, treatment T_2 where application of RDF + *Azotobacter* + B + Zn was done recorded maximum weight of seeds (3.81 g). Lowest seed weight (3.35 g) was in T_7 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (100 ppm)] which were at par with treatment of T_5 and T_{11} recording a value of 3.42 g and 3.48 g, respectively.

Data combined for two years (2021 and 2022), recorded maximum seed weight (3.73 g) in treatments T_{10} and T_8, which was equivalent to treatments T_1, T_2, T_3, T_4, T_5 and T_{12}. Minimum seed weight (3.41 g) was in T_{11} [(RDF+*Azotobacter* + nB (60 ppm) + nZn (150 ppm)].

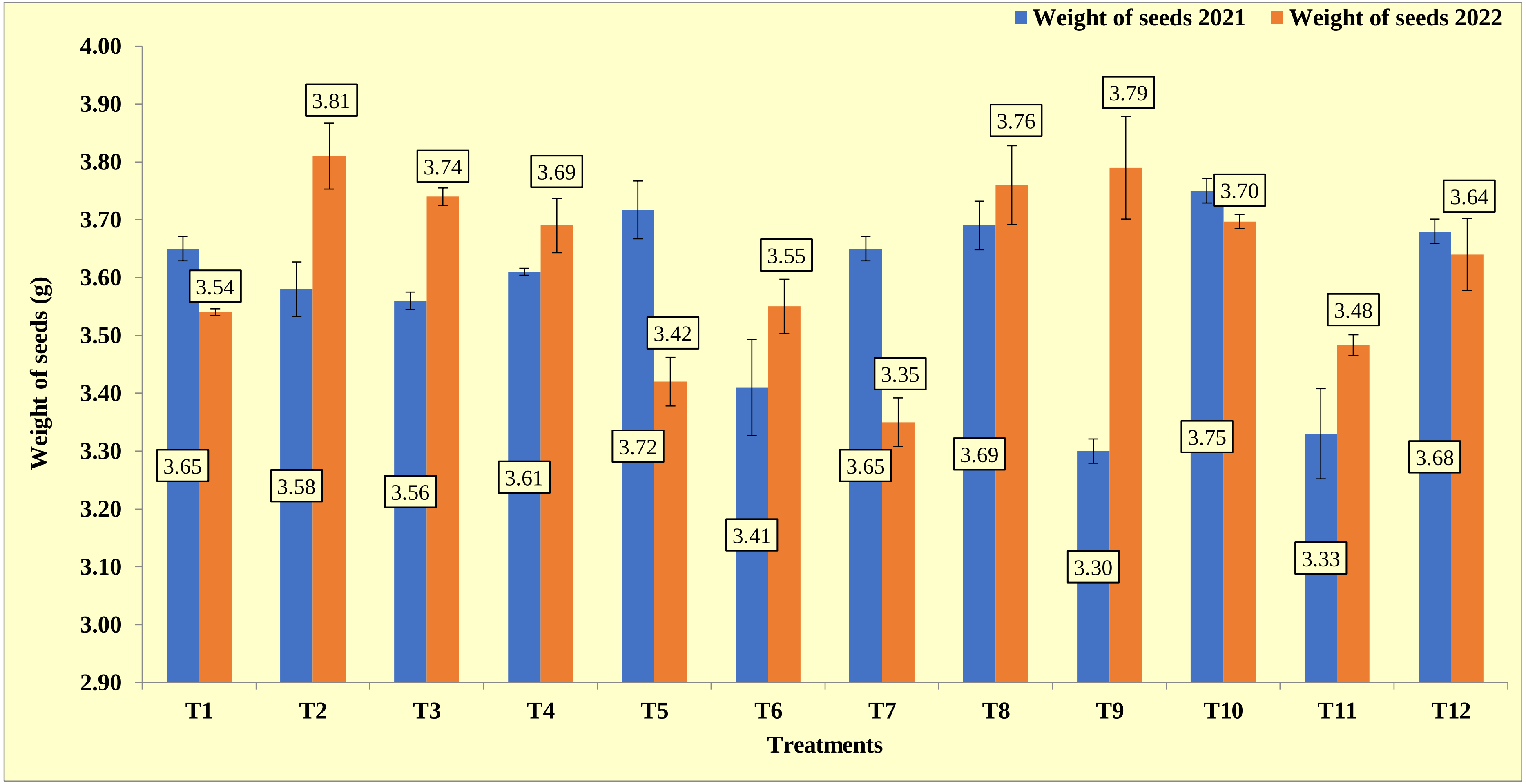

Fig. 10: Effect of *Azotobacter* and nano-micronutrients on weight of seeds in Kinnow mandarin

4.2.8 Peel Weight (g)

Table 4.4 shows the data pertaining to the variation in peel weight during the two years of the experiment (2021 and 2022) along with the pooled data and is represented in Fig. 4.11. Data revealed negligible effect of different micronutrient treatments on peel wt. of Kinnow mandarins during the two years of the trial.

In the initial year of the experiment (2021), it was observed that the maximum peel weight was found in treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], with a recorded weight of 48.66 g. The minimum peel weight (43.51 g) was observed in treatment T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)].

During the second trial year (2022), the maximum peel weight (49.06 g) was observed in the T_2 treatment when RDF + *Azotobacter* + B + Zn were applied. Minimum peel weight (44.37 g) was recorded in treatment T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)].

Two years (2021 and 2022) of pooled data showed that the experiment revealed, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum peel weight, with a recorded value of 48.78 g. On the other hand, treatment T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)] resulted the minimum peel weight, with a recorded value of 44.44 g.

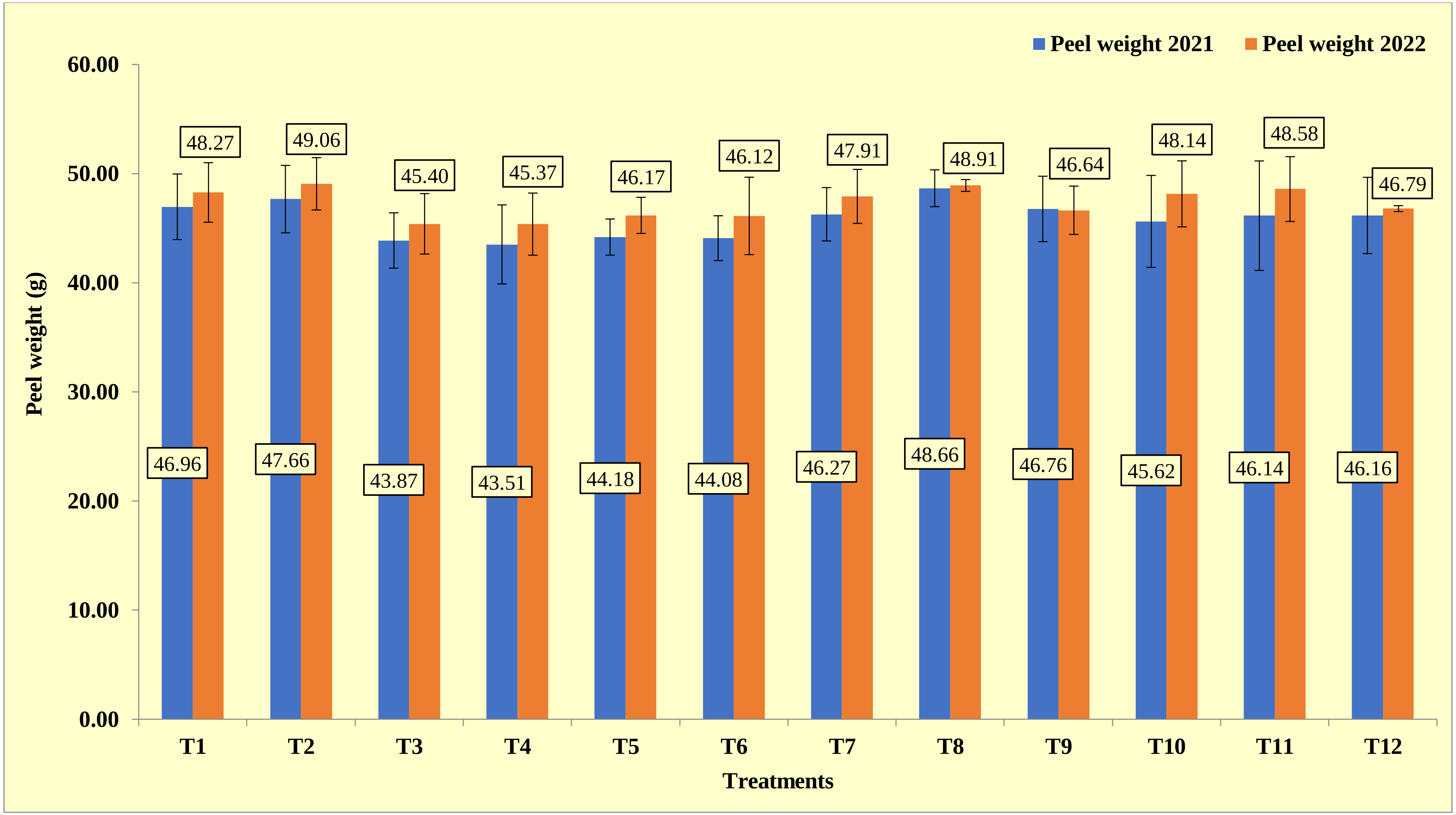

Fig. 11: Effect of *Azotobacter* and nano-micronutrients on peel weight in Kinnow mandarin

Table no. 4.4: Effect of *Azotobacter* and nano micro nutrients on number of seeds per fruit, weight of seeds and peel weight of Kinnow mandarin.

Treatments	Weight of seeds (g)			Peel weight (g)		
	2021	2022	Pooled	2021	2022	Pooled
T_1	3.65^{bcd}	3.54^{bc}	3.60^{bcde}	46.96^{a}	48.27^{a}	47.62^{a}
T_2	3.58^{bc}	3.81^{e}	3.70^{de}	47.66^{a}	49.06^{a}	48.36^{a}
T_3	3.56^{b}	3.74^{de}	3.65^{cde}	43.87^{a}	45.40^{a}	44.63^{a}
T_4	3.61^{bcd}	3.69^{cde}	3.65^{cde}	43.51^{a}	45.37^{a}	44.44^{a}
T_5	3.72^{cd}	3.42^{ab}	3.57^{bcd}	44.18^{a}	46.17^{a}	45.18^{a}
T_6	3.41^{a}	3.55^{bc}	3.48^{ab}	44.08^{a}	46.12^{a}	45.10^{a}
T_7	3.65^{bcd}	3.35^{a}	3.50^{ab}	46.27^{a}	47.91^{a}	47.09^{a}
T_8	3.69^{bcd}	3.76^{de}	3.73^{e}	48.66^{a}	48.91^{a}	48.78^{a}
T_9	3.30^{a}	3.79^{de}	3.55^{bc}	46.76^{a}	46.64^{a}	46.70^{a}
T_{10}	3.75^{d}	3.70^{cde}	3.73^{e}	45.62^{a}	48.14^{a}	46.88^{a}
T_{11}	3.33^{a}	3.48^{ab}	3.41^{a}	46.14^{a}	48.58^{a}	47.36^{a}
T_{12}	3.68^{bcd}	3.64^{cd}	3.66^{cde}	46.16^{a}	46.79^{a}	46.48^{a}
S. Em (±)	0.043	0.05	0.041	3.227	2.483	1.719
C.D (5%)	0.128	0.149	0.12	N/A	N/A	N/A

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

4.2.9 Pulp Weight (g)

Table 4.5 presents the data related to the changes in pulp weight observed throughout the two-year duration of the experiment (2021 and 2022). The pooled data is also illustrated in Figure 4.12. A careful examination of the data reveals a influence of micro nutrient treatments on pulp weight of Kinnow fruits during both years of experiment.

During first year (2021) of trial, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum pulp weight (105.41 g) which was significantly higher than T_3. The other micronutrient treatments had similar patterns in their pulp weight. On the other hand, treatment T_{12} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (200 ppm)] had the lowest pulp weight of 96.63 g.

In the subsequent year of experiment (2022), observed that treatment T_9, which involved the use of RDF + *Azotobacter* + nB (40 ppm) + nZn (200 ppm), resulted in the maximum pulp weight of 105.09 g which was significantly higher than T_3. This finding was not significantly different from most other treatments, except for treatments T_3, T_{10}, T_{11}, and T_{12}. Treatment T_{12} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (200 ppm)] had recorded the minimum pulp weight of 97.25 g, which was similar to treatments T_3, T_{10}, and T_{11}.

When the data from both years (2021 & 2022) was combined, treatment T_9 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (200 ppm)] recorded the maximum pulp weight, reaching a value of 105.01 g which was significantly higher than T_3. On the other hand, treatment T_{12} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (200 ppm)] recorded the lowest pulp weight, measuring 96.60 g.

Micronutrients led to synthesis of metabolites, specifically carbohydrates, and facilitated their movements to fruits. This process resulted in relatively higher pulp content, thereby increasing the overall juice content. This increase in pulp content may be attributed to metabolites were diverted from the source to the sink. These findings align with a previous study by Singh et al. (2012), which observed highest pulp content was obtained in aonla fruit through B, Zn, and Cu sprays. Furthermore, minimal thickness of peel in Kinnow following micronutrients spray may be explained by the using of urea and B. These additions due to zinc and K, which are known to increase thickness of fruit peel, as reported by Eman et al. in 2007.

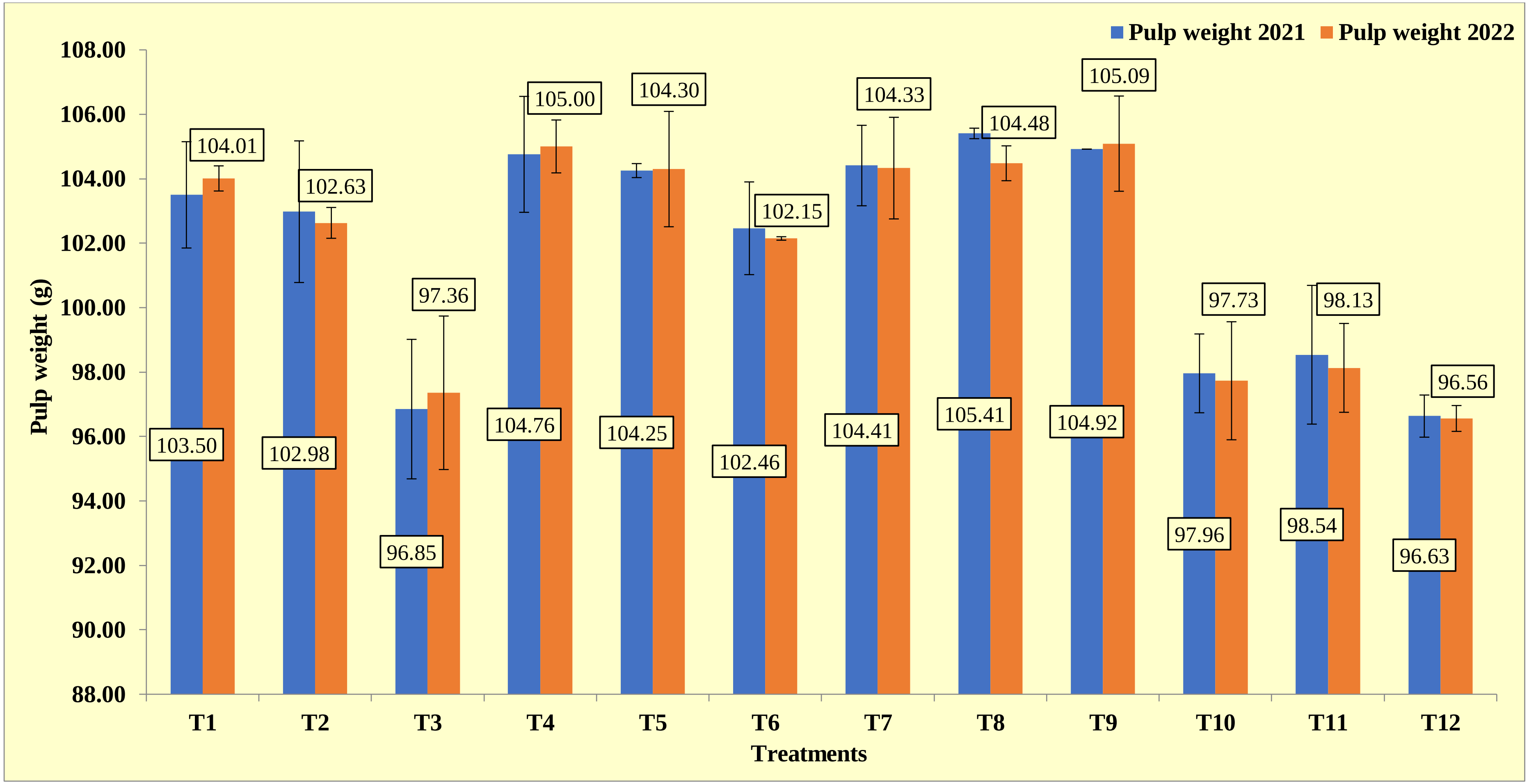

Fig. 12: Effect of *Azotobacter* and nano-micronutrients on pulp weight in Kinnow mandarin

4.2.10 Juice Content (%)

Table 4.5 shows the data on the change in juice content over the two years of the trial (2021 and 2022) together with the aggregated data and is depicted in Fig. 4.13. Data made a significant effect of different micronutrient treatments on the juice content of Kinnow mandarins during the two years of the trial.

During the first trail (2021), an observation was made regarding the percentage of juice content. Treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] displayed a juice content of 57.58%, which was found at par with treatments T_7, T_9, and T_2. These treatments exhibited juice contents of 57.17%, 56.80%, and 55.95% respectively. Conversely, the minimum juice content of 49.61% was in T_3 (RDF + *Azotobacter*), treatments T_{12}, T_{10}, and T_{11} were at par. These treatments had juice contents of 50.14%, 50.71%, and 51.86% respectively.

During the experimental year of 2022, the maximum juice content (58.08%) was observed in treatment T_8, where RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) were applied which was significantly higher than T_3. This result was at par with treatments T_7, T_2, and T_1, which recorded juice contents of 57.67%, 57.30%, and 56.45% respectively. Conversely, the minimum juice content (50.11%) was in T_3 (RDF + *Azotobacter*), treatments T_{10}, T_{11}, and T_{12} were at par. These treatments exhibited juice contents of 50.64%, 51.21%, and 52.36% respectively.

Pooled data for the two years also registered maximum per cent juice content (57.83%) under the treatment T_8 [RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] which was significantly higher than T_3. Minimum juice content (49.86%) was recorded in treatment T_3 (RDF + *Azotobacter*). Statistically, all the treatments found to be significant among each other.

The increase in juice concentrations is linked to role of Zn in promoting production of tryptophan, which has a positive impact on plant growth and fruit development (Razzaq et al., 2013; Khan et al., 2015). Achieving a balanced diet can help maintain an optimal juice-to-fruit size ratio. Previous studies by Mostafa and Saleh (2006) reported that maximum juice weight in 'Kinnow' mandarin was achieved through the combination of nitrogen (N), phosphorus (P), and potassium (K_2O). Furthermore, research has shown that incorporating 75 kg of K_2O per hectare along with N and P significantly improves the fruit's juice ratio (Ashraf et al., 2012). Improper management of nutrients can result in thin-skinned fruit. Nitrogen and potassium are role in cell multiplication and growth processes, which ultimately contribute to the thickness of citrus peels (Omaima & Metally, 2007).

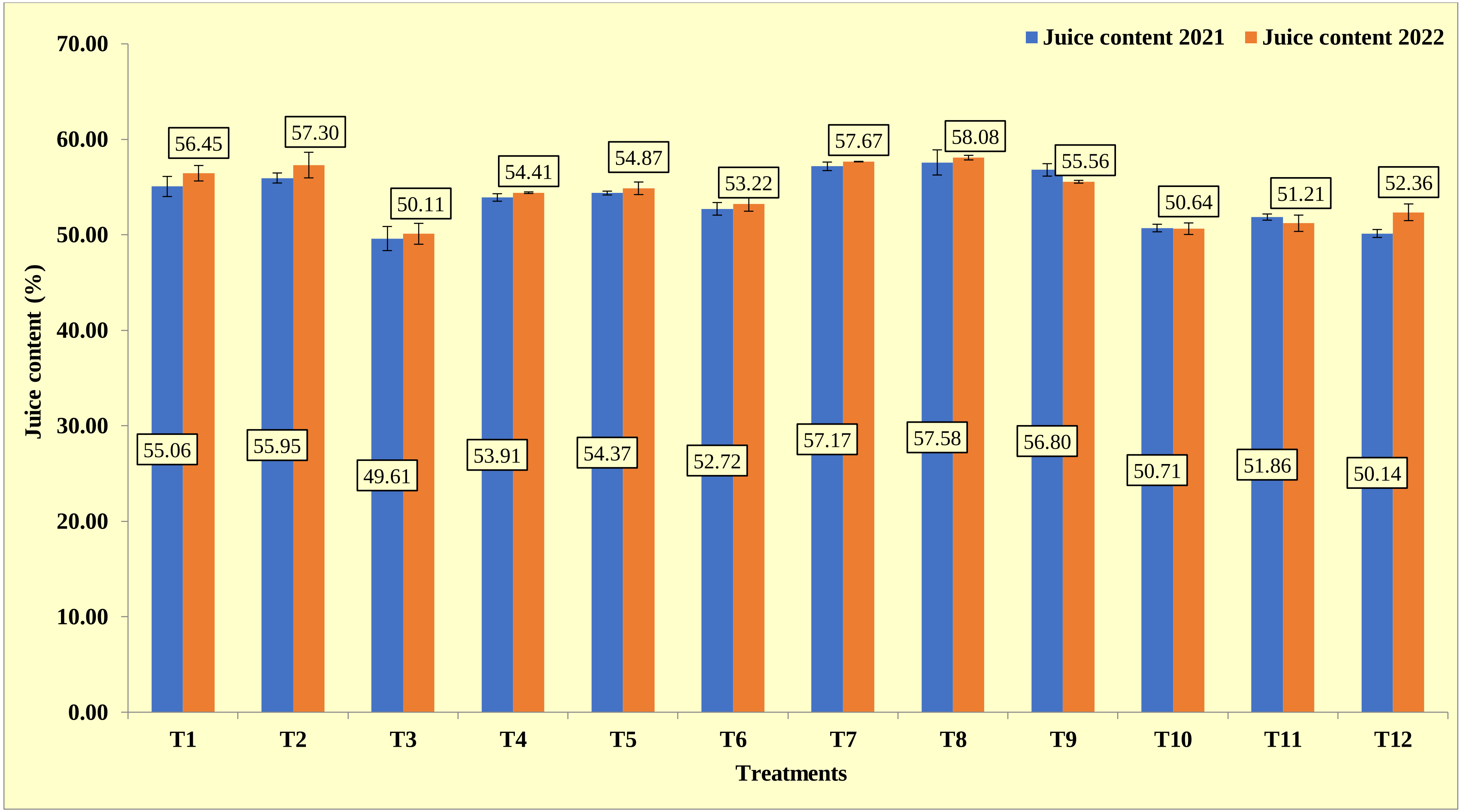

Fig. 13: Effect of *Azotobacter* and nano-micronutrients on juice content in Kinnow mandarin

4.2.11 Fruit Drop (%)

Table 4.5 provides information about the variation in fruit drop observed throughout the two years of the experiment (2021 and 2022). The combined data is also presented in Figure 4.14. A keen perusal of the data indicates there is a significant effect of micro nutrient on fruit drop in Kinnow mandarin during both the years of the experiment.

During the first year of the experiment (2021), maximum fruit drop per cent was in treatment T_3 (RDF + *Azotobacter*) where 48.69 per cent was recorded. The minimum fruit drop was recorded in treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)]. Statistically, all the treatments made significant impact on the fruit drop per cent of the Kinnow plants.

In the second year of the trial (2022), a similar tendency to fruit drop was observed in Kinnow mandarin plants. The maximum fruit drop rate (47.44%) was recorded in treatment T_3, using RDF + *Azotobacter*. This result was at par with treatment T_{12} (46.81%) and T_6 (45.76%). On the other hand, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the minimum fruit drop rate (33.68%).

Data combined for two years (2021 and 2022) showed that treatment T_3 (RDF + *Azotobacter*) had the maximum fruit drop percentage, reaching 48.06%. This was at par with treatment T_{12}. On the other hand, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the lowest fruit drop percentage, measuring 33.91%. Statistically, all the treatments made significant impact on fruit drop per cent of the Kinnow plants.

Fruit retention in Zn applied plants could be due to increased IAA synthesis, which increases auxin levels, which then inhibit synthesis of C_2H_2 to prevent fruit drop (Goren et al., 2000). Zn plays an important part in auxin synthesis, leading to better photosynthesis, more starch accumulation in fruit, and auxin creating stability in the plant, helping to control shedding of fruits and increase the total number of fruits per plant.

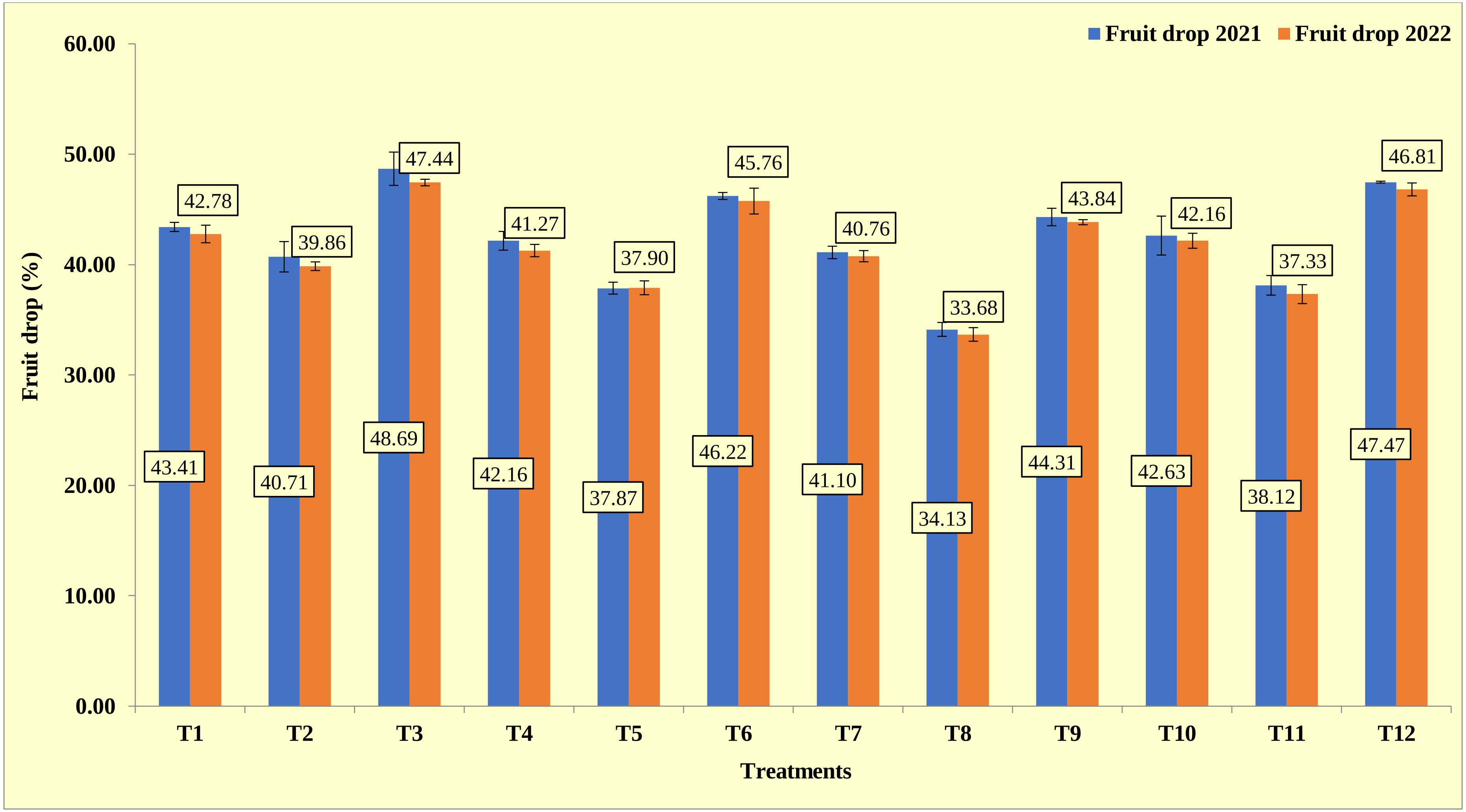

Fig. 14: Effect of *Azotobacter* and nano-micronutrients on fruit drop in Kinnow mandarin

Table no. 4.5: Effect of *Azotobacter* and nano micro nutrients on pulp weight, juice content, fruit drop of Kinnow mandarin.

Treatments	Pulp weight (g)			Juice content (%)			Fruit drop (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	103.50[c]	104.01[b]	103.76[b]	55.06[ef]	56.45[efg]	55.76[fg]	43.41[cde]	42.78[de]	43.10[ef]
T_2	102.98[bc]	102.63[b]	102.80[b]	55.95[efg]	57.30[fg]	56.63[ghi]	40.71[bc]	39.86[c]	40.28[c]
T_3	96.85[a]	97.36[a]	97.10[a]	49.6[a]	50.11[a]	49.86[a]	48.69[f]	47.44[g]	48.06[h]
T_4	104.76[c]	105.00[b]	104.88[b]	53.91[cde]	54.41[cde]	54.16[de]	42.16[cd]	41.27[cd]	41.72[cde]
T_5	104.25[c]	104.30[b]	104.28[b]	54.37[de]	54.87[de]	54.62[ef]	37.87[b]	37.90[b]	37.88[b]
T_6	102.46[bc]	102.15[b]	102.31[b]	52.72[bcd]	53.22[bcd]	52.97[cd]	46.22[ef]	45.76[fg]	45.99[g]
T_7	104.41[c]	104.33[b]	104.37[b]	57.17[fg]	57.67[fg]	57.42[hi]	41.10[c]	40.76[cd]	40.93[cd]
T_8	105.41[c]	104.48[b]	104.94[b]	57.58[g]	58.08[g]	57.83[i]	34.13[a]	33.68[a]	33.91[a]
T_9	104.92[c]	105.09[b]	105.01[b]	56.80[fg]	55.56[def]	56.18[fgh]	44.31[de]	43.84[ef]	44.08[f]
T_{10}	97.96[a]	97.73[a]	97.85[a]	50.71[ab]	50.64[a]	50.68[ab]	42.63[cd]	42.16[de]	42.40[def]
T_{11}	98.54[ab]	98.13[a]	98.33[a]	51.86[abc]	51.21[ab]	51.54[bc]	38.12[b]	37.33[b]	37.73[b]
T_{12}	96.63[a]	96.56[a]	96.60[a]	50.14[a]	52.36[abc]	51.25[ab]	47.47[f]	46.81[g]	47.14[gh]
S. Em (±)	1.503	1.355	0.962	0.737	0.753	0.512	0.929	0.642	0.532
C.D (5%)	4.436	4.001	2.839	2.174	2.221	1.511	2.743	1.895	1.571

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

4.2.12 Number of fruits per tree (no.)

Table 4.6 displays information about the variation in the no. of fruits per tree during the two years of the experiment (2021 and 2022), and it is represented in Figure 4.15. Upon analysing the data, it was found that micronutrient treatments made a significant impact on the fruits/tree in Kinnow mandarins throughout the two years of the trial.

In the study conducted in 2021, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] had highest fruits per tree (530.58) which was significantly higher than T_3. On the other hand, treatment T_3 (RDF + *Azotobacter*) had lowest fruits per tree, with 330.51. Treatment T_6 and T_{12} was found at par with T_3 recording a fruits per tree, with 365.31 and 346.76 respectively.

During 2022 trail, fruits per tree in Kinnow mandarins followed a similar pattern. Treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] yielded the maximum fruits per tree, reaching 554.15 which was significantly higher than T_3. Conversely, treatment T_3 (RDF + *Azotobacter*) had the lowest number of fruits per plant (342.74). These results demonstrate a statistically significant impact on fruit production of Kinnow mandarins.

The two-year (2021 and 2022) aggregated data also noted a trend similar to that observed in the two-year trial. Max. fruits per tree (542.36) was in T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] which was significantly higher than T_3. The minimum fruits per tree (336.62) were in T_3 (RDF + *Azotobacter*).

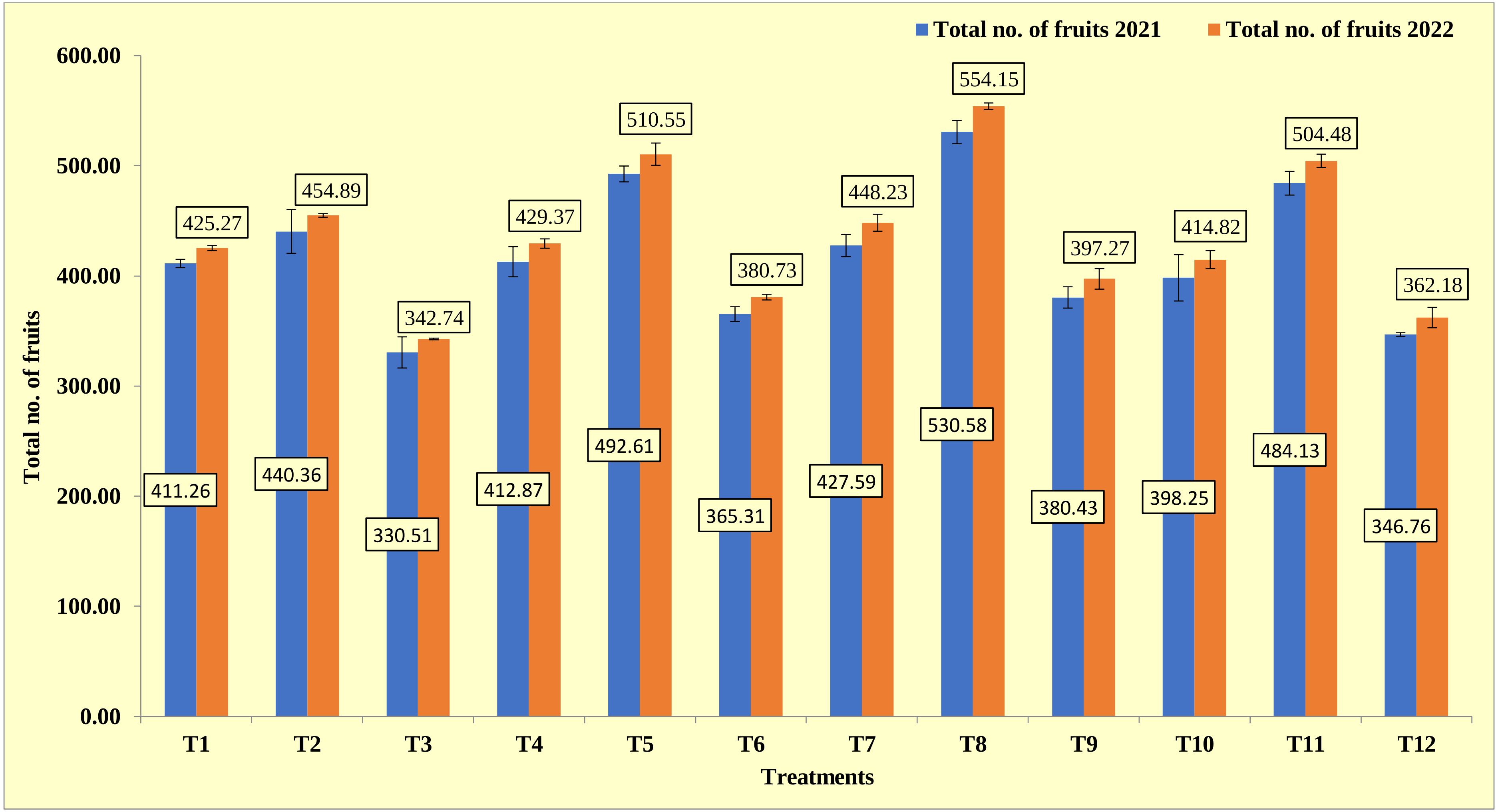

Fig. 15: Effect of *Azotobacter* and nano-micronutrients on number of fruits per plant in Kinnow mandarin

4.2.13 Fruit Yield (Kg/plant)

Table 4.6 presents the data on changes in fruit yield over the two years of the trial (2021 and 2022) together with aggregated data and is depicted in Fig. 4.16. A keen observation of the data indicated that there was a significant impact of different micronutrient treatments on the fruit yield of Kinnow mandarins during the two years of the trial.

During the first year of the experimentation (2021), the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] produced the maximum fruit yield, with 81.78 kg per plant. On the other hand, treatment T_3 (RDF + *Azotobacter*) recorded the minimum fruit yield, with 46.44 kg per plant.

In the second-year trial (2022), the fruit yield of Kinnow mandarin trees followed a similar pattern. The maximum fruit yield of 85.00 kg per tree was observed in treatment T_8, where RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) were applied. This was found to be significantly higher than T_3. On the other hand, the minimum fruit yield of 48.93 kg per tree was in T_3 (RDF + *Azotobacter*).

Similar trend was recorded in both years (2021 and 2022), treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum fruit yield, reaching 83.39 kg/plant which was significantly higher than T_3. On the other hand, treatment T_3 (RDF + *Azotobacter*) had the minimum fruit yield (47.69 kg/plant).

Spraying zinc or boron on the leaves of citrus trees can improve the overall fruit yield. These treatments help with pollen germination, improved the pollen tube, fruit set, & ultimately increase the yield (Qinli, 2003). Boron spray specifically enhances flower production and fruit yield (Maji et al., 2017). When boron and zinc are applied together, trees show a maximum no. fruit compared to untreated plants. This could be attributed to better retention on plant, which reduces fruit drop and increases the yield. Alligned results were found by Ismail (1994) who observed increased yield in Valencia oranges through zinc spray. The positive effects of zinc and boron sprays on citrus yield were also confirmed by Perveen and Rehman (2002), who noted that correcting nutrient deficiencies with these micronutrients led to higher citrus yields. However, boron alone did not produce satisfactory results. These findings align with Mishra et al. (2003) reported micronutrient can be useful for maximizing yield in Kinnow mandarins compared to untreated trees. Tariq et al. (2007) observed a positive link between Zn and B, which increased fruit set, lowered fruit drop, and ultimately led to higher yield in sweet oranges. Findings of Razzaq et al. (2013) and Ullah et al. (2012) for Kinnow mandarin, where foliar application of zinc and boron, respectively, significantly increased the fruit yield.

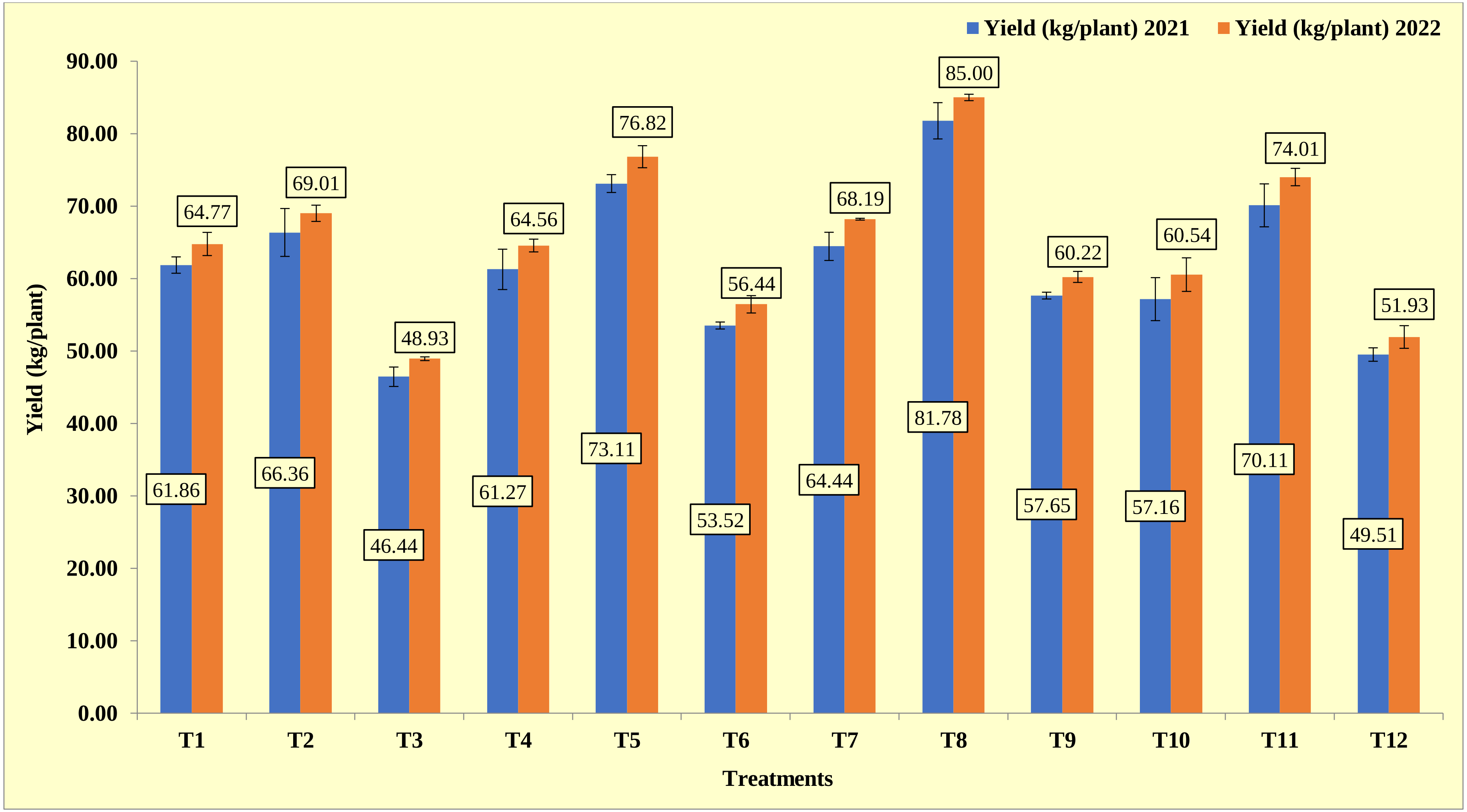

Fig. 16: Effect of *Azotobacter* and nano-micronutrients on yield (kg/plant) in Kinnow mandarin

Table no. 4.6: Effect of *Azotobacter* and nano micro nutrients on number of fruits and fruit yield of Kinnow mandarin.

Treatments	Number of fruits per tree (no.)			Fruit yield (kg/plant)		
	2021	2022	Pooled	2021	2022	Pooled
T_1	411.26^{def}	425.27^{e}	418.26^{ef}	61.86^{de}	64.77^{d}	63.32^{d}
T_2	440.36^{f}	454.89^{f}	447.62^{g}	66.36^{ef}	69.01^{e}	67.69^{e}
T_3	330.51^{a}	342.74^{a}	336.62^{a}	46.44^{a}	48.93^{a}	47.69^{a}
T_4	412.87^{def}	429.37^{e}	421.12^{ef}	61.27^{de}	64.56^{d}	62.91^{d}
T_5	492.61^{g}	510.55^{g}	501.58^{h}	73.11^{g}	76.82^{f}	74.97^{f}
T_6	365.31^{abc}	380.73^{c}	373.02^{bc}	53.52^{bc}	56.44^{b}	54.98^{b}
T_7	427.59^{ef}	448.23^{f}	437.91^{fg}	64.44^{ef}	68.19^{de}	66.32^{de}
T_8	530.58^{h}	554.15^{h}	542.36^{i}	81.78^{h}	85.00^{g}	83.39^{g}
T_9	380.43^{bcd}	397.27^{cd}	388.85^{cd}	57.65^{cd}	60.22^{c}	58.94^{c}
T_{10}	398.25^{cde}	414.82^{de}	406.54^{de}	57.16^{cd}	60.54^{c}	58.85^{c}
T_{11}	484.13^{g}	504.48^{g}	494.31^{h}	70.11^{fg}	74.01^{f}	72.06^{f}
T_{12}	346.76^{ab}	362.18^{b}	354.47^{ab}	49.51^{ab}	51.93^{a}	50.72^{a}
S. Em (±)	12.012	6.528	6.847	2.092	1.284	1.26
C.D (5%)	35.458	19.269	20.21	6.176	3.79	3.718

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

4.3 Fruit Quality Parameters

4.3.1 Total Soluble Solids (°Brix)

Table 4.7 shows the TSS data for the duration of the experiment, encompassing the years 2021 and 2022. The table also includes the combined data, and a visual representation can be found in Figure 4.17. Examination of the data reveals a significant impact of various micronutrient treatments on the TSS levels in Kinnow mandarin throughout both years of the experiment.

In the first year of the experiment (2021), maximum TSS was under T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], recording 11.29 °Brix. This was at par with TSS for treatments T_5, T_{11}, T_7, and T_4 recording a value of 11.23, 11.13, 11.07 and 11.03 °Brix respectively. The minimum TSS (10.30 °Brix) was measured with treatment T_3 (RDF + *Azotobacter*), treatments T_{12}, T_6, T_9 and T_1 was at par recording a value of 10.50, 10.57, 10.63 and 10.73 °Brix respectively.

In the subsequent year of the experiment (2022), observations were made regarding the TSS variations. The treatment T_5, involving the application of RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm), exhibited the maximum increase in TSS with a measurement of 11.36 °Brix which was significantly higher than T_3. This finding was at par with to the TSS values recorded under treatments T_8, T_{11}, T_7 and T_4, which were 11.32, 11.30, 11.22, and 11.20 °Brix, respectively. Conversely, the treatment T_3 (RDF+ *Azotobacter*) demonstrated the lowest TSS value of 10.26 °Brix, T_{12}, T_6, and T_9 treatments were at par, recording TSS values of 10.58, 10.61, and 10.61 °Brix, respectively.

Combined data from both years (2021 and 2022), it was observed that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] demonstrated the maximum TSS value of 11.31 °Brix which was significantly higher than T_3. Remarkably, this finding was at par with the TSS levels observed in treatments T_4, T_5, T_7, T_{10}, and T_{12}. On the other hand, the treatment T_3 (RDF + *Azotobacter*) displayed the minimum TSS value of 10.28 °Brix, which was at par with TSS levels observed in treatments T_6, T_9, and T_{12}.

The observed increase in TSS resulting from the application of nutrient combinations may be attributed to several factors. Firstly, it could be linked to an enhancement in photosynthesis activity, as noted by Kulkarni in 2004. Sugars from source to sink and the conversion of polysaccharides to simpler forms such as glucose and fructose in fruits, as described by Eman et al. in 2007, may contribute to the increased TSS. These processes are facilitated by the heightened enzymatic activities stimulated by Zn and potassium. Findings are in aligning with previous research conducted by other investigators. For instance, Gurung et al. in 2016 reported the highest TSS in Kinnow mandarin when foliar application of GA_3 with zinc and boron was implemented. Mishra et al. in 2003 also observed that the foliar application of Zn + B led to increased TSS in Kinnow mandarin fruits. Ashraf et al. in the same study noted that foliar spray of potassium (K) with zinc (Zn) enhanced the TSS of Kinnow fruits. Collectively, these findings suggest that the application of specific nutrient combinations and minerals, such as zinc, potassium, phosphorus, and boron, can positively influence enzymatic activities and metabolic processes related to sugar, protein, and acid metabolism, leading to an increase in TSS levels in Kinnow mandarin and other related fruits.

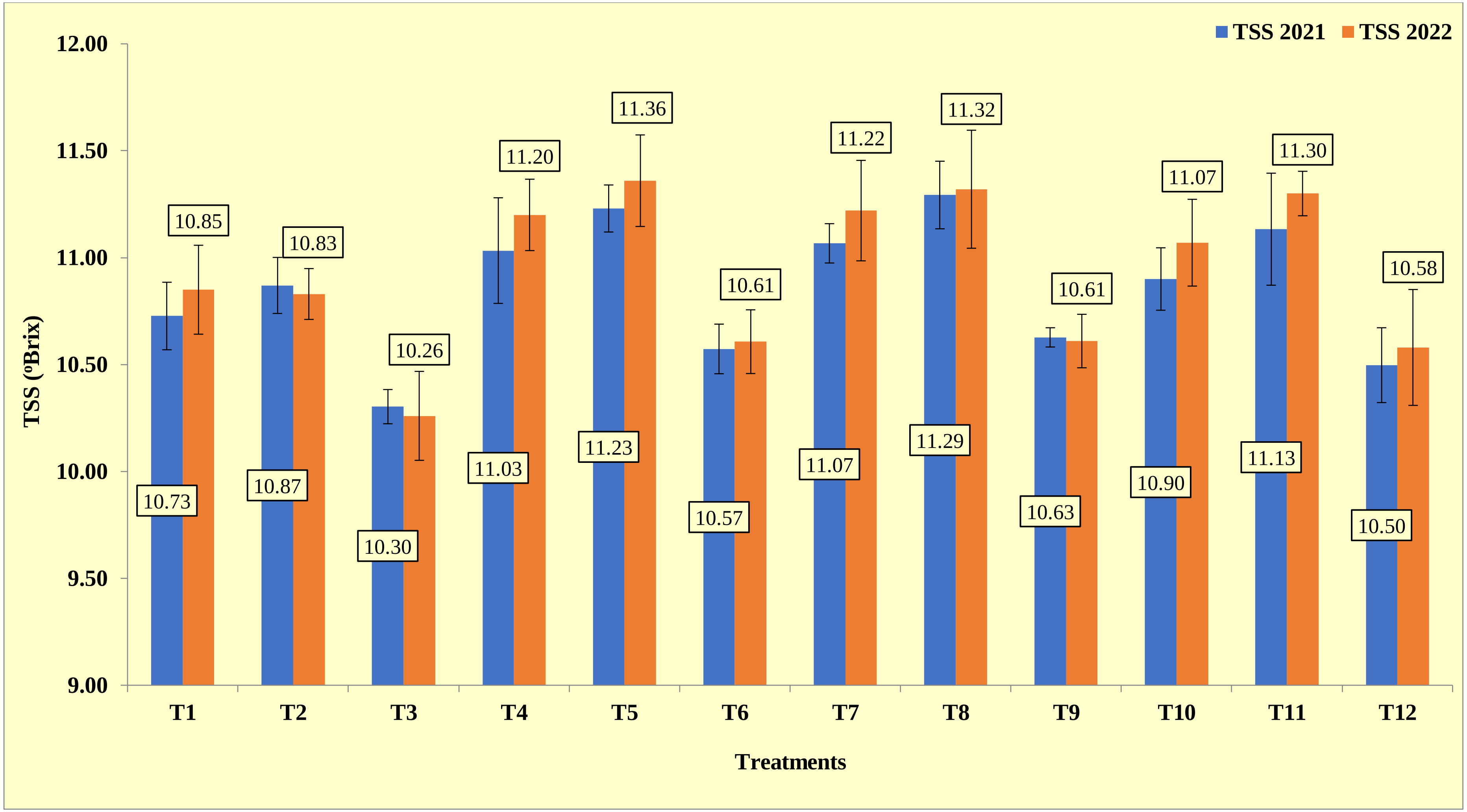

Fig. 17: Effect of *Azotobacter* and nano-micronutrients on TSS in Kinnow mandarin

4.3.2 Titratable Acidity (%)

Table 4.7 shows the data pertaining to the variation in titratable acidity during the two years of the experiment (2021 and 2022) along with the pooled data and is represented in Fig. 4.18. A keen perusal of the data indicates that there is a non-significant effect of different micro nutrient treatments on titratable acidity in Kinnow mandarin during both the years of the experiment.

During the first year of the experiment (2021), maximum titratable acidity was under T_{1}, T_{8}, and T_{9} where 0.81 per cent was recorded. Minimum titratable acidity (0.78%) was recorded in treatment T_{3} and T_{12}.

In the second trial year (2022), statistically, treatments made a non-significant impact on the titratable acidity of Kinnow mandarin fruits. Maximum titratable acidity (0.82) was recorded under treatment T_{1}, T_{2}, and T_{7}. Minimum titratable acidity (0.79) was in T_{3} (RDF+ *Azotobacter*).

Aggregate data from both years (2021 and 2022), it was found that treatments T_{1}, T_{2}, T_{7} and T_{8} gave the maximum titratable acidity, with a value of 0.82. In contrast, treatments T_{3} and T_{12} had the lowest titratable acidity, with a value of 0.79. However, based on statistical analysis of the data, it was non-significant effect was observed on the titratable acidity of the Kinnow mandarin fruits among the treatments.

The elevated acidity levels observed in the Kinnow fruits are contradictory to the desired quality characteristics. The reduction in acidity resulting from nutrient spray treatments may be attributed to metabolic processes involving the conversion of organic acids into sugars. The findings of our study align with previous research conducted by scientists reported lower acidity levels in the fruit juice receiving balanced nutrition, as compared control (Kazi et al., 2012).

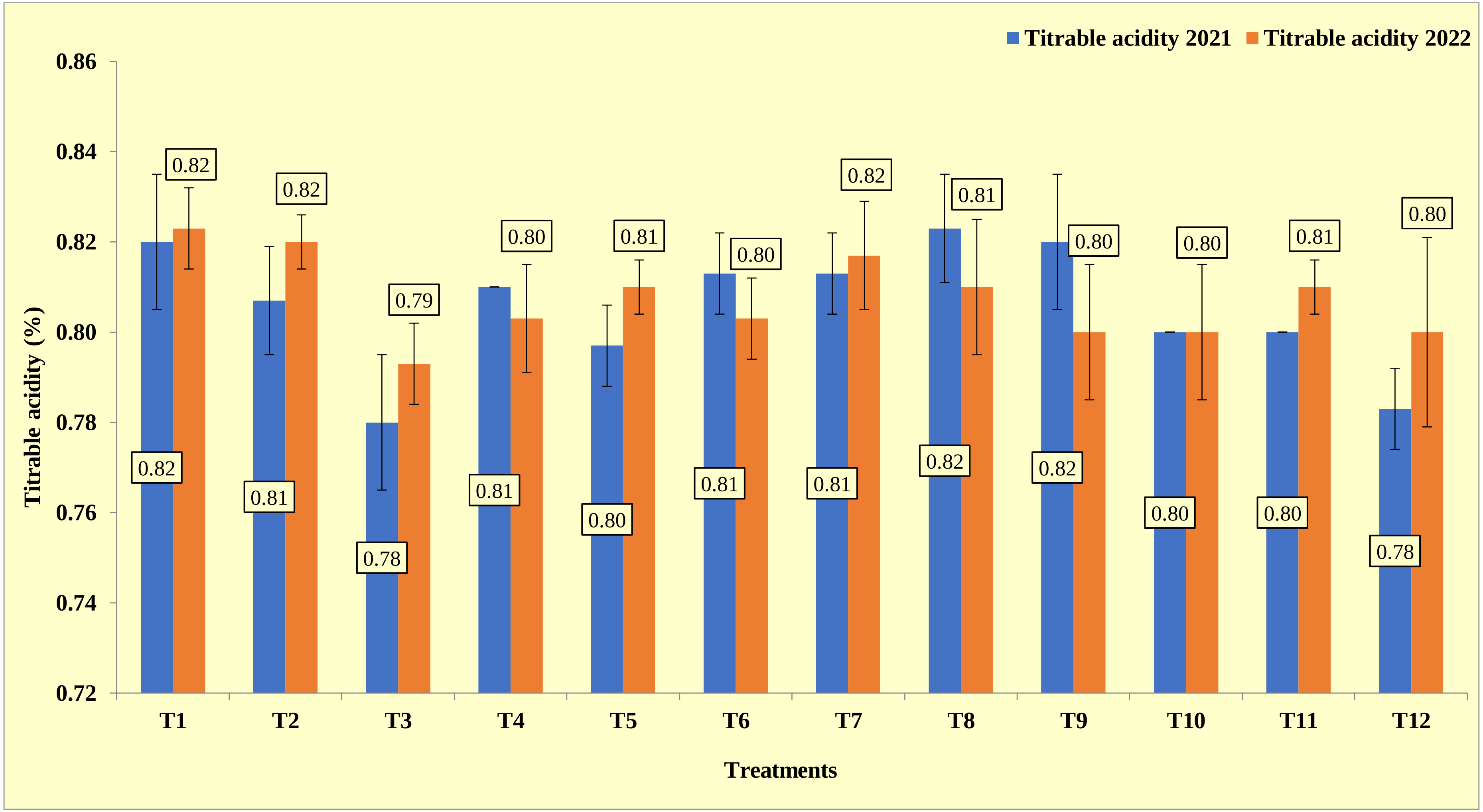

Fig. 18: Effect of *Azotobacter* and nano-micronutrients on titrable acidity in Kinnow mandarin

4.3.3 TSS Acid Ratio

Table 4.7 presents the data regarding the TSS:Acid ratio variation during the two-year experimental period (2021 and 2022), and this information is graphically depicted in Figure 4.19. Upon careful examination of the data, it becomes evident that there is no impact of the micronutrient treatments on the TSS acid ratio in Kinnow mandarin throughout both years of the experiment. However, when considering the pooled data, there is a notable significance observed among the treatments regarding the TSS:Acid ratio in Kinnow mandarin.

In the initial year of the experiment (2021), the treatment T_5 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm)] exhibited the maximum TSS/acid ratio, recording a value of 14.04. However, upon statistical analysis, it was found that none treatments had a significant impact on the TSS/acid ratio on Kinnow mandarin fruits among the treatments. The treatment T_9 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (200 ppm)] resulted in the minimum TSS:acid ratio, measuring 12.96.

In the second year of the experimentation (2022), the treatment T_5, involving the application of RDF+ *Azotobacter*+ nB (20 ppm) + nZn (150 ppm), exhibited the maximum TSS:acid ratio, measuring 14.02. On the other hand, the treatment T_3 (RDF+ *Azotobacter*) resulted in the minimum TSS/acid ratio of 12.99. Statistically, all the treatments had a non-significant effect on TSS/acid of the Kinnow mandarin fruits

The combined data from both years (2021 and 2022) revealed that the treatment T_5 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm)] exhibited the maximum TSS:acid ratio, measuring 14.03 which was significantly higher than T_3. Notably, this value was statistically at par to the TSS:acid ratios observed in treatments T_4, T_7, T_8, and T_{10}. On the other hand, the treatment T_3 (RDF + *Azotobacter*) recorded the minimum TSS/acid ratio of 13.10, which was found to be significant with treatment T_4, $T_{8,}$ and T_{11}.

Scientists have noticed improvement in TSS/acid when applying K and micronutrients in oranges (Abd-Allah, 2006). Some workers have suggested a similar improvement in TSS/acid ratio when applying Zn + Mn @1000 ppm each(Kaur et al., 2015).

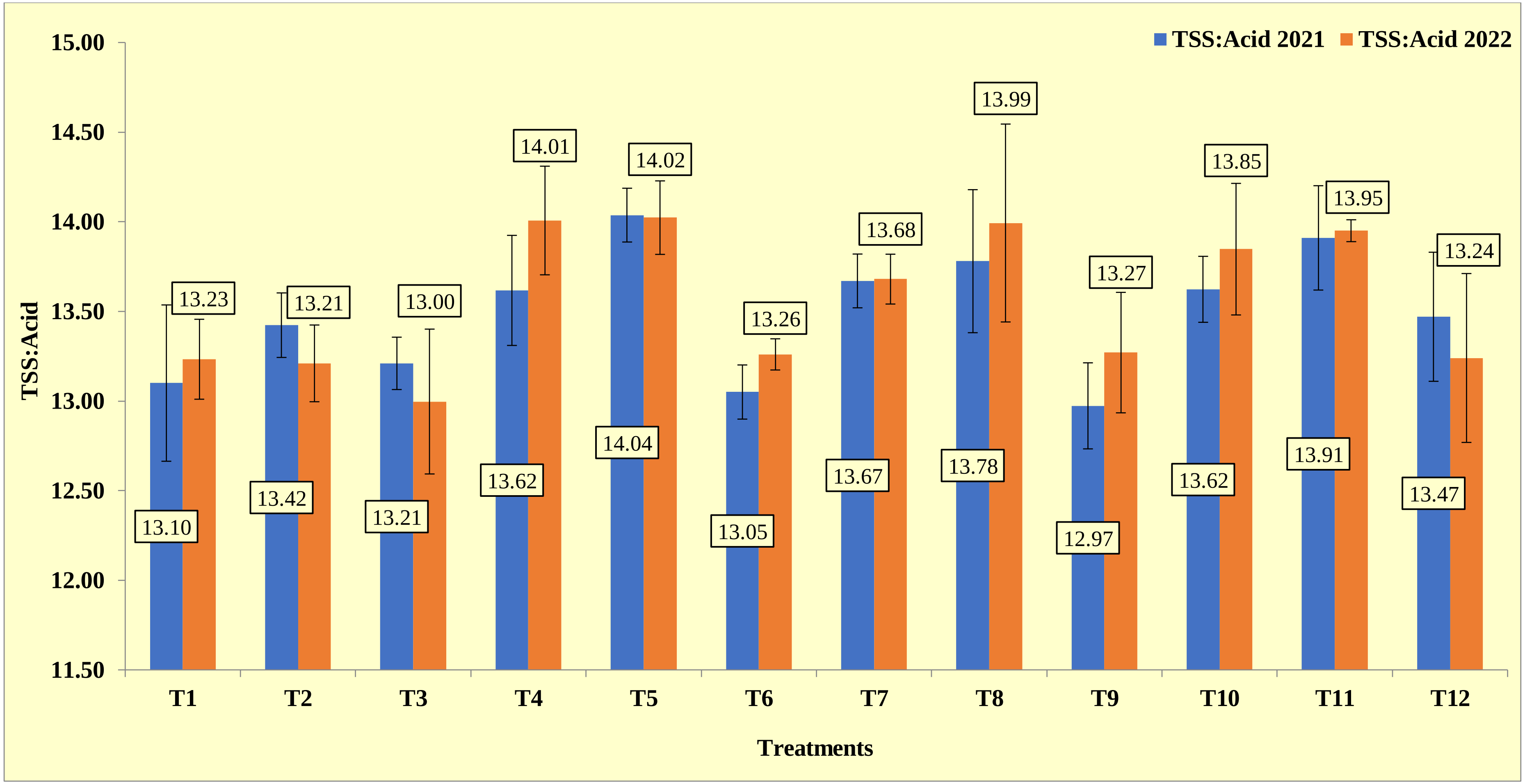

Fig. 19: Effect of *Azotobacter* and nano-micronutrients on TSS:Acid in Kinnow mandarin

Table no. 4.7: Effect of *Azotobacter* and nano micro nutrients on TSS, titrable acidity and TSS acid ratio of Kinnow mandarin.

Treatments	TSS (°Brix)			Titrable acidity (%)			TSS:Acid		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	10.73^{abcde}	10.85^{abc}	10.79^{bc}	0.82^{b}	0.82^{a}	0.82^{a}	13.09^{ab}	13.23^{a}	13.16^{ab}
T_2	10.87^{bcdef}	10.83^{abc}	10.85^{bcd}	0.81^{ab}	0.82^{a}	0.82^{a}	13.42^{abc}	13.21^{a}	13.31^{abc}
T_3	10.30^{a}	10.26^{a}	10.28^{a}	0.78^{a}	0.79^{a}	0.79^{a}	13.21^{abc}	12.99^{a}	13.10^{a}
T_4	11.03^{cdef}	11.20^{bc}	11.12^{cde}	0.81^{ab}	0.80^{a}	0.81^{a}	13.62^{abc}	14.00^{a}	13.81^{bcd}
T_5	11.23^{ef}	11.36^{c}	11.30^{e}	0.80^{ab}	0.81^{a}	0.81^{a}	14.04^{c}	14.02^{a}	14.03^{d}
T_6	10.57^{abc}	10.61^{ab}	10.59^{ab}	0.81^{ab}	0.80^{a}	0.81^{a}	13.05^{ab}	13.26^{a}	13.16^{ab}
T_7	11.07^{cdef}	11.22^{bc}	11.15^{cde}	0.81^{ab}	0.82^{a}	0.82^{a}	13.67^{abc}	13.68^{a}	13.67^{abcd}
T_8	11.29^{f}	11.32^{c}	11.31^{e}	0.82^{b}	0.81^{a}	0.82^{a}	13.77^{abc}	13.98^{a}	13.87^{cd}
T_9	10.63^{abcd}	10.61^{ab}	10.62^{ab}	0.82^{b}	0.80^{a}	0.81^{a}	12.96^{a}	13.26^{a}	13.11^{a}
T_{10}	10.90^{bcdef}	11.07^{bc}	10.99^{cde}	0.80^{ab}	0.80^{a}	0.80^{a}	13.63^{abc}	13.84^{a}	13.73^{abcd}
T_{11}	11.13^{def}	11.30^{c}	11.22^{de}	0.80^{ab}	0.81^{a}	0.81^{a}	13.91^{bc}	13.95^{a}	13.93^{cd}
T_{12}	10.50^{ab}	10.58^{ab}	10.54^{ab}	0.78^{a}	0.80^{a}	0.79^{a}	13.46^{abc}	13.23^{a}	13.34^{abc}
S. Em (±)	0.161	0.192	0.111	0.01	0.011	0.009	0.277	0.328	0.206
C.D (5%)	0.474	0.565	0.329	N/A	N/A	N/A	N/A	N/A	0.608

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

4.3.4 Ascorbic acid (mg/100ml of juice)

Table 4.8 shows the data pertaining to the variation in ascorbic acid during the two years of the experiment (2021 and 2022) along with the pooled data and is represented in Fig. 4.20. A keen perusal of the data indicates that there is a significant effect of different micro nutrient treatments on ascorbic acid in Kinnow mandarin during both the years of the experiment.

In the study conducted in 1st year trial (2021), max. ascorbic acid was under T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] where 25.85 mg/100ml of juice was recorded, which were at par with treatment T_5 recording a value of 25.81 mg/100ml of juice. Statistically, all the treatments had a significant effect on the per cent increase in the ascorbic acid of the Kinnow mandarin fruits. Min. ascorbic acid (20.49 mg/100ml of juice) was in T_3 (RDF + *Azotobacter*).

During the second year of experimentation (2022), maximum ascorbic acid (26.29 mg/100ml of juice) was under T_8 where application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) was done, this was found to be significantly higher than T_3. Min. ascorbic acid (20.84 mg/100ml of juice) was in T_3 (RDF + *Azotobacter*).

Analysed data from the two years (2021 and 2022) registered maximum ascorbic acid (26.07 mg/100ml of juice) under the treatment T_8 [(RDF + *Azotobacter*+ nB (40 ppm) + nZn (150 ppm)] which was at par with treatment T_5. Min. ascorbic acid (20.67 mg/100ml of juice) was in T_3 (RDF + *Azotobacter*), which was found to be significant among all the treatment.

Zinc sprays have a significant effect on improving the chemical traits of Kinnow fruits, particularly the content of ascorbic acid. This is because zinc plays a crucial role in the synthesis of auxins, which are plant hormones that contribute to fruit development (Razzaq et al., 2013). Increased auxin synthesis has been associated with maximum accumulation of vitamin C in Kinnow fruits. Additionally, foliar application of potassium has also been found to increase the ascorbic acid content, possibly by improving sugar metabolism in the fruit (Nawaz et al., 2008). The findings of this study align with previous research that reported higher ascorbic acid content in fruits treated with combinations of 2,4-D, zinc, & potassium or salicylic acid, zinc, & potassium (Ashraf et al., 2012). Other scientists have also observed maximum ascorbic acid content in fruits treated with potassium nitrate and 2,4-D or potassium nitrate and zinc sulphate (Gurjar and Rana, 2014).

4.3.5 Polyphenols (mg GAE/100g fresh weight)

Table 4.8 shows the polyphenols variation data for the two experimental years (2021 and 2022) together with the aggregated data and is depicted in Fig. 4.21. A keen reading of the data indicated that there was a significant effect of different micronutrient treatments on the Kinnow mandarin polyphenols during the two years of the trial.

During the primary year of the trial (2021), observed that the maximum polyphenol content (61.55 mg GAE/100 g fresh weight) was recorded T_3 (RDF + *Azotobacter*) treatment. This was found to be at par with T_{12} and T_{10} treatments registering values of 59.81 and 59.35 mg GAE/100 g fresh weight, respectively. Minimal polyphenols (54.78 mg GAE/100 g fresh weight) were recorded in treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], treatment T_7, T_2, T_1 and T_9 were at par, recording a value of 55.59, 56.42, 56.78, and 57.33 mg GAE/100g fresh weight respectively.

In the 2022 year experiment, treatment T_3 (RDF+ *Azotobacter*) exhibited the maximum polyphenol content, measuring 61.34 mg GAE/100g fresh weight. Conversely, the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] had the minimum polyphenol content, measuring 53.86 mg GAE/100g fresh weight. This result was par with T_7, T_2, T_1, T_9, T_4, and T_5 recording a value of 54.68, 55.81, 56.41, 56.92, 57.13 and 57.13 mg GAE/100g fresh weight respectively.

Pooled data from the two years (2021 and 2022) experiment revealed that the treatment T_3 (RDF + *Azotobacter*) exhibited the maximum polyphenol content, measuring 61.45 mg GAE/100g fresh weight. Conversely, the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] had the lowest polyphenol content, measuring 54.32 mg GAE/100g fresh weight, which was at par with treatment T_7.

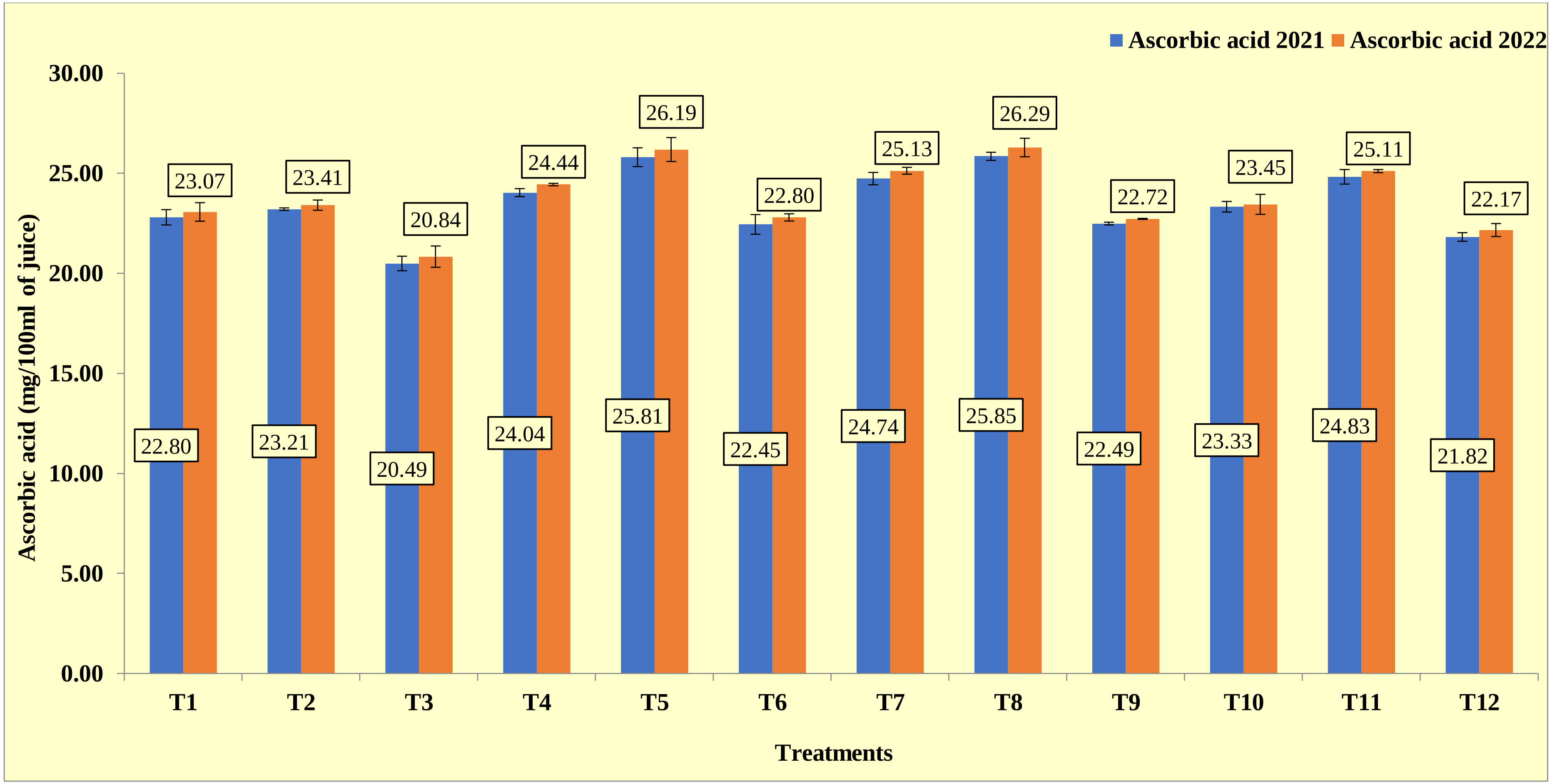

Fig. 20: Effect of *Azotobacter* and nano-micronutrients on ascorbic acid in Kinnow mandarin

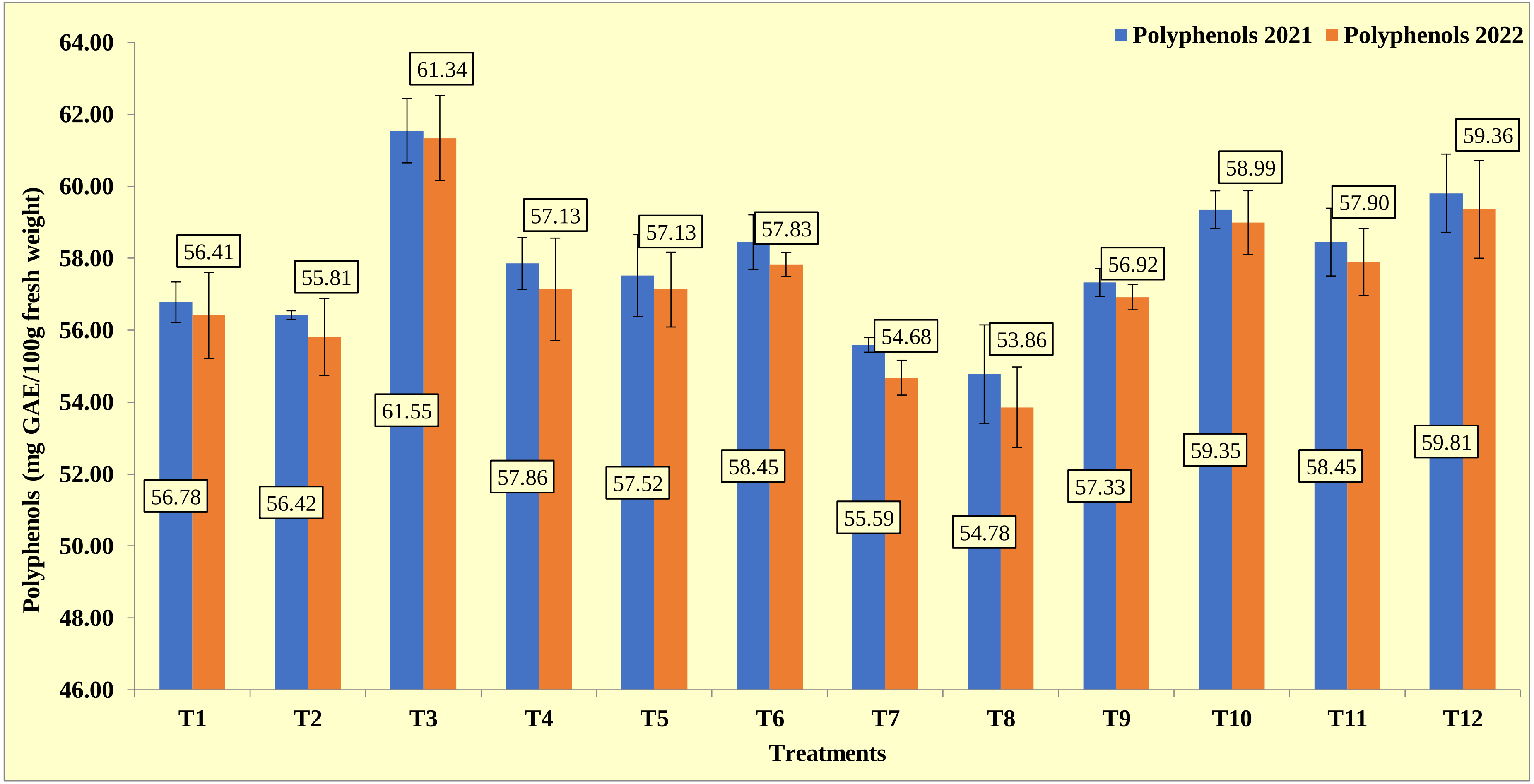

Fig. 21: Effect of *Azotobacter* and nano-micronutrients on polyphenols in Kinnow mandarin

Table no. 4.8: Effect of *Azotobacter* and nano micro nutrients on ascorbic acid and polyphenols of Kinnow mandarin.

Treatments	Ascorbic acid (mg/100ml of juice)			Polyphenols (mg GAE/100g fresh weight)		
	2021	2022	Pooled	2021	2022	Pooled
T_1	22.80^{bc}	23.07^{bc}	22.94^{c}	56.78^{abcd}	56.41^{abcd}	56.60^{bcd}
T_2	23.21^{cd}	23.41^{cd}	23.31^{c}	56.42^{abc}	55.81^{abc}	56.12^{abc}
T_3	20.49^{a}	20.84^{a}	20.67^{a}	61.55^{f}	61.34^{e}	61.45^{g}
T_4	24.04^{de}	24.44^{de}	24.24^{d}	57.86^{bcde}	57.13^{abcd}	57.50^{cde}
T_5	25.81^{f}	26.19^{fg}	26.00^{e}	57.52^{bcde}	57.13^{abcd}	57.33^{cde}
T_6	22.45^{bc}	22.80^{bc}	22.63^{bc}	58.45^{cde}	57.83^{bcd}	58.14^{def}
T_7	24.74^{e}	25.13^{ef}	24.94^{d}	55.59^{ab}	54.68^{ab}	55.14^{ab}
T_8	25.85^{f}	26.29^{g}	26.07^{e}	54.78^{a}	53.86^{a}	54.32^{a}
T_9	22.49^{bc}	22.72^{bc}	22.61^{bc}	57.33^{abcde}	56.92^{abcd}	57.13^{cd}
T_{10}	23.33^{cd}	23.45^{cd}	23.39^{c}	59.35^{def}	58.99^{cde}	59.17^{ef}
T_{11}	24.83^{e}	25.11^{ef}	24.97^{d}	58.45^{cde}	57.90^{bcd}	58.18^{def}
T_{12}	21.82^{b}	22.17^{b}	22.00^{b}	59.81^{ef}	59.36^{de}	59.59^{f}
S. Em (±)	0.293	0.351	0.266	0.849	1.044	0.613
C.D (5%)	0.865	1.037	0.785	2.505	3.083	1.809

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

4.3.6 Total Sugars (%)

Table 4.9 and Fig. 4.22 illustrate the variation in total sugars during the two years of the experiment (2021 and 2022), including the pooled data. A thorough examination of the data reveals significant effect of various micro nutrient treatments on the total sugar content in Kinnow mandarin throughout both years of the experiment.

In the experiment of 2021, the maximum level of total sugars (5.92%) in Kinnow mandarin fruits was observed under treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] during the first year (2021) which was significantly higher than T_3. Treatment T_3 (RDF + *Azotobacter*) exhibited the minimum total sugar content (5.31%) among all the treatments.

During the second trail conducted in 2022, the maximum level of total sugars (5.98%) in Kinnow mandarin fruits was observed under treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] which was significantly higher than T_3. Treatment T_3 (RDF + *Azotobacter*) exhibited the minimum total sugar content (5.34%).

Combining the data from both years (2021 and 2022), found that the T_8 treatment [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the maximum total sugar content (5.95%) in Kinnow mandarin fruits. This was at par to total sugar levels observed with treatments T_2, T_4, T_5, T_7, T_{10}, and T_{11}. In contrast, the total sugar content of treatment T_3 (RDF + *Azotobacter*) was the lowest among all treatments (5.33%).

The presence of nitrogen in the fertilizers stimulates the activity of enzymes involved in various physiological processes, leading to an increase in TSS of the fruits. Higher levels of sugars observed in the study can be due to nitrogen role in facilitating energy sources such as amino sugars and acid. Similar findings were reported by Sharma et al. (2013), who observed improved total soluble solids and sugar content in guava fruits with the application of biofertilizers and organic manure. Khan et al. (2015) also found that foliar sprays of boron (B) and zinc (Zn) significantly affected the sugar content of Kinnow fruits. The increase in sugar levels may be attributed to the effects of B and Zn sprays on the enzyme aldolase, which plays a role in fruit sugar formation, as discussed by Alloway (2008) and Ullah et al. (2012).

4.3.7 Reducing Sugars (%)

Table 4.9 shows the data pertaining to the variation in reducing sugars experiment (2021 and 2022) along with the pooled data and is represented in Fig. 4.23. A keen perusal of data indicates that there is a non-significant effect of different micro nutrient treatments on reducing sugars in Kinnow mandarin during both the years of the experiment.

First year of experiment (2021), it was observed that maximum reducing sugars were recorded under the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] where 2.82 per cent was recorded. This was followed by treatment T_5 recording reducing sugars 2.81 per cent. All other micronutrient treatments recorded a near similar trend in reducing sugars. Minimum total sugars (2.70%) were recorded in treatment T_3 (RDF + *Azotobacter*).

During the second year of experimentation (2022), similar trend was observed regarding reducing sugars in the Kinnow mandarin fruits. Maximum reducing sugars (2.84%) were recorded under treatment T_8 where application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) was done. This was followed by treatments T_5, T_7, and T_{11} recording reducing sugars content of 2.82%, 2.80%, and 2.78% respectively. Minimum reducing sugars (5.34%) were recorded in treatment T_3 (RDF + *Azotobacter*).

Pooled data for the two years also registered the same trend as observed in the two years of the experimentation. Statistically, all the treatments had a non-significant effect on reducing sugars of the Kinnow mandarin fruits among each other. Maximum reducing sugars (2.83%) was recorded under the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)]. Minimum reducing sugars (2.71%) were recorded in treatment T_3 (RDF+ *Azotobacter*).

4.3.8 Non-Reducing Sugars (%)

Data in Table 4.9 represents the variation in non-reducing sugars over the course of the two-year experiment (2021 and 2022). This information is also visually depicted in Figure 4.24.

During the trail conducted in 2021, maximum amount of non-reducing sugar (3.10%) was in T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)]. The lowest amount of non-reducing sugars (2.61%) was in T_3 (RDF + *Azotobacter*).

In the second year of experimentation (2022), similar trend was observed regarding non-reducing sugars in the Kinnow mandarin fruits. Maximum non-reducing sugars (3.14%) were recorded under treatment T_8 where application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) was done. The minimum non-reducing sugars (2.63%) were recorded in treatment T_3 (RDF + *Azotobacter*).

Trend observed in the two-year experimentation (2021 and 2022) remained same with the pooled data. Maximum non-reducing sugars (3.12%) were under T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)]. Minimum non-reducing sugars (2.62%) were recorded in treatment T_3 (RDF+ *Azotobacter*).

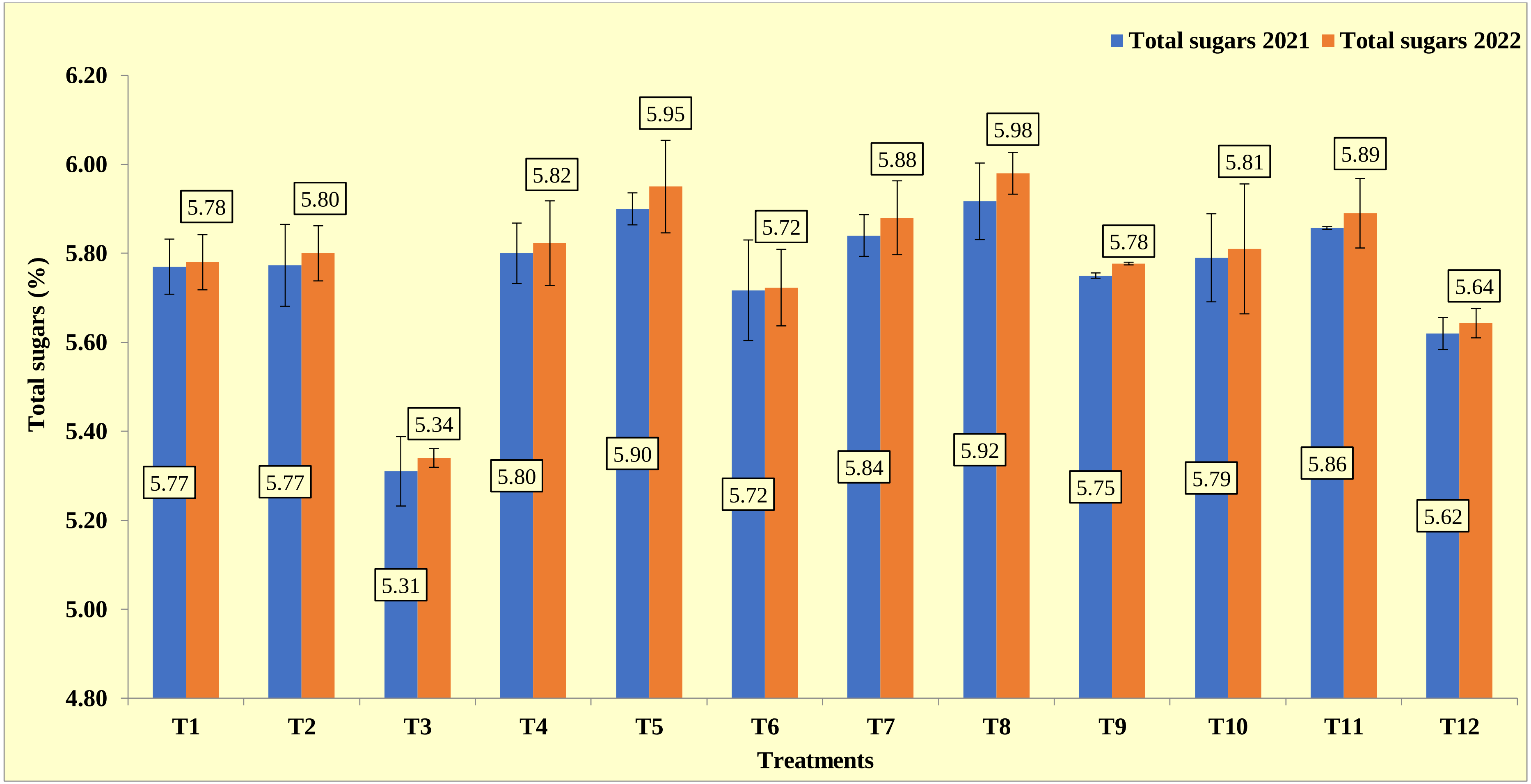

Fig. 22: Effect of *Azotobacter* and nano-micronutrients on total sugars in Kinnow mandarin

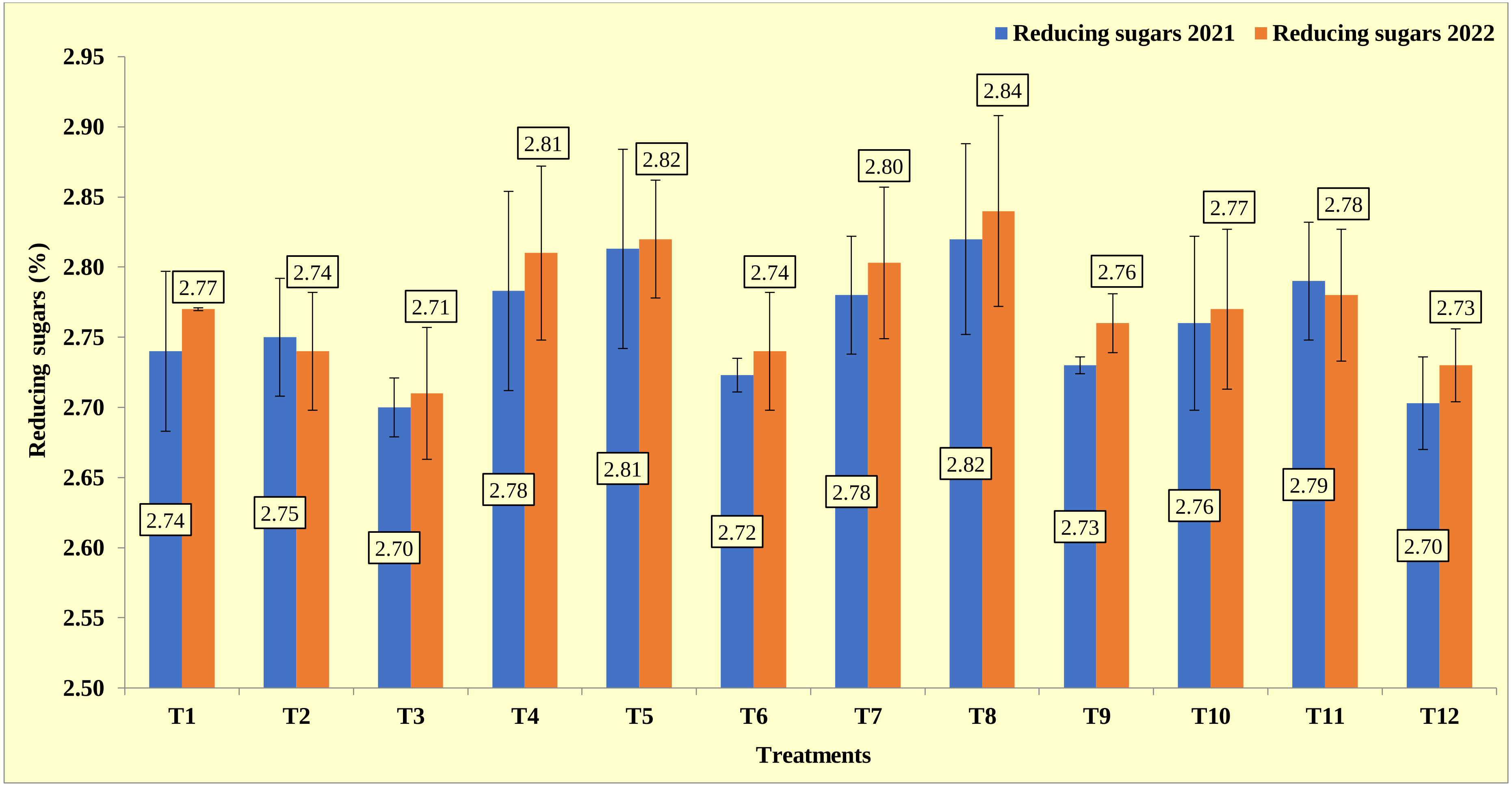

Fig. 23: Effect of *Azotobacter* and nano-micronutrients on reducing sugars in Kinnow mandarin

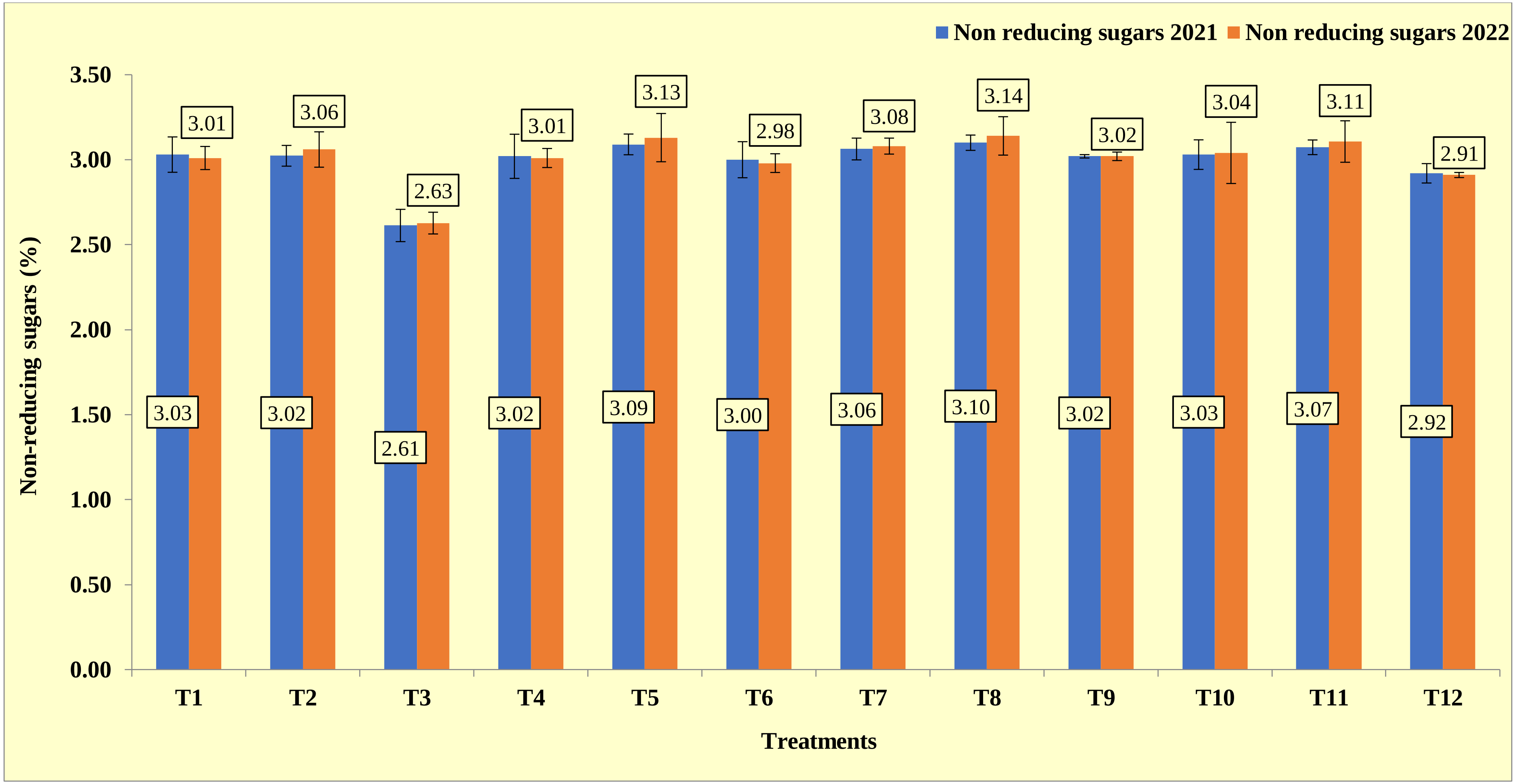

Fig. 24: Effect of *Azotobacter* and nano-micronutrients on non-reducing sugars in Kinnow mandarin

Table no. 4.9: Effect of *Azotobacter* and nano micro nutrients on total sugars, non-reducing sugars and reducing sugars of Kinnow mandarin.

Treatments	Total sugars (%)			Reducing sugars (%)			Non-reducing sugars (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	5.77^{bc}	5.78^{bc}	5.78^{bcd}	2.74^{a}	2.77^{a}	2.76^{abc}	3.03^{b}	3.01^{b}	3.02^{b}
T_2	5.77^{bc}	5.80^{bc}	5.79^{bcde}	2.75^{a}	2.74^{a}	2.75^{abc}	3.02^{b}	3.06^{b}	3.04^{b}
T_3	5.31^{a}	5.34^{a}	5.33^{a}	2.70^{a}	2.71^{a}	2.71^{a}	2.61^{a}	2.63^{a}	2.62^{a}
T_4	5.80^{bc}	5.82^{bc}	5.81^{cde}	2.78^{a}	2.81^{a}	2.80^{abc}	3.02^{b}	3.01^{b}	3.02^{b}
T_5	5.90^{c}	5.95^{c}	5.93^{de}	2.81^{a}	2.82^{a}	2.82^{bc}	3.09^{b}	3.13^{b}	3.11^{b}
T_6	5.72^{bc}	5.72^{bc}	5.72^{bc}	2.72^{a}	2.74^{a}	2.73^{ab}	3.00^{b}	2.98^{b}	2.99^{b}
T_7	5.84^{bc}	5.88^{bc}	5.86^{cde}	2.78^{a}	2.80^{a}	2.79^{abc}	3.06^{b}	3.08^{b}	3.07^{b}
T_8	5.92^{c}	5.98^{c}	5.95^{e}	2.82^{a}	2.84^{a}	2.83^{c}	3.10^{b}	3.14^{b}	3.12^{b}
T_9	5.75^{bc}	5.78^{bc}	5.77^{bcd}	2.73^{a}	2.76^{a}	2.75^{abc}	3.02^{b}	3.02^{b}	3.02^{b}
T_{10}	5.79^{bc}	5.81^{bc}	5.80^{cde}	2.76^{a}	2.77^{a}	2.77^{abc}	3.03^{b}	3.04^{b}	3.04^{b}
T_{11}	5.86^{c}	5.89^{bc}	5.88^{cde}	2.79^{a}	2.78^{a}	2.79^{abc}	3.07^{b}	3.11^{b}	3.09^{b}
T_{12}	5.62^{b}	5.64^{b}	5.63^{b}	2.70^{a}	2.73^{a}	2.72^{a}	2.92^{b}	2.91^{b}	2.92^{b}
S. Em (±)	0.072	0.081	0.052	0.05	0.048	0.028	0.082	0.098	0.067
C.D (5%)	0.213	0.239	0.152	N/A	N/A	N/A	0.241	N/A	0.198

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

Leaf nutrient status in Kinnow Mandarin

The findings of the study demonstrated a significant enhancement in the levels of nitrogen (N), phosphorus (P), and potassium (K) in the leaves of the plants through the application of boron (B) and zinc (Zn) via foliar spraying. Increase in essential macro-nutrients can be attributed to a synergistic interaction among N, P, and K with B and Zn. Previous research has documented the favorable impact of B and Zn on the mineral composition of leaves in mandarins, as well as 'Valencia' orange (Razzaq et al., 2013; Ullah et al., 2012). Likewise, studies have indicated that foliar application of Zn, either alone or in conjunction with K, can elevate the concentrations of N, P, Zn, and K in the leaves of 'Washington Navel' orange trees (Omaima and El-Metwally, 2007). The increase in concentrations of Zn and B in the trees suggests the advantages of exogenously spray of boron and zinc to enhance tree health and nutrition.

Nitrogen content in leaves (ppm)

Table 4.10 presents the leaf nitrogen content data over the two-year period of the experiment (2021 and 2022), as well as the combined data, which is represented in Figure 4.25.

In the experiment's first year (2021), maximum nitrogen content in leaves was observed in treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] with 34700 ppm recorded, which was at par with T_7, T_5, T_9, and T_4 treatment. This was found to be significantly higher than T_3. Minimum leaf nitrogen content (31000 ppm) was observed in treatment T_3 (RDF + *Azotobacter*).

Experiment conducted in 2022, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] once again displayed the maximum leaf nitrogen content (34900 ppm). Statistically, all treatments, with the exception of T_3, T_6, T_5, and T_{10}, showed non-significant impact on the nitrogen content of Kinnow mandarin leaves. Among the treatments, treatment T_3 (RDF + *Azotobacter*) exhibited the lowest leaf nitrogen content (31200 ppm).

Aggregated data from the two-year experiment (2021 and 2022), showed that the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] observed the maximum nitrogen content in leaves (34800 ppm). This result was at par with the nitrogen content observed in treatments T_7, T_9, T_4, and T_2. Conversely, the treatment T_3 (RDF + *Azotobacter*) displayed the minimum nitrogen in leaves (31100 ppm).

Phosphorous content in leaves (ppm)

Table 4.10 shows the data pertaining to the phosphorous content in leaves during the two years of the experiment (2021 and 2022) along with the pooled data and is represented in Fig. 4.26.

In 2021 trail, the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the maximum phosphorous content in leaves, measuring 336.50 ppm, it was at par with the phosphorous levels observed in treatments T_6, T_4, T_{11}, T_9 and T_5. Conversely, the treatment T_3 (RDF + *Azotobacter*) displayed the minimum phosphorous content in leaves, measuring 303.80 ppm.

In an experiment performed in 2022, treatment T_8 [(RDF+ *Azotobacter*+ nB (40 ppm) + nZn (150 ppm)] exhibited the maximum phosphorous content in leaves, measuring 343.30 ppm which was significantly higher than T_3. In contrast, treatment T_3 (RDF + *Azotobacter*) recorded the lowest phosphorous content in leaves, measuring 304.50 ppm, which was at par with to the phosphorous levels observed in the remaining treatments, except for T_5, T_6, and T_9.

Two-year aggregated data also recorded that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum phosphorous content in leaves, measuring 339.90 ppm. On the other hand, the treatment T_3 (RDF+ *Azotobacter*) recorded the minimum phosphorous content in leaves, measuring 304.15 ppm.

Potassium content in leaves (ppm)

The potassium in leaves during two-year experiment (2021 and 2022) is in Table 4.10 and Fig. 4.27.

The experiment conducted in 2021, results were obtained regarding the potassium content in leaves. Treatment T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)] showed the maximum potassium content, measuring 1197.00 ppm, which was at par to the potassium levels observed in treatments T_6 and T_8. In contrast, treatment T_3 (RDF + *Azotobacter*) exhibited the minimum potassium content in leaves, measuring 1060.70 ppm, it was statistically significant when compared to all treatments except T_8, T_6, and T_4.

In the year 2022, treatment T_6 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (200 ppm)] displayed the maximum potassium content in leaves, measuring 1172.60 ppm which was significantly higher than T_3. On the other hand, treatments T_3 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm)] showed the lowest potassium content in leaves, measuring 1089.00 ppm.

The combined data from the two years (2021 and 2022) resulted that treatment T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)] observed the maximum potassium content in leaves, measuring 1180.05 ppm, which was at par with the potassium content observed in treatments T_6 and T_8. On the other hand, treatment T_3 (RDF + *Azotobacter*) recorded the minimum potassium content in leaves, measuring 1074.85 ppm.

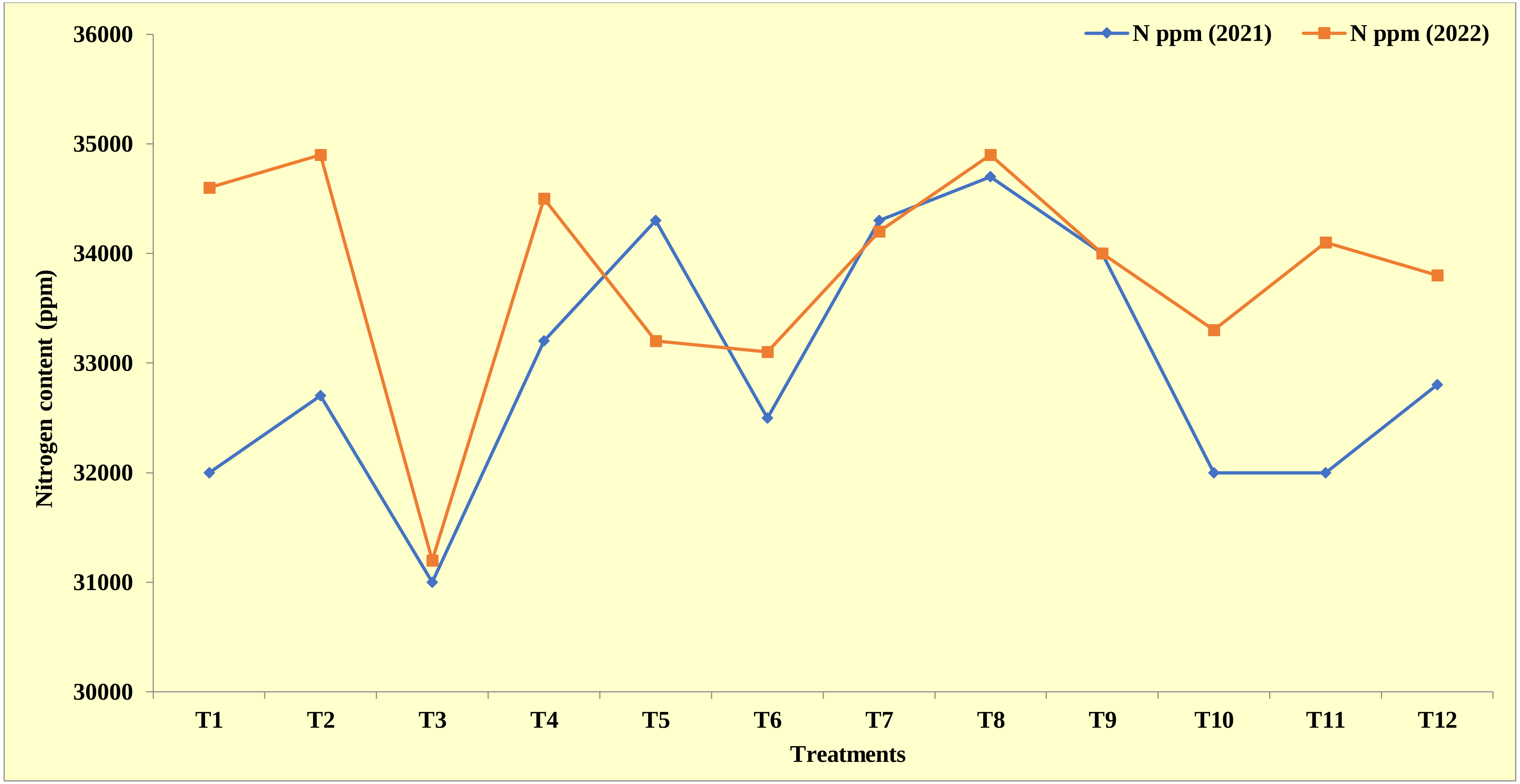

Fig. 25: Effect of *Azotobacter* and nano-micronutrients on nitrogen content in leaves of Kinnow mandarin

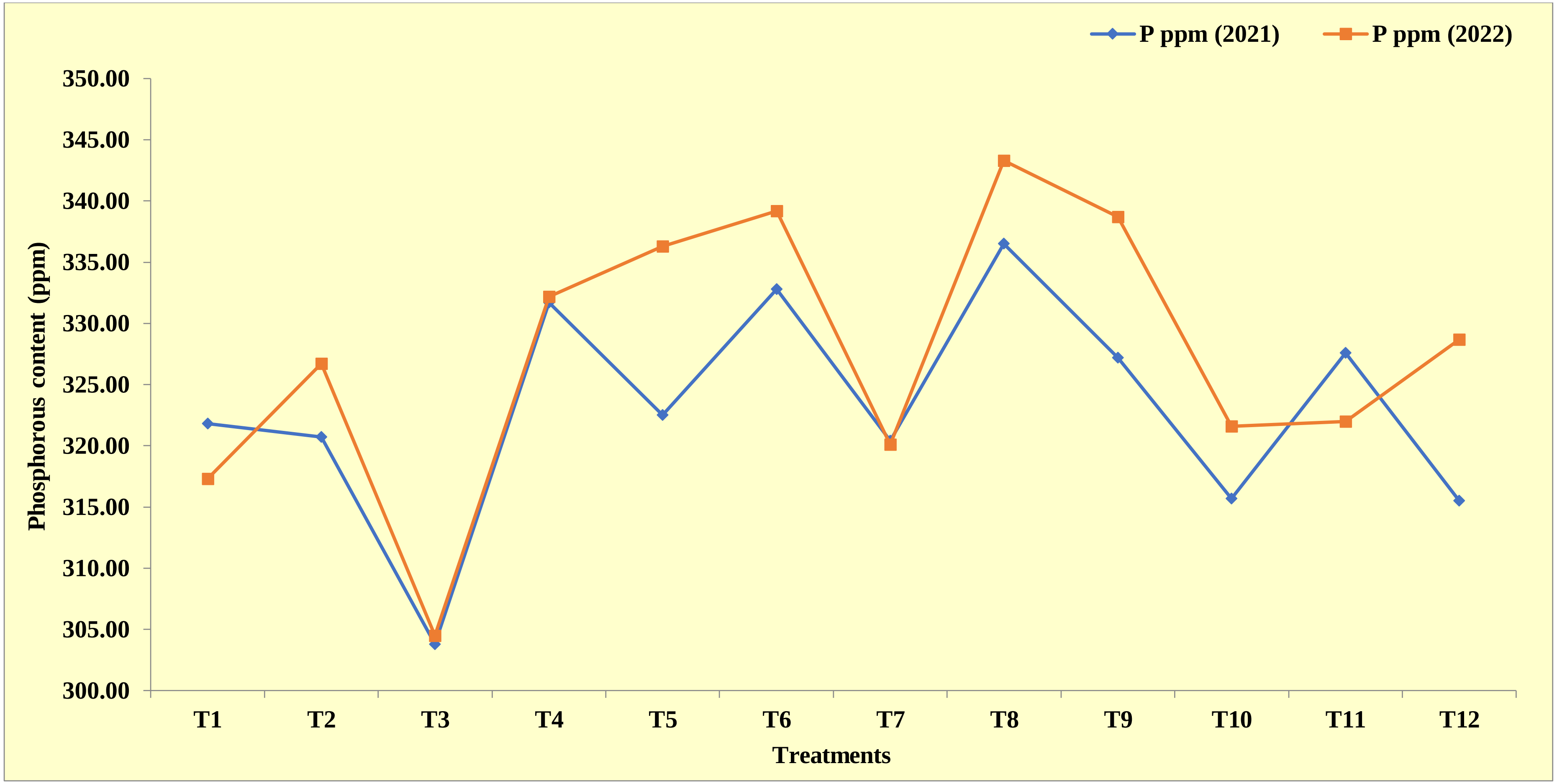

Fig. 26: Effect of *Azotobacter* and nano-micronutrients on Phosphorous content in leaves of Kinnow mandarin

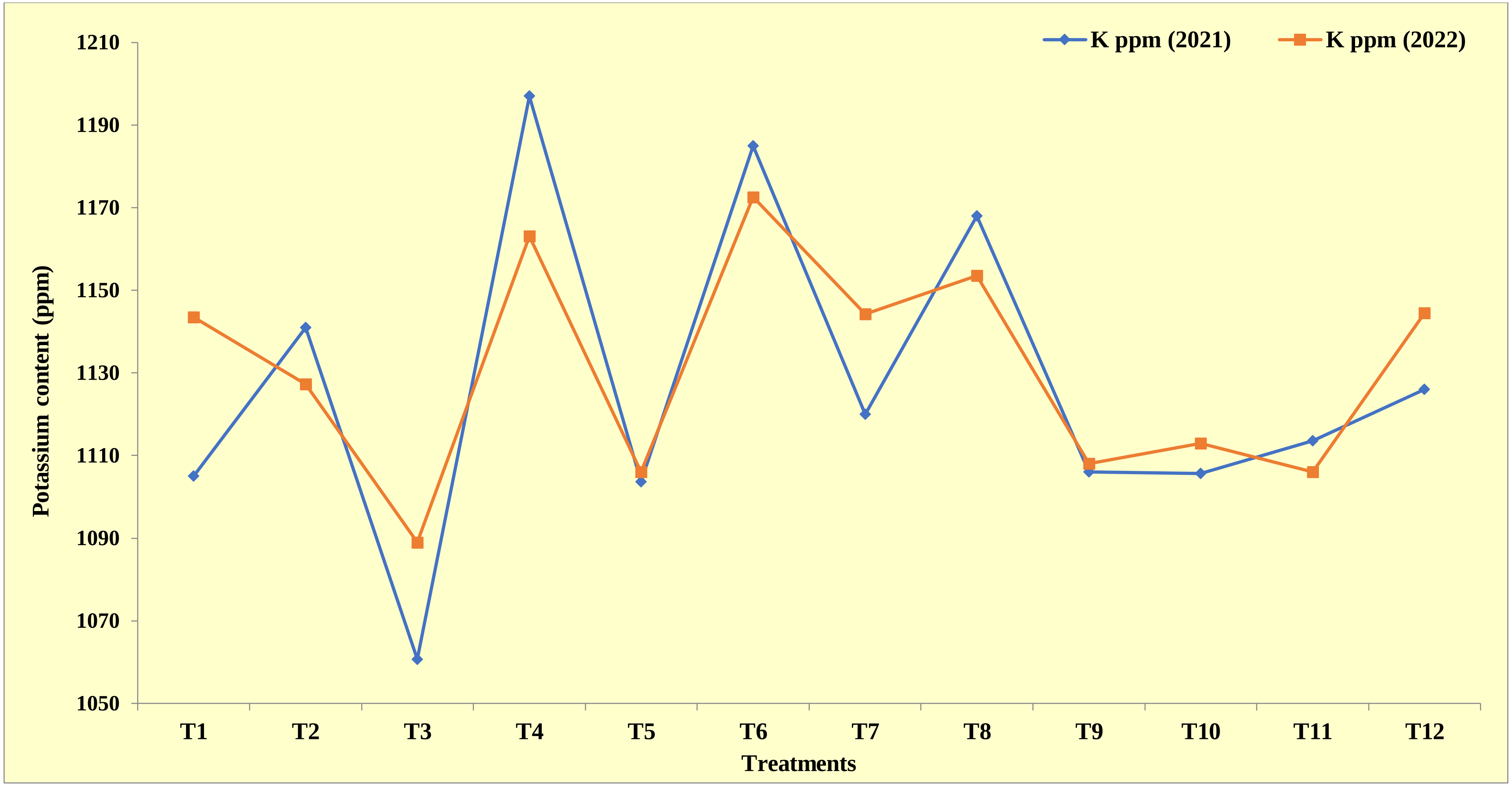

Fig. 27: Effect of *Azotobacter* and nano-micronutrients on Potassium content in leaves of Kinnow mandarin

Table no. 4.10: Effect of *Azotobacter* and nano micro nutrients on leaf nutrient analysis of Kinnow mandarin.

Treatments	Nitrogen (PPM)	Nitrogen (PPM)	Nitrogen (PPM)	Phosphorus (PPM)	Phosphorus (PPM)	Phosphorous (PPM)	Potassium (PPM)	Potassium (PPM)	Potassium (PPM)
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	32000^{ab}	34600^{bc}	33300^{bcde}	321.80^{bc}	317.30^{ab}	319.55^{b}	1105.00^{ab}	1143.50^{bcd}	1124.25^{b}
T_2	32700^{abc}	34900^{c}	33800^{cdef}	320.70^{bc}	326.70^{bcde}	323.70^{bcd}	1141.00^{bcd}	1127.30^{abcd}	1134.15^{bc}
T_3	31000^{a}	31200^{a}	31100^{a}	303.80^{a}	304.50^{a}	304.15^{a}	1060.70^{a}	1089.00^{a}	1074.85^{a}
T_4	33200^{bcd}	34500^{bc}	33850^{def}	331.70^{cd}	332.20^{cdef}	331.95^{defg}	1197.00^{e}	1163.10^{d}	1180.05^{d}
T_5	34300^{cd}	33200^{b}	33750^{cde}	322.50^{bc}	336.30^{def}	329.40^{cdef}	1103.60^{ab}	1106.00^{ab}	1104.80^{ab}
T_6	32500^{abc}	33100^{b}	32800^{bc}	332.80^{cd}	339.20^{ef}	336.00^{fg}	1185.00^{de}	1172.60^{d}	1178.80^{d}
T_7	34300^{cd}	34200^{bc}	34250^{ef}	320.40^{bc}	320.10^{bc}	320.25^{b}	1120.00^{b}	1144.30^{bcd}	1132.15^{bc}
T_8	34700^{d}	34900^{c}	34800^{f}	336.50^{d}	343.30^{f}	339.90^{g}	1168.00^{cde}	1153.60^{cd}	1160.80^{cd}
T_9	34000^{cd}	34000^{bc}	34000^{def}	327.20^{bcd}	338.70^{ef}	332.95^{efg}	1106.00^{ab}	1108.00^{abc}	1107.00^{ab}
T_{10}	32000^{ab}	33300^{b}	32650^{b}	315.70^{ab}	321.60^{bc}	318.65^{b}	1105.70^{ab}	1113.00^{abc}	1109.35^{ab}
T_{11}	32000^{ab}	34100^{bc}	33050^{bcd}	327.60^{bcd}	322.00^{bcd}	324.80^{bcde}	1113.60^{b}	1106.00^{ab}	1109.80^{ab}
T_{12}	32800^{abc}	33800^{bc}	33300^{bcde}	315.50^{ab}	328.70^{bcdef}	322.10^{bc}	1126.00^{bc}	1144.50^{bcd}	1135.25^{bc}
S. Em (±)	563.73	455.83	320.50	4.34	4.30	2.93	15.24	13.75	11.05
C.D (5%)	1664.03	1345.52	946.07	12.82	12.70	8.63	44.98	40.60	32.62

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

Boron content in leaves (ppm)

Table 4.11 shows the data of boron in leaves during the two years of the experiment (2021 and 2022) along with the pooled data and is represented in Fig. 4.28.

In the first year (2021) experimentation, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum boron content in leaves, measuring 36.84 ppm, which was at par with treatment T_7 and it was significantly higher than T_3. Conversely, treatment T_3 (RDF + *Azotobacter*) showed the lowest boron content in leaves, measuring 19.98 ppm.

Similar observations were made during the second year of experimentation (2022), where treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] demonstrated the maximum boron content in leaves, measuring 40.89 ppm which was significantly higher than T_3. Whereas, treatment T_3 (RDF + *Azotobacter*) recorded the minimum boron content in leaves, measuring 20.49 ppm.

Pooled data for the two years also registered similar trend for boron content in leaves. Maximum boron in leaves (38.87 ppm) was recorded under the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)]. Lowest boron content in leaves (20.23 ppm) was recorded in treatment T_3 (RDF + *Azotobacter*).

Zinc content in leaves (ppm)

Table 4.11 presents the data on zinc content in leaves throughout the two-year experiment (2021 and 2022), along with the pooled data, shown in Fig. 4.29.

In the initial year (2021) of experimentation, the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] showed the maximum zinc content in leaves, measuring 26.04 ppm, it was at par with treatments T_5 and T_{11}. Conversely, the treatment T_3 (RDF+ *Azotobacter*) recorded the lowest zinc content in leaves, measuring 14.58 ppm.

During the subsequent year (2022) of the experiment, similar pattern was observed regarding the zinc content in leaves among the treatments. Treatment T_8, involving the application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm), displayed the maximum zinc content in leaves, measuring 27.83 ppm which was significantly higher than T_3. This value was found to be at par with treatments T_5 and T_{11}. On the other hand, treatment T_3 (RDF + *Azotobacter*) registered the minimum zinc content in leaves, recording 15.62 ppm.

Two-year pooled data (2021 and 2022) further confirmed a similar trend in the zinc content of leaves across the treatments. Treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] demonstrated the maximum zinc content in leaves, measuring 26.93 ppm, which was at par with treatments T_5 and T_{11}. Meanwhile, treatment T_3 (RDF + *Azotobacter*) displayed the minimum zinc content in leaves, measuring 15.10 ppm.

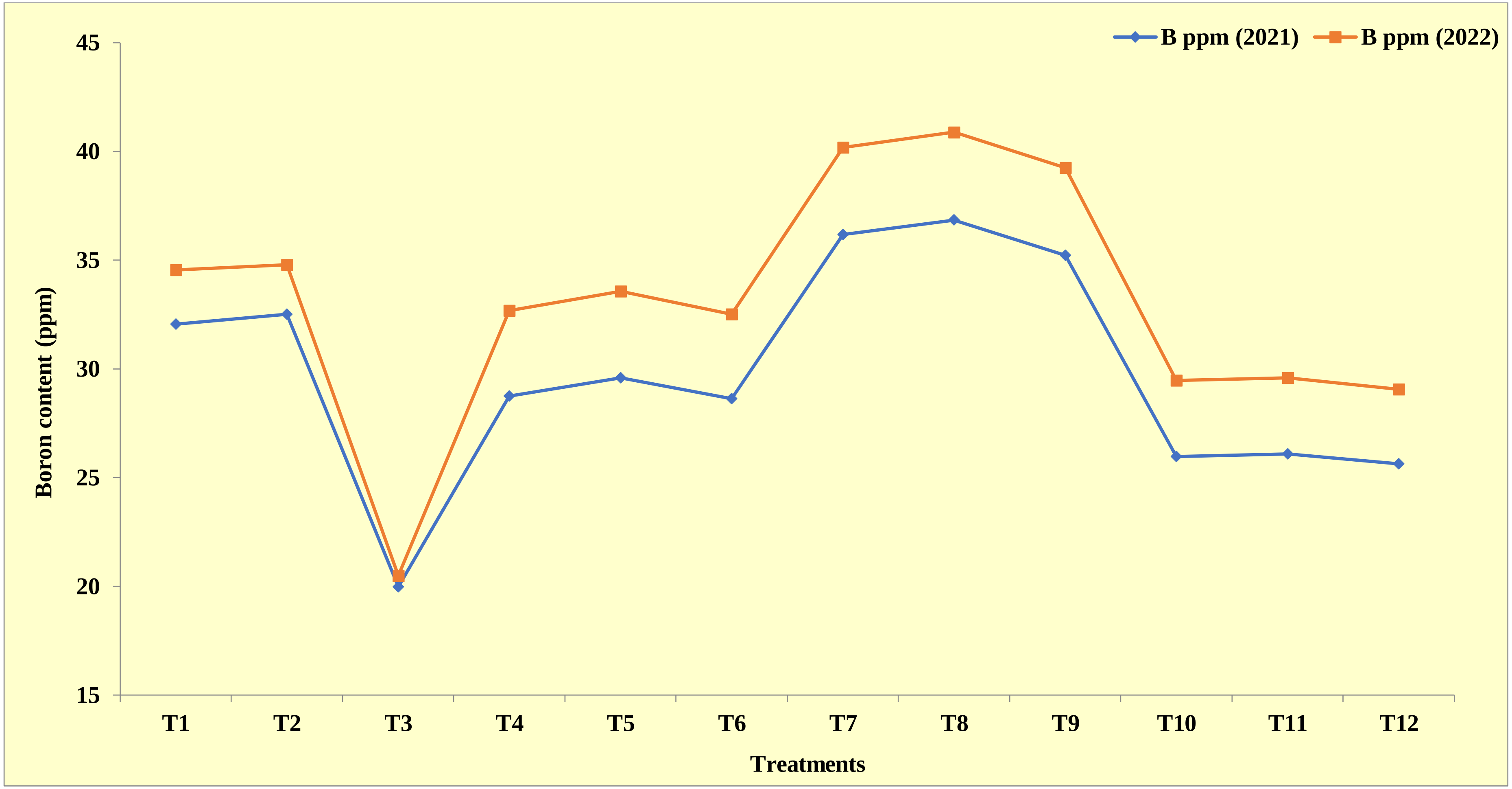

Fig. 28: Effect of *Azotobacter* and nano-micronutrients on Boron content in leaves of Kinnow mandarin

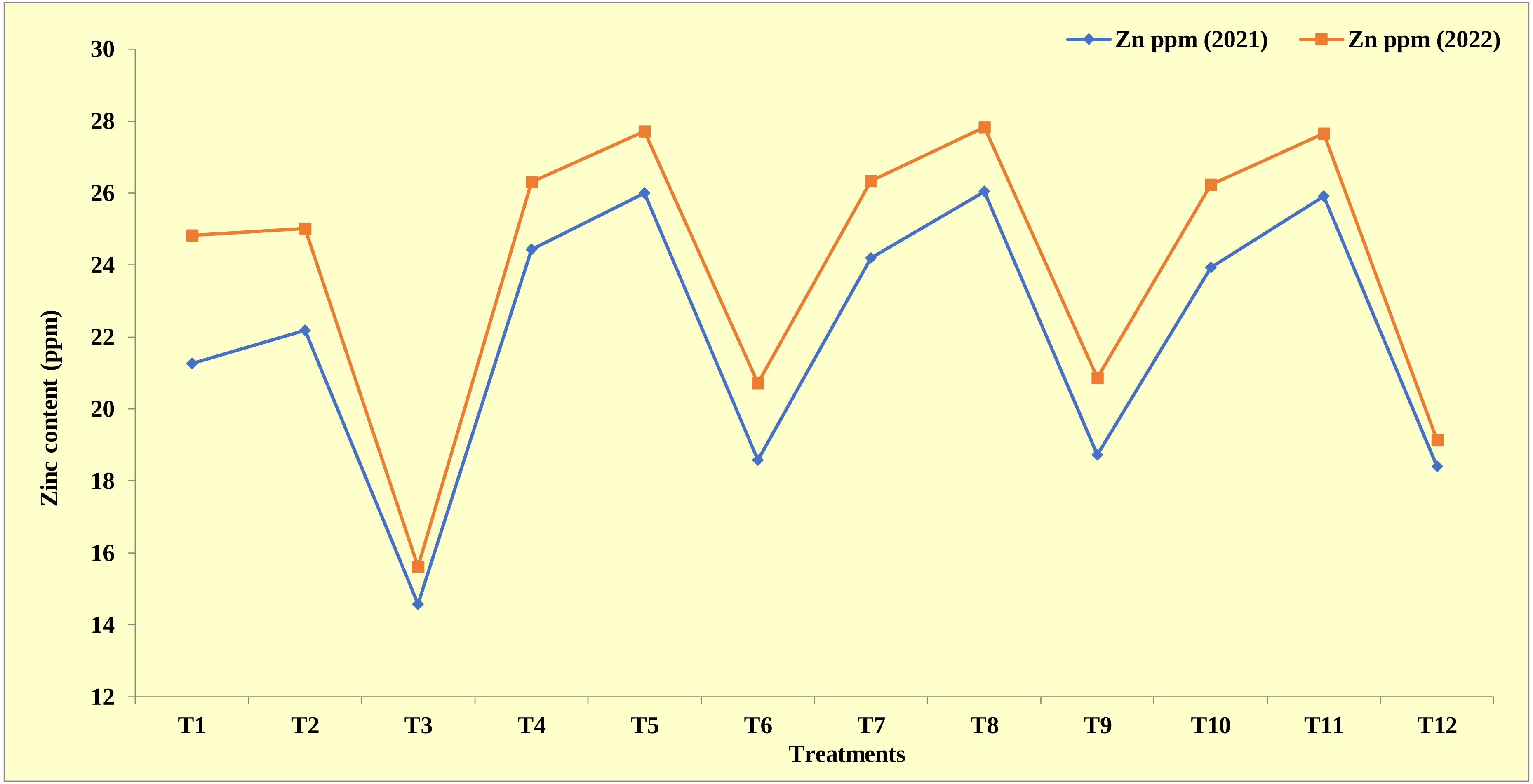

Fig. 29: Effect of *Azotobacter* and nano-micronutrients on Zinc content in leaves of Kinnow mandarin

Table no. 4.11: Effect of *Azotobacter* and nano micro nutrients on leaf nutrient analysis of Kinnow mandarin.

Treatments	Zinc (PPM)	Zinc (PPM)	Zinc (PPM)	Boron (PPM)	Boron (PPM)	Boron (PPM)
	2021	2022	Pooled	2021	2022	Pooled
T_1	21.26[c]	24.82[d]	23.04[d]	32.05[d]	34.56[d]	33.31[e]
T_2	22.19[d]	25.01[d]	23.60[d]	32.51[d]	34.79[d]	33.65[e]
T_3	14.58[a]	15.62[a]	15.10[a]	19.98[a]	20.49[a]	20.24[a]
T_4	24.43[e]	26.31[e]	25.37[e]	28.75[c]	32.69[c]	30.72[cd]
T_5	26.00[f]	27.72[f]	26.86[f]	29.59[c]	33.56[cd]	31.58[d]
T_6	18.58[b]	20.72[c]	19.65[c]	28.63[c]	32.52[c]	30.58[c]
T_7	24.20[e]	26.34[e]	25.27[e]	36.17[ef]	40.18[ef]	38.18[g]
T_8	26.04[f]	27.83[f]	26.94[f]	36.84[f]	40.89[f]	38.87[g]
T_9	18.72[b]	20.86[c]	19.79[c]	35.23[e]	39.26[e]	37.25[f]
T_{10}	23.93[e]	26.23[e]	25.08[e]	25.98[b]	29.46[b]	27.72[b]
T_{11}	25.91[f]	27.66[f]	26.79[f]	26.08[b]	29.59[b]	27.84[b]
T_{12}	18.40[b]	19.13[b]	18.77[b]	25.63[b]	29.05[b]	27.34[b]
S. Em (±)	0.33	0.27	0.21	0.48	0.47	0.32
C.D (5%)	0.96	0.80	0.63	1.425	1.376	0.953

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

Effect of *Azotobacter* and nano micro nutrients on economics of Cultivation of Kinnow mandarin

All treatments underwent an evaluation of the economic aspects of cultivation, and the data is shown in Table 4.12 and the Fig. 30. Prevailing market prices served as the basis for determining the conclusive benefit-cost ratios. The interpretation of results employed common cost concepts rooted in agricultural economics. The inputs utilized in the cultivation of Kinnow mandarin were classified into two components: variable costs and fixed costs. The costs associated with these components were calculated separately for different treatments. Variable costs include labour expenses and the cost of fertilizers. Fixed costs included rent paid for leased land and the interest paid on working capital. Gross returns were calculated by multiplying the total production per hectare per treatment by the prevailing market price.

In the initial year of the experiment (2021), the maximum cost of cultivation (Rs. 1,64,679.61) was observed in treatment T_{12}, where the application of RDF + *Azotobacter* + nB (60 ppm) + nZn (200 ppm) was done. This was followed by treatment T_{11} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], with a recorded total cost of cultivation of Rs. 1,61,778.87. On the other hand, the lowest cost of cultivation (Rs. 1,23,983.47) was observed in treatment T_3 (RDF + *Azotobacter*).

Treatment T_8, consisting of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm), obtained the maximum gross returns of Rs. 6,34,285.68. This was followed by treatment T_5, which generated gross returns of Rs. 5,26,538.22. On the other hand, the lowest gross returns of Rs. 3,08,733.12 was recorded under treatment T_3, involving RDF + *Azotobacter*.

The table further revealed that net returns were highest (Rs.4,79,456.19) under treatment T_8 where plants were applied with RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm) followed by net returns of Rs. 3,78,658.10 obtained under treatment T_5 [(RDF+ *Azotobacter* + nB (20 ppm)+ nZn (150 ppm)]. Lowest net returns (Rs. 1,64,462.87) were obtained under treatment T_{12} [(RDF + *Azotobacter* + nB (60 ppm)+ nZn (200 ppm)].

The treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] yielded the maximum benefit-cost ratio of 1:3.10, indicating a favourable economic outcome. This was followed by treatment T_2 [(RDF+ *Azotobacter* + B (0.25%) + Zn

(1000 ppm)] with a benefit-cost ratio of 1:2.85 and treatment T_1 [(RDF + B (0.25%) + Zn (1000 ppm)] with a benefit-cost ratio of 1:2.74. On the other hand, the lowest B:C ratio of 1:1.00 was observed under treatment T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)], indicating relatively lower economic returns compared to the investment.

The experiment conducted in 2022, similar pattern was observed among all treatments in terms of the economic aspects of cultivation, as displayed in Table 4.13. The maximum cost of cultivation (Rs. 1,65,356.05) was observed under treatment T_{12}, where RDF + *Azotobacter* + nB (60 ppm) + nZn (200 ppm) were applied. This was followed by treatment T_{11} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], with a recorded total cost of cultivation of Rs. 1,62,455.31. Conversely, the lowest cost of cultivation (Rs. 1,24,553.87) was observed under treatment T_3 (RDF + *Azotobacter*).

Maximum gross returns (Rs. 6,59,260.00) was obtained under treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], which was followed by gross returns of Rs. 5,95,815.92 under treatment T_5. Minimum gross returns (Rs. 3,25,286.64) were recorded under treatment T_3 (RDF + *Azotobacter*).

The analysis indicated that treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum net returns of Rs. 5,03,754.07, followed by treatment T_5 [(RDF+ *Azotobacter*+ nB (20 ppm)+ nZn (150 ppm)] with net returns of Rs. 4,47,259.37. The lowest net returns of Rs. 1,79,874,59 were observed under treatment T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)].

Treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] displayed the maximum benefit cost ratio of 1:3.24, indicating a favorable economic outcome which was significantly higher than T_3. This was followed by treatment T_5 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm)] and T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)] with benefit cost ratios of 1:3.01 and 1:2.98, respectively. On the other hand, treatment T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)] exhibited the lowest benefit cost ratio of 1:1.09, suggesting a relatively less favourable economic return.

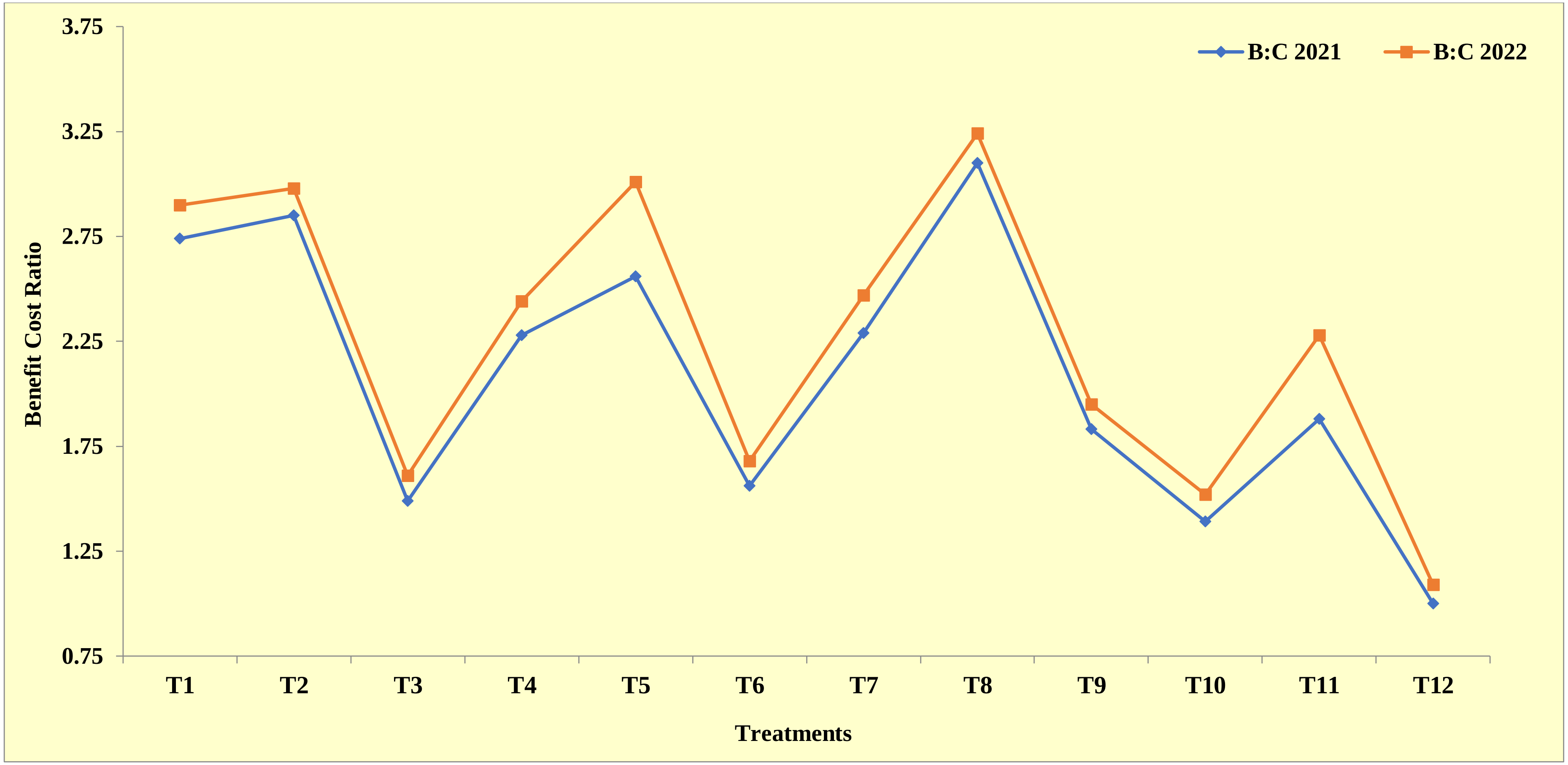

Fig. 30: Effect of *Azotobacter* and nano-micronutrients on Benefit cost ratio Kinnow mandarin cultivation

Table no. 4.12: Effect of *Azotobacter* and nano micro nutrients on Cost Benefit ratio of Kinnow mandarin in year 2021.

Items of cost	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
Variable cost												
Labour	33670.28	34506.40	27144.76	34506.40	34506.40	34506.40	34506.40	34506.40	34506.40	34506.40	34506.40	34506.40
Cost of fertilizers per ha	18257.07	22412.07	21054.77	32439.47	35029.42	37619.37	38644.27	41234.22	43824.17	44849.07	47439.02	50028.97
Interest on working capital @ 12%	6231.28	6830.22	5783.94	8033.50	8344.30	8655.09	8778.08	9088.87	9399.67	9522.66	9833.45	10144.24
Total variable cost	**58158.63**	**63748.69**	**53983.47**	**74979.37**	**77880.12**	**80780.86**	**81928.75**	**84829.49**	**87730.24**	**88878.13**	**91778.87**	**94679.61**
Fixed cost												
Rent paid for leased in land per ha	62500	62500	62500	62500	62500	62500	62500	62500	62500	62500	62500	62500
Interest paid on fixed capital @ 12%	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
Total fixed cost	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**
Returns												
Average yield (kg/ha)	17135.22	18381.72	12863.88	16971.79	20251.47	14825.04	17849.88	22653.06	15969.05	15833.32	19420.47	13714.27
Selling price per kg	28	28	24	28	26	26	28	28	28	24	24	24
Gross income	**479786.16**	**514688.16**	**308733.12**	**475210.12**	**526538.22**	**385451.04**	**499796.64**	**634285.68**	**447133.40**	**379999.68**	**466091.28**	**329142.48**
Return Structure												
Total cost of cultivation	128158.63	133748.69	123983.47	144979.37	147880.12	150780.86	151928.75	154829.49	157730.24	158878.13	161778.87	164679.61
Gross income	479786.16	514688.16	308733.12	475210.12	526538.22	385451.04	499796.64	634285.68	447133.40	379999.68	466091.28	329142.48
Net return	351627.53	380939.47	184749.65	330230.75	378658.10	234670.18	347867.89	479456.19	289403.16	221121.55	304312.41	164462.87
C:B ratio	**1:2.74**	**1:2.85**	**1:1.49**	**1:2.28**	**1:2.56**	**1:1.56**	**1:2.29**	**1:3.10**	**1:1.83**	**1:1.39**	**1:1.88**	**1:1.00**

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

Table no. 4.13: Effect of *Azotobacter* and nano micro nutrients on Cost Benefit ratio of Kinnow mandarin in year 2022.

Items of cost	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
Variable cost												
Labour	34258.32	35110.36	27654.04	35110.36	35110.36	35110.36	35110.36	35110.36	35110.36	35110.36	35110.36	35110.36
Cost of fertilizers per ha	18257.07	22412.07	21054.77	32439.47	35029.42	37619.37	38644.27	41234.22	43824.17	44849.07	47439.02	50028.97
Interest on working capital @ 12%	6301.85	6902.69	5845.06	8105.98	8416.77	8727.57	8850.56	9161.35	9472.14	9595.13	9905.93	10216.72
Total variable cost	**58817.24**	**64425.12**	**54553.87**	**75655.81**	**78556.55**	**81457.30**	**82605.19**	**85505.93**	**88406.67**	**89554.56**	**92455.31**	**95356.05**
Fixed cost												
Rent paid for leased in land per ha	62500	62500	62500	62500	62500	62500	62500	62500	62500	62500	62500	62500
Interest paid on fixed capital @ 12%	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
Total fixed cost	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**	**70000**
Returns-												
Average yield (kg/ha)	17941.29	19115.77	13553.61	17883.12	21279.14	15633.88	18888.63	23545	16680.94	16769.58	20500.77	14384.61
Selling price per kg	28	28	24	28	28	26	28	28	28	24	26	24
Gross income	**502356.12**	**535241.56**	**325286.64**	**500727.36**	**595815.92**	**406480.88**	**528881.64**	**659260.00**	**467066.32**	**402469.92**	**533020.02**	**345230.64**
Return Structure												
Total cost of cultivation	128817.24	134425.12	124553.87	145655.81	148556.55	151457.30	152605.19	155505.93	158406.67	159554.56	162455.31	165356.05
Gross income	502356.12	535241.56	325286.64	500727.36	595815.92	406480.88	528881.64	659260.00	467066.32	402469.92	533020.02	345230.64
Net return	373538.88	400816.44	200732.77	355071.55	447259.37	255023.58	376276.45	503754.07	308659.65	242915.36	370564.71	179874.59
C:B ratio	**1:2.90**	**1:2.98**	**1:1.61**	**1:2.44**	**1:3.01**	**1:1.68**	**1:2.47**	**1:3.24**	**1:1.95**	**1:1.52**	**1:2.28**	**1:1.09**

T_1 [RDF + B (0.25%) + Zn (1000 ppm)], T_2 [(RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm)], T_3 (RDF+ *Azotobacter*), T_4 (RDF+ *Azotobacter* + nB (20 ppm) + nZn (100 ppm)], T_5 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (150 ppm)], T_6 [RDF+ *Azotobacter* + nB (20 ppm) + nZn (200 ppm)], T_7 [RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)], T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)], T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)], T_{10} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (100 ppm)], T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)], T_{12} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (200 ppm)]

Chapter 5

SUMMARY AND CONCLUSION

The use of *Azotobacter* and nano micronutrients application can improve the growth, yield & quality of Kinnow mandarin. Current research "Studies on the effect of *Azotobacter* and nano micronutrients application on growth, yield and quality of Kinnow mandarin" was undertaken during 2021-2022 in the Kinnow orchard of Lovely Professional University, Punjab. The results of the findings have clearly shown the positive impact of nano micronutrients on the growth, and other parameters. The improvement in leaf nutrient was also obtained with treatments which involved the use of nano micronutrients. This chapter summarizes the findings of the experimentation conducted in two years (2021 & 2022) along with the pooled data.

5.1 Growth parameters

5.1.1 Increase in plant height (%)

- During the first year of experimentation (2021), max. increase in plant height (5.26%) was in T_{11} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)].
- In the second year of experimentation (2022), the highest increase in plant height (5.56%) was also recorded under treatment T_{11} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)].
- Similar trend was observed in pooled estimates with maximum increase in plant height (5.41%) under the treatment T_{11} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (200 ppm)].

5.1.2 Increase in canopy spread (%) of Kinnow mandarin

- In 2021, the treatment T_{11} [(RDF+ *Azotobacter* + nB (60 ppm) + nZn (150 ppm)] resulted in the maximum percentage increase in canopy volume, recording a value of 22.82%.
- During the second trial year (2022), maximum increase in canopy volume (22.73%) was observed in treatment T_9 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (200 ppm)].

- Pooled data for the two years (2021 & 2022) registered maximum increase in canopy volume (22.46%) under the treatment T_{11} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (150 ppm)].

5.1.3 Leaves per flush (no.) of Kinnow mandarin

- In the experiment's first year (2021), the treatment T_6 (consisting of RDF, *Azotobacter*, nB (20 ppm), and nZn (200 ppm) showed the maximum number of leaves per flush. A total of 180.74 leaves per flush were recorded for this treatment.
- In the second year of the trial (2022), the treatment T_9, which included the application of RDF, *Azotobacter*, nB (40 ppm) and nZn (200 ppm), resulted in the maximum number of leaves per flush (181.33).
- Two-year (2021 & 2022) aggregate data shows the highest number of leaves/flush (178.79) in treatment T_6 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (200 ppm)].

5.2 Yield Parameters

5.2.1 Fruit weight (g) of Kinnow mandarin

- In 2021, the treatment T_8, which consisted of RDF, *Azotobacter*, nB (40 ppm), and nZn (150 ppm), exhibited the maximum fruit weight during the experiment. The recorded fruit weight under this treatment was 154.06 g.
- In the second experiment (2022), the max. fruit wt. (152.13 g) was in T_8 using RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm).
- By combining the data from both years (2021 & 2022), the observed trend remained consistent throughout the two-year experimentation. The treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum fruit weight of 153.73 g.

5.2.2 Fruit length (cm) of Kinnow mandarin

- In the study conducted in 2021, the treatment T_8 (which involved RDF, *Azotobacter*, nB (40 ppm), and nZn (150 ppm) led to the maximum fruit length. The recorded length of the fruit under this treatment was 5.84 cm.

- Experiment conducted in 2022, both treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] and T_7 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)] exhibited the maximum fruit length, with a recorded measurement of 5.83 cm.
- Analysing the data from both years (2021 & 2022), it was found that the T_8 treatment, consisting of RDF, *Azotobacter*, nB (40 ppm), and nZn (150 ppm), resulted in the maximum fruit length of 5.84 cm.

5.2.3 Fruit width (cm) of Kinnow mandarin

- In the primary year of the experiment (2021), the treatment T_7 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)] recorded the maximum fruit width of 6.52 cm.
- During 2022 trial, treatment T_8 with the application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) recorded the maximum fruit width, measuring 6.55 cm.
- Aggregate data for the two years (2021 & 2022), registered maximum fruit width (6.53 cm) under the treatment T_7 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)].

5.2.4 Fruit size (cm^2) of Kinnow mandarin

- The experiment conducted in 2021, revealed that the treatment T_7 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (100 ppm)] resulted in the largest fruit size, measuring 37.95 cm^2.
- In second year of experiment (2022), maximum fruit size of 38.19 cm^2 was achieved under treatment T_8, where RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm) were applied.
- Pooled data for the two years (2021 & 2022), registered maximum fruit size (38.01 cm^2) under the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] and T_7 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (100 ppm)].

5.2.5 Specific gravity of Kinnow mandarin

- In the 2021 experiment, no significant different was observed among the treatments. However, treatment T_4, T_7, T_9, T_{10}, and T_{11} exhibited the maximum specific gravity, with a maximum value of 1.00 and remaining treatments recorded a value of 0.99.
- In the second-year trail (2022), no significant variation in specific gravity was observed among the treatments under investigation.
- Similar trend was recorded in both years (2021 & 2022), no significant difference observed in specific gravity among all the treatments. However, the maximum recorded specific gravity was 1.00, while the minimum recorded value was 0.99.

5.2.6 Rind thickness (mm) of Kinnow mandarin

- In the first year of trail (2021), treatment T_2, T_7, and T_8 and recorded the maximum rind thickness, measuring 0.52 mm.
- During the second year of experimentation (2022), maximum rind thickness 0.53 mm was recorded under treatment T_8 where application of RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm) was done.
- Combined data from both years (2021 & 2022), recorded the maximum rind thickness of 0.53 mm under the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

5.2.7 Weight of seeds (g) of Kinnow mandarin

- During the first trail of experimentation (2021), maximum weight of seeds (3.75 g) was observed under treatment T_{10} [(RDF + *Azotobacter* + nB (60 ppm) + nZn (100 ppm)].
- In the second year of experiment (2022), maximum weight of seeds (3.81 g) was recorded under treatment T_2 where application of RDF + *Azotobacter* + B (0.25%) + Zn (1000 ppm) was done.
- Combined data for the two years (2021 & 2022) registered maximum weight of seeds (3.73) under the treatment T_{10} and T_8.

5.2.8 Peel weight (g) of Kinnow mandarin

- In the study conducted in 2021, the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded maximum peel weight of 48.66 g.
- During second trail (2022), treatment T_2, which involved the application of RDF+ *Azotobacter* + B (0.25%) + Zn (1000 ppm), recorded the maximum peel weight of 49.06 g.
- Two-year pooled data (2021 & 2022) recorded the maximum peel weight (48.78 g) under treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

5.2.9 Pulp weight (g) of Kinnow mandarin

- In the primary year of the experiment (2021), treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the maximum pulp weight of 105.41 g.
- During the experiment conducted in 2022, the treatment T_9, which involved the application of RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm), recorded the maximum pulp weight of 105.09 g.
- Aggregated data of two years (2021 & 2022) showed that the treatment T_9 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (200 ppm)] exhibited the maximum pulp weight (105.01 g).

5.2.10 Juice content (%) of Kinnow mandarin

- During the experiment of 2021, it was observed that the percentage of maximum juice content (57.58%) was recorded in treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].
- During second year of the trial conducted in 2022, the treatment T_8, which utilized RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm), resulted in the maximum recorded juice content of 58.08%.
- Pooled data obtained from the two-year (2021 & 2022) indicated that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum percentage of juice content (57.83%).

5.2.11 Fruit drop (%) of Kinnow mandarin

- In the experiment's first year (2021), observations revealed that the treatment T_3 (RDF+ *Azotobacter*) exhibited the maximum fruit drop percentage (48.69%). Whereas, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the minimum fruit drop (34.13%) among all the treatments.
- Experiment conducted in 2022, resulted in a consistent pattern in terms of fruit drop among Kinnow mandarin plants. The treatment T_3, which involved the application of RDF+ *Azotobacter*, exhibited the maximum fruit drop percentage of 47.44%. In contrast, the treatment T_8, which included RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm), recorded the lowest fruit drop percentage of 33.68%.
- Aggregate data of two years (2021 & 2022), recorded that treatment T_3 (RDF+ *Azotobacter*) recorded the maximum percentage of fruit drop, with a notable value of 48.06%. In contrast, the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the minimum fruit drop rate, recording a percentage of 33.91%.

5.2.12 Number of fruits per tree (no.) of Kinnow mandarin

- In the first-year trail (2021), observation was made that the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the max. fruits per tree, with a count of 530.58.
- In the second-year trail (2022), consistent pattern was recorded in terms of the number of fruits per tree in Kinnow mandarin plants. The treatment T_8, which involved the application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm), recorded the maximum count of fruits per tree, recording a value of 554.15.
- Aggregated data from the two-year study (2021 & 2022), showed the similar trend in the two-year trial. Treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum number of fruits per tree, reaching a significant count of 542.36.

5.2.13 Fruit yield (kg/plant) of Kinnow mandarin

- In the year 2021, observations recorded that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum fruit yield, reaching a value of 81.78 kg/plant.
- In the secondary year of the experimentation (2022), the treatment T_8, which involved the application of RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm), resulted in the maximum fruit yield of 85.00 kg/plant.
- Pooled data from the two-year experiment (2021 & 2022) confirmed the consistent trend observed throughout the study. Treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum fruit yield of 83.39 kg/plant.

5.3 Quality Parameters

5.3.1 Effect of *Azotobacter* and nano micronutrients on TSS (°Brix) of Kinnow mandarin

- During the study conducted in 2021, it was found that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum total soluble solids (TSS), with a recorded value of 11.29 °Brix.
- In 2022 trail, it was found that the treatment T_5, which involved the application of RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm), resulted in the maximum TSS of 11.36 °Brix.
- Aggregated data from the two-year study (2021 & 2022), showed that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded maximum TSS, recording a value of 11.31 °Brix.

5.3.2 Titrable acidity (%) of Kinnow mandarin

- In the experiment's first year (2021), an observation was made that the treatments T_1, T_8, and T_9 recorded the maximum titratable acidity, with a maximum value of 0.81%.
- During the second year of experimentation (2022), maximum titratable acidity (0.82%) was recorded under treatment T_1, T_2, and T_7.

- Pooled data from two years (2021 & 2022), resulted in the maximum titratable acidity (0.82%) in treatments T_1, T_2, T_7 and T_8.

5.3.3 TSS:acid of Kinnow mandarin

- First year of the experiment (2021), resulted in maximum TSS:acid (14.04) in the treatment T_5 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm)].
- In the second year of the experimentation (2022), the treatment T_5, with the application of RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm), again recorded the maximum TSS:acid of 14.02.
- Combining the data from both years (2021 & 2022) revealed the same results. The treatment T_5 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (150 ppm)] exhibited the maximum TSS:acid value of 14.03.

5.3.4 Ascorbic acid (mg/100 ml of juice) of Kinnow mandarin

- During the first year of the experiment (2021), the maximum value of ascorbic acid (25.85 mg/100 ml of juice) was recorded under treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].
- In an experiment performed in 2022, maximum ascorbic acid (26.29 mg/100 ml of juice) was recorded in treatment T_8 where application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) was done.
- Two- year aggregate data also recorded the maximum value of ascorbic acid (26.07 mg/100 ml of juice) under treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

5.3.5 Polyphenols (mg GAE/100g fresh weight) of Kinnow mandarin

- In first year (2021), maximum polyphenols (61.55 mg GAE/100g fresh weight) content was recorded under the treatment T_3 (RDF + *Azotobacter*). Minimum polyphenols (54.78 mg GAE/100g fresh weight) was recorded in T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].
- In 2022 trail, maximum polyphenols (61.34 mg GAE/100g fresh weight) was recorded under treatment T_3 where application of RDF + *Azotobacter* was done.

Minimum polyphenols (53.86 mg GAE/100g fresh weight) was recorded in T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

- Pooled data for the two years also registered maximum polyphenols (61.45 mg GAE/100g fresh weight) was recorded under the treatment T_3 (RDF + *Azotobacter*). Minimum polyphenols (54.32 mg GAE/100g fresh weight) was recorded in T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

5.3.6 Total sugars (%) of Kinnow mandarin

- In the primary year of trail (2021), the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum recorded value of total sugar (5.92%).
- During the second year of experimentation (2022), maximum total sugars (5.98%) were recorded under treatment T_8 where application of RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm) was done.
- Two-year pooled data (2021 & 2022) revealed that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum level of total sugars, with a value of 5.95%.

5.3.7 Reducing sugars (%) of Kinnow mandarin

- During the year 2021 trail, the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum value of reducing sugars of 2.82%.
- In the second year of the experiment (2022), the treatment T_8, which involved the application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm), recorded the maximum level of reducing sugars with the value of 2.84%.
- Pooled data for the two years also registered the same trend as observed in two years of experimentation. Max. reducing sugars (2.83%) recorded under T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

5.3.8 Non-reducing sugars (%) of Kinnow mandarin

- The experiment conducted in 2021, showed that the highest non-reducing sugar (3.10%) under the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].
- In the 2022 trail, maximum amount of non-reducing sugar (3.14%) in treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].
- The combined data from the two years (2021 & 2022) also resulted in maximum non-reducing sugars under treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recording a value of 3.12%.

5.4 Leaf Nutrients Status

5.4.1 Nitrogen content (ppm) in leaves of Kinnow mandarin

- In the study conducted in 2021, it was found that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum nitrogen content in the leaves (34700 ppm).
- During the second year (2022) of the experimental study, the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] again recorded the highest nitrogen content in the leaves, exhibiting a value of 34900 ppm.
- Two years (2021 & 2022) data showed max. leaf nitrogen (34800 ppm) under treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

5.4.2 Phosphorous content (ppm) in leaves of Kinnow mandarin

- In the initial year of the experiment (2021), treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] showed the maximum phosphorus content in leaves, recording a value of 336.50 ppm.
- During the experimental year of 2022, again treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum phosphorus content (343.30 ppm) in leaves.
- Data combined for two years (2021 & 2022) showed that the maximum phosphorus content in leaves (339.90 ppm) under the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].

5.4.3 Potassium content (ppm) in leaves of Kinnow mandarin

- During the first year (2021), max. potassium (1197.00 ppm) in leaves was recorded under the treatment T_4 [(RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm)].
- In second-year trail (2022), maximum potassium content in leaves (1172.60 ppm) was observed under treatment T_6 where application of RDF + *Azotobacter* + nB (20 ppm) + nZn (200 ppm) was done.
- Pooled data for the two years (2021 & 2022), registered maximum potassium content in leaves (1180.05 ppm) under the treatment T_4 where application of RDF + *Azotobacter* + nB (20 ppm) + nZn (100 ppm) was done.

5.4.4 Boron content (ppm) in leaves of Kinnow mandarin

- During the first trail (2021), the max. boron in leaves (36.84 ppm) was recorded in the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)].
- The experiment conducted in 2022, treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum Boron content in leaves (40.89 ppm)
- Aggregated data for the two years (2021 & 2022) registered similar trend. Maximum Boron content in leaves (38.87 ppm) was recorded under the treatment T_8 where RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) was applied.

5.4.5 Zinc content (ppm) in leaves of Kinnow mandarin

- In the 2021 trial, it was observed that the treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the maximum recorded zinc content in leaves (26.04 ppm).
- During the second year of experimentation (2022), treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] recorded the maximum zinc content (27.83 ppm) in leaves.
- Analysing the data from both years of experiment (2021 & 2022), similar pattern was observed among the different treatments. The treatment T_8 [(RDF +

Azotobacter + nB (40 ppm) + nZn (150 ppm)] exhibited the maximum zinc content in leaves, with a recorded value of 26.93 ppm.

5.5 EFFECT OF *AZOTOBACTER* AND NANO MICRONUTRIENTS ON ECONOMICS OF CULTIVATION OF KINNOW MANDARIN

- In 1st year (2021), treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] resulted in the maximum Benefit-cost ratio (1:3.10).
- During the second year of trail (2022), treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] maintained its position with the max. BCR of 1:3.24.

CONCLUSION

Conclusions derived from the current study reveal that *Azotobacter* and nano micronutrients application in Kinnow mandarin can significantly improve the growth, yield and quality parameters. The positive effect on fruit drop as well as plant nutrient status was also observed with the application of the nano-micronutrients. Although fruit is the final entity desired for an economic fruit production activity, yet luxuriant vegetative growth is required for proper sink performance in fruit crop. In this context, the vegetative parameters were significantly affected and maximum increment in vegetative parameters was recorded under the treatment T_{11} where recommended dose of fertilizers was applied along with *Azotobacter*, nano boron @ 60 ppm and nano zinc @ 200ppm as compared to other treatments. For the quality characters, it was observed that treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] was effective for fruit quality (TSS, TA, Ascorbic acid content, total sugars and minimum polyphenols). The yield attributing characters viz. fruit weight, fruit length, fruit size, rind thickness, weight of seeds, peel weight, juice content, number of fruits, fruit yield were maximum in treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)]. Fruit drop, a major concern in Kinnow mandarin cultivation was also minimum under the treatment T_8 [(RDF+ *Azotobacter* + nB (40 ppm) + nZn (150 ppm)]. Use of nano-micronutrients also resulted in Better absorption of nutrients By the Kinnow mandarin plant as revealed by the leaf nutrient analysis. The maximum uptake of nitrogen, phosphorous, boron and zinc was observed where the application of RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm) was done. Also, the B:C ratio was recorded maximum in treatment T_8 [(RDF + *Azotobacter* + nB (40 ppm) + nZn (150 ppm)] for both the years of experiment. It can be concluded that for successful cultivation of Kinnow mandarin using nano-micronutrients, application of recommended dose of fertilizer with *Azotobacter* @100g per plant, nano boron @ 40 ppm and nano zinc @ 150 ppm can be recommended based on the results of the present study.

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APPENDICES

Appendix 1

Standard Meteorological Data for the year 2021

Date	Max T	Min T	RH	Wind Speed (km/h)	RF (mm)	Evaporation (mm)
01-01-2021	21	8	73.0	3	0	2.1
02-01-2021	10	8	71.5	0	0	0.9
03-01-2021	22	13	44.5	6	0	8
04-01-2021	12	9	72.0	2	0	1.2
05-01-2021	11	8	70.0	0	0	1
06-01-2021	12	8	70.5	2	0	0.9
07-01-2021	11	8	69.5	0	0	0.8
08-01-2021	12	8	72.0	0	0	0.9
09-01-2021	11	8	71.5	0	0	1.1
10-01-2021	20	10	71.0	8	0	1.2
11-01-2021	11	8	72.0	2	0	1.1
12-01-2021	13	8	71.5	0	0	1.1
13-01-2021	13	8	72.5	2	0	1
14-01-2021	12	8	72.5	0	0	0.8
15-01-2021	12	8	76.0	0	0	0.9
16-01-2021	12	8	78.5	0	0	0.8
17-01-2021	11	9	78.5	5	0	0.7
18-01-2021	11	8	77.5	0	0	1
19-01-2021	11	8	78.5	2	0	0.7
20-01-2021	12	9	78.5	13	0	0.6
21-01-2021	12	8	84.5	2	0	0.8
22-01-2021	11	8	79.5	8	0	1.2
23-01-2021	11	8	80.0	0	0	0.6
24-01-2021	20	9	80.0	5	0	0.8
25-01-2021	11	8	80.0	4	0	0.7
26-01-2021	19	10	79.5	9	0	0.9
27-01-2021	12	8	78.0	8	0	0.8
28-01-2021	12	8	66.0	5	0	0.8
29-01-2021	12	8	64.5	6	0	0.9
30-01-2021	19	7	64.5	2	0	1.1
31-01-2021	20	8	40.0	10	0	0.9
01-02-2021	21	11	40.5	14	0	1.3
02-02-2021	23	11	38.0	9	0	1.6
03-02-2021	20	9	36.5	6	0	1.4
04-02-2021	24	12	36.5	6	0	1.8
05-02-2021	20	10	61.5	9	0	1.5
06-02-2021	21	10	59.0	12	0	1.6
07-02-2021	21	10	53.0	11	0	1.5
08-02-2021	21	12	58.0	9	0	1.8
09-02-2021	20	12	57.0	4	0	1.5

10-02-2021	21	12	68.0	0	0	1.7
11-02-2021	21	10	64.5	4	0	1.6
12-02-2021	18	10	81.5	2	0	1.4
13-02-2021	21	12	84.5	2	0	1.1
14-02-2021	21	11	82.5	4	0	1.2
15-02-2021	22	11	81.5	2	0	1.1
16-02-2021	22	12	81.0	2	0	1.2
17-02-2021	21	11	82.5	4	0	1.2
18-02-2021	22	12	84.0	6	0	1
19-02-2021	22	11	83.0	2	0	1
20-02-2021	22	11	81.0	4	0	1.2
21-02-2021	24	11	79.0	2	0	1.3
22-02-2021	26	12	74.0	2	0	1.4
23-02-2021	27	14	71.5	2	0	1.6
24-02-2021	27	16	68.5	4	0	2
25-02-2021	28	16	66.0	6	0	2
26-02-2021	28	18	67.0	4	0	3
27-02-2021	29	19	54.5	2	0	2.8
28-02-2021	29	16	53.0	2	0	2.9
03-01-2021	29	16	54.0	2	0	2.8
03-02-2021	29	15	54.0	2	0	3
03-03-2021	29	16	52.0	2	0	3
03-04-2021	29	16	52.0	4	0	3.1
03-05-2021	29	16	52.5	4	0	2.9
03-06-2021	29	16	52.0	8	0	3
03-07-2021	29	16	53.0	2	0	3
03-08-2021	29	17	55.5	2	0	2.9
03-09-2021	30	19	54.0	2	0	3
03-10-2021	29	20	51.5	2	0	2.9
03-11-2021	31	20	50.5	2	0	2.8
03-12-2021	30	20	51.0	20	0	2.6
03-13-2021	31	20	47.5	2	0	3.1
03-14-2021	31	20	49.0	2	0	3
03-15-2021	30	19	50.0	4	0	3.1
03-16-2021	31	19	50.5	2	0	3.1
03-17-2021	30	19	52.0	2	0	3
03-18-2021	31	19	52.0	4	0	3.1
03-19-2021	31	20	52.0	2	0	3
03-20-2021	28	19	51.5	0	0	2.9
03-21-2021	29	19	51.0	2	0	2.9
03-22-2021	28	15	56.0	2	2.2	0.3
03-23-2021	28	14	55.5	2	2	0
03-24-2021	28	14	54.0	2	0	2.5
03-25-2021	28	14	52.5	2	0	2.6
03-26-2021	28	15	51.0	4	0	2.8
03-27-2021	32	15	16.0	0	0	2.8
03-28-2021	31	16	48.0	4	0	2.9
03-29-2021	32	17	47.0	6	0	3
03-30-2021	34	19	48.5	2	0	3

03-31-2021	30	11	35.0	2	0	3.5
04-01-2021	34	13	35.0	2	0	4
04-02-2021	33	12	35.0	4	0	3
04-03-2021	34	13	34.5	4	0	4
04-04-2021	33	12	35.0	22	0	3.5
04-05-2021	29	13	35.5	2	0	4
04-06-2021	29	14	37.0	8	0	4
04-07-2021	33	14	36.5	2	5	0
04-08-2021	31	14	37.5	2	0	2.9
04-09-2021	30	15	36.5	2	0	3
04-10-2021	32	16	32.0	0	0	4
04-11-2021	31	16	33.5	2	0	4
04-12-2021	32	16	33.5	2	0	4
04-13-2021	34	18	30.0	4	0	4
04-14-2021	35	16	34.5	2	0	5
04-15-2021	30	16	33.0	2	0	5
04-16-2021	30	21	33.5	0	0	5
04-17-2021	32	21	37.5	2	0.2	4
04-18-2021	30	16	33.0	2	0	4
04-19-2021	29	18	36.0	4	0	4
04-20-2021	30	19	32.5	2	0	4
04-21-2021	31	19	36.0	4	0.4	3.5
04-22-2021	31	18	42.5	2	0	3
04-23-2021	23	16	46.5	8	18	0
04-24-2021	30	17	35.0	2	0	4
04-25-2021	30	17	36.5	4	0	4
04-26-2021	31	17	35.0	2	0	5
04-27-2021	31	17	37.0	2	0	5
04-28-2021	31	18	36.0	2	0	5
04-29-2021	33	21	35.5	4	0	5
04-30-2021	33	19	37.5	2	4	0
05-01-2021	33	20	37.5	2	0	1
05-02-2021	32	21	37.0	2	0	4
05-03-2021	33	20	37.0	4	0	5
05-04-2021	32	21	36.0	2	0	4
05-05-2021	33	20	37.0	2	4	2
05-06-2021	34	21	37.0	2	0	4
05-07-2021	34	22	36.0	2	0	4
05-08-2021	37	24	36.5	8	0	4.8
05-09-2021	40	25	26.5	10	0	5
05-10-2021	41	27	26.5	4	0	5
05-11-2021	43	27	24.5	14	0	4.5
05-12-2021	35	28	34.0	19	0	5
05-13-2021	31	24	47.0	21	0	5
05-14-2021	37	22	43.0	19	0	4.8
05-15-2021	38	27	27.0	8	0	5.2
05-16-2021	40	28	22.0	13	0	5
05-17-2021	42	29	20.5	12	0	5.5
05-18-2021	40	30	21.0	10	0	5.8

05-19-2021	35	29	33.5	9	0	5.6
05-20-2021	37	20	74.0	11	34	5.8
05-21-2021	35	23	49.0	23	5.2	6.2
05-22-2021	38	25	39.0	8	9	6.5
05-23-2021	37	27	29.0	15	0	6.4
05-24-2021	41	29	20.0	16	0	5.9
05-25-2021	42	30	17.0	8	0	5.8
05-26-2021	43	29	9.5	8	0	5.8
05-27-2021	44	32	11.0	19	0	6
05-28-2021	43	29	37.5	25	0	5.8
05-29-2021	42	28	38.5	24	0	5.6
05-30-2021	45	30	29.5	19	0	4.5
05-31-2021	43	26	28.0	14	0	7
06-01-2021	38	22	50.0	4	0	5
06-02-2021	39	23	51.5	4	0	6.8
06-03-2021	33	21	52.5	2	10	0
06-04-2021	28	20	63.5	10	10.5	0
06-05-2021	40	21	64.5	6	6	0
06-06-2021	40	23	52.0	4	4	5
06-07-2021	41	20	47.5	4	0	5.5
06-08-2021	36	30	58.5	6	0	4.5
06-09-2021	40	33	47.5	8	0	5
06-10-2021	42	31	55.5	10	0	6
06-11-2021	33	29	60.0	18	5	0
06-12-2021	42	23	60.0	18	0	5
06-13-2021	41	24	49.0	4	0	5.5
06-14-2021	42	27	70.5	6	6.9	0
06-15-2021	30	28	48.5	8	0	5
06-16-2021	34	27	67.5	12	1.1	4
06-17-2021	36	27	65.5	2	1	4
06-18-2021	36	28	64.5	10	0	5.5
06-19-2021	40	31	47.0	10	0	6.2
06-20-2021	41	32	48.0	10	0	6.2
06-21-2021	42	32	45.0	4	0	6.8
06-22-2021	40	21	45.0	10	0	6.5
06-23-2021	31	30	51.5	4	0	6.2
06-24-2021	38	28	47.0	6	0	6.1
06-25-2021	31	22	49.5	4	1.3	4.7
06-26-2021	34	28	48.5	4	1.1	5.2
06-27-2021	35	29	49.5	10	2.9	4.2
06-28-2021	31	27	52.0	8	0	5.6
06-29-2021	40	31	51.0	2	0	6.5
06-30-2021	38	31	44.5	4	0	6.2
07-01-2021	41	32	46.0	8	0	7.8
07-02-2021	40	31	49.0	2	0	8.5
07-03-2021	39	32	48.0	6	24	0
07-04-2021	40	33	55.0	4	0	10.2
07-05-2021	42	34	50.5	4	0	10.5
07-06-2021	41	32	47.5	8	0	10

07-07-2021	40	28	49.0	4	0	9.8
07-08-2021	40	34	46.5	2	0	10.2
07-09-2021	41	28	48.0	6	34	0
07-10-2021	42	32	46.0	10	0	10.5
07-11-2021	42	34	48.5	4	0	10.2
07-12-2021	42	35	47.0	6	0	10.1
07-13-2021	38	27	51.0	2	28	0
07-14-2021	42	33	48.5	2	0	10.2
07-15-2021	41	34	49.5	4	0	9.9
07-16-2021	42	34	46.5	8	0	10.1
07-17-2021	42	28	63.0	4	0	8.6
07-18-2021	41	29	63.0	2	0	8.2
07-19-2021	38	28	69.5	4	6	0
07-20-2021	37	28	70.0	4	7	0
07-21-2021	38	29	69.0	2	6	0
07-22-2021	43	28	75.0	6	29	0
07-23-2021	45	29	71.0	4	0	8.6
07-24-2021	42	28	70.5	Calm condition	0	8.5
07-25-2021	41	29	70.0	2	0	8
07-26-2021	30	29	68.0	6	1	7.5
07-27-2021	39	29	73.0	4	0	7.8
07-28-2021	34	30	75.0	4	12.2	0
07-29-2021	33	28	73.5	6	8.5	0
07-30-2021	41	30	73.5	4	9	0
07-31-2021	39	31	74.0	4	1	7.2
08-01-2021	42	30	73.0	2	0	7.5
08-02-2021	41	31	71.5	4	0	7.4
08-03-2021	42	30	73.5	2	0	7.3
08-04-2021	41	29	74.0	4	0	7.6
08-05-2021	42	31	72.5	4	0	7.5
08-06-2021	41	29	70.5	4	0	7.2
08-07-2021	40	30	73.5	6	0	7.1
08-08-2021	39	28	68.5	2	0	7.6
08-09-2021	40	28	71.0	4	0	7.4
08-10-2021	41	29	70.0	6	0	7.2
08-11-2021	39	29	68.5	2	0	7.5
08-12-2021	42	30	68.0	16	0	7.5
08-13-2021	40	31	70.5	4	0	7.2
08-14-2021	42	31	72.5	10	9.6	0
08-15-2021	41	28	67.5	6	0	7.1
08-16-2021	42	30	73.0	2	0	7.5
08-17-2021	40	31	66.5	2	0	8.2
08-18-2021	41	30	70.0	2	0	7.5
08-19-2021	40	29	69.5	4	0	7
08-20-2021	40	30	70.0	4	0	6.5
08-21-2021	40	29	67.0	6	0	6
08-22-2021	39	30	70.0	4	25	0
08-23-2021	41	29	70.5	Calm condition	35	0
08-24-2021	40	30	67.0	4	0	6

08-25-2021	41	31	67.0	6	0	6.2
08-26-2021	40	29	69.5	8	0	6
08-27-2021	40	30	70.0	6	0	6
08-28-2021	41	30	66.0	6	0	6.5
08-29-2021	40	30	69.0	4	0	6
08-30-2021	40	27	65.5	10	22	0
08-31-2021	39	28	69.5	4	40	0
09-01-2021	42	30	69.5	2	0	6
09-02-2021	41	30	70.0	4	0	4
09-03-2021	40	31	70.0	2	0	6
09-04-2021	35	28	68.0	4	28	0
09-05-2021	40	30	71.0	4	0	6
09-06-2021	40	29	72.5	Calm condition	0	6
09-07-2021	41	30	70.0	4	0.2	5.8
09-08-2021	40	30	68.0	4	0	5.5
09-09-2021	38	30	67.5	6	0	5.5
09-10-2021	40	31	69.5	4	0	6
09-11-2021	37	29	68.0	2	22.4	0
09-12-2021	38	28	69.5	4	0	4
09-13-2021	39	28	65.5	2	0	4
09-14-2021	40	28	69.5	Calm condition	0	2
09-15-2021	40	30	69.0	Calm condition	0	4.5
09-16-2021	38	31	68.0	6	0	4
09-17-2021	39	30	71.5	4	0	6
09-18-2021	37	28	65.5	2	12	0
09-19-2021	39	29	68.0	4	0	4
09-20-2021	39	28	66.0	2	0	4
09-21-2021	38	27	66.5	8	30	0
09-22-2021	35	30	65.5	4	25	0
09-23-2021	40	29	64.5	4	0	4
09-24-2021	41	30	63.5	2	0	4.5
09-25-2021	42	30	66.5	4	0	4
09-26-2021	41	29	69.5	6	0	6
09-27-2021	40	28	71.0	4	0	4
09-28-2021	39	27	69.5	6	0	6
09-29-2021	38	28	67.0	4	0	4
09-30-2021	40	28	70.5	8	0	4
10-01-2021	40	28	50.5	4	0	5.1
10-02-2021	31	29	46.0	6	0	4.5
10-03-2021	37	27	51.0	2	0	4.2
10-04-2021	39	27	49.0	Calm Condition	0	4
10-05-2021	38	28	49.5	4	0	4
10-06-2021	39	27	52.0	2	0	4.1
10-07-2021	38	26	53.5	4	0	4.5
10-08-2021	37	26	46.5	2	0	4.5
10-09-2021	36	26	48.0	2	0	4.2
10-10-2021	36	27	51.0	4	0	4.5
10-11-2021	35	27	50.5	Calm Condition	0	4.5
10-12-2021	36	24	46.0	6	0	4.8

10-13-2021	32	23	51.0	2	0	4
10-14-2021	32	20	49.0	2	0	4.2
10-15-2021	36	24	51.5	4	0	4.8
10-16-2021	34	20	46.5	2	0	5
10-17-2021	32	23	50.0	4	0	4.4
10-18-2021	32	20	49.0	Calm Condition	0	4.8
10-19-2021	32	21	50.5	2	0	4.4
10-20-2021	31	20	51.0	2	0	4.2
10-21-2021	31	19	47.5	2	0	5.2
10-22-2021	30	19	45.5	2	0	4.2
10-23-2021	30	20	50.0	2	0	4.5
10-24-2021	30	19	49.5	2	0	4.6
10-25-2021	29	18	51.5	2	0	4.7
10-26-2021	30	18	47.0	8	0	4.5
10-27-2021	29	18	48.0	2	0	4.5
10-28-2021	30	18	49.5	2	0	4.4
10-29-2021	29	16	47.5	2	0	4.2
10-30-2021	29	19	46.5	Calm Condition	0	4.1
10-31-2021	30	19	46.5	2	0	3.5
11-01-2021	30	19	48.0	4	0	3.5
11-02-2021	28	18	49.5	2	0	3.4
11-03-2021	28	19	53.0	6	0	3.4
11-04-2021	29	17	48.0	2	0	3.3
11-05-2021	27	18	49.5	2	0	3.4
11-06-2021	29	18	49.0	2	0	3.5
11-07-2021	29	16	49.5	2	0	3.4
11-08-2021	28	14	51.0	2	0	3.5
11-09-2021	28	14	48.5	Calm Condition	0	3.4
11-10-2021	27	14	48.0	2	0	3.4
11-11-2021	27	16	47.5	2	0	3.6
11-12-2021	27	13	48.0	2	0	3.4
11-13-2021	27	13	51.5	2	0	3.5
11-14-2021	27	14	50.0	2	0	3.4
11-15-2021	26	14	52.5	4	0	3.7
11-16-2021	27	13	52.5	2	0	3.4
11-17-2021	26	14	53.0	2	0	3.4
11-18-2021	27	14	52.0	2	0	3.5
11-19-2021	26	14	53.0	2	0	3.4
11-20-2021	25	13	54.0	2	0	3.4
11-21-2021	24	14	52.5	2	0	3.5
11-22-2021	24	13	53.5	2	0	3.2
11-23-2021	23	12	50.0	0	0	3.1
11-24-2021	24	12	50.0	2	0	3
11-25-2021	24	15	51.0	0	0	1
11-26-2021	21	14	52.0	0	0	1.7
11-27-2021	21	12	49.5	0	0	1
11-28-2021	22	10	46.5	0	0	1
11-29-2021	22	10	50.0	0	0	1
11-30-2021	23	10	48.0	0	0	1.4

12-01-2021	20	11	57.5	2	0	1.3
12-02-2021	21	10	58.0	2	0	1
12-03-2021	20	12	58.5	4	0	1
12-04-2021	22	13	59.5	0	0	1
12-05-2021	23	12	59.5	2	0	1.7
12-06-2021	20	10	60.5	0	0	0
12-07-2021	22	11	62.5	0	0	1
12-08-2021	22	12	69.0	2	0	1
12-09-2021	20	10	57.5	2	0	1
12-10-2021	21	10	58.0	0	0	1.3
12-11-2021	20	9	57.5	2	0	1
12-12-2021	22	11	57.5	4	0	1.6
12-13-2021	20	9	60.5	0	0	1
12-14-2021	19	9	57.5	0	0	1.3
1215-2021	18	8	61.0	2	0	0
12-16-2021	19	8	60.0	4	0	0.3
12-17-2021	20	9	60.0	2	0	1.3
12-18-2021	22	11	58.0	0	0	1
12-19-2021	21	10	58.0	2	0	1.7
12-20-2021	19	5	63.0	0	0	1
12-21-2021	18	7	54.0	0	0	0.5
12-22-2021	22	10	59.5	2	0	1
12-23-2021	19	11	60.0	0	0	1.7
12-24-2021	19	12	58.0	2	0	1
12-25-2021	20	12	56.0	0	0	0.5
12-26-2021	19	11	63.5	0	0	0.7
12-27-2021	20	9	59.5	4	0.5	0
12-28-2021	18	8	61.0	0	0	0.7
12-29-2021	20	6	60.0	0	0	1.5
12-30-2021	18	6	58.0	2	0	1.7
12-31-2021	17	6	61.0	0	0	0.7

Appendix 2

Standard Meteorological Data for the year 2022

Date	Max T	Min T	RH	Wind Speed (km/hr)	RF (mm)	Evaporation (mm)
01-01-2022	18	6	69.5	0	0	0.7
02-01-2022	19	6	66.0	0	0	0
03-01-2022	18	12	69.5	2	0	1.5
04-01-2022	16	12	72.0	4	1	0
05-01-2022	15	8	65.0	2	21.5	0
06-01-2022	14	7	71.5	0	19.5	0
07-01-2022	14	8	67.0	0	21	0
08-01-2022	12	6	68.5	2	18.5	0
09-01-2022	11	9	70.0	2	15	0
10-01-2022	14	11	64.5	0	9	0
11-01-2022	15	11	74.0	8	0	0
12-01-2022	18	11	72.0	4	0	0
13-01-2022	17	11	69.5	2	0	0
14-01-2022	15	13	67.0	4	0	0.5
15-01-2022	19	12	71.0	2	0	1
16-01-2022	18	11	66.0	2	0	0.8
17-01-2022	18	13	69.0	4	0	0.5
18-01-2022	19	10	69.0	4	0	0
19-01-2022	17	10	68.0	2	0	0.5
20-01-2022	16	14	67.5	0	2	0
21-01-2022	15	10	65.0	0	0	0
22-01-2022	15	13	64.5	4	0	0.5
23-01-2022	14	12	65.0	0	0	0.7
24-01-2022	14	13	70.0	2	0	0.1
25-01-2022	15	12	67.0	4	0	0.2
26-01-2022	16	13	69.0	0	0	0.2
27-01-2022	12	10	74.0	4	0	0
28-01-2022	18	9	77.0	2	0	0
29-01-2022	18	10	72.0	0	0	0
30-01-2022	17	8	74.0	4	0	0
31-01-2022	18	8	76.0	4	0	0
01-02-2022	14	8	75.0	4	0	0
02-02-2022	15	8	76.0	Calm Condition	0	0
03-02-2022	16	8	64.0	2	0.5	0
04-02-2022	17	9	66.0	4	0	0.2
05-02-2022	16	10	66.0	2	0	0.3
06-02-2022	12	11	67.5	Calm Condition	0	0.5
07-02-2022	13	8	74.0	Calm Condition	0	0.5
08-02-2022	10	7	72.0	4	0	0.7
09-02-2022	14	7	73.0	Calm Condition	0	1.5

10-02-2022	12	10	68.0	4	0	1
11-02-2022	11	8	69.0	2	0	1.7
12-02-2022	17	8	69.0	4	0	2
13-02-2022	16	10	73.0	2	0	1.7
14-02-2022	17	8	72.0	4	0	0
15-02-2022	18	9	65.0	Calm Condition	0	0
16-02-2022	17	8	67.0	4	0	1.7
17-02-2022	18	8	66.0	2	0	2
18-02-2022	17	8	66.0	Calm Condition	0	2.5
19-02-2022	16	9	63.0	Calm Condition	0	1
20-02-2022	18	9	63.5	4	0	1.5
21-02-2022	21	10	61.0	Calm Condition	0	1
22-02-2022	20	11	58.5	2	0	1
23-02-2022	22	11	59.5	4	0	1.7
24-02-2022	20	11	58.5	Calm Condition	0	2.5
25-02-2022	20	12	59.0	2	0	0
26-02-2022	15	8	54.0	6	16	0
27-02-2022	18	10	55.0	2	0	1.7
28-02-2022	16	9	56.0	4	0	1
01-03-2022	18	10	54.0	2	0	2.5
02-03-2022	16	9	56.0	0	0	2
03-03-2022	17	10	54.5	4	0	1.7
04-03-2022	20	9	53.0	4	0	1.5
05-03-2022	21	10	51.0	0	0	2
06-03-2022	22	10	48.0	0	0	1.7
07-03-2022	20	11	49.5	4	0	1.5
08-03-2022	22	13	50.0	0	0	1.7
09-03-2022	24	18	48.0	0	0	2.5
10-03-2022	20	18	49.5	0	0	2.7
11-03-2022	20	20	49.0	4	0	2.6
12-03-2022	18	18	48.0	2	0	3
13-03-2022	22	20	49.0	0	0	2
14-03-2022	26	20	53.0	4	0	2
15-03-2022	28	20	45.0	4	0	2.5
16-03-2022	32	19	50.0	0	0	2.7
17-03-2022	30	22	48.0	2	0	2
18-03-2022	32	20	49.0	4	0	2
19-03-2022	32	20	47.0	0	0	2.1
20-03-2022	30	19	48.5	8	0	2
21-03-2022	32	23	46.0	0	0	2.7
22-03-2022	33	23	48.0	0	0	2
23-03-2022	34	22	48.0	0	0	3
24-03-2022	32	23	47.0	4	0	3
25-03-2022	30	21	46.0	4	0	3
26-03-2022	31	20	46.0	12	0	4.7

27-03-2022	32	21	44.0	0	0	4.5
28-03-2022	30	20	46.5	4	0	3.5
29-03-2022	31	19	50.0	2	0	4
30-03-2022	32	20	48.0	6	0	5.5
31-03-2022	32	25	47.0	4	0	5.7
01-04-2022	32	22	46.0	0	0	3.5
02-04-2022	33	23	47.5	6	0	4.5
03-04-2022	34	22	47.5	4	0	3.5
04-04-2022	30	24	46.0	12	0	5.5
05-04-2022	34	24	43.5	2	0	4
06-04-2022	32	24	41.5	0	0	3.8
07-04-2022	34	26	40.0	0	0	3.7
08-04-2022	35	26	38.0	0	0	3.7
09-04-2022	40	27	38.5	4	0	4.5
10-04-2022	40	27	36.0	16	0	6.5
11-04-2022	42	26	38.0	0	0	5
12-04-2022	44	28	42.5	4	0	6.5
13-04-2022	42	29	40.5	0	0	5.5
14-04-2022	40	26	39.0	2	0.5	5.6
15-04-2022	41	27	38.0	2	0	6.5
16-04-2022	40	27	39.5	4	0	6
17-04-2022	42	28	40.5	0	0	7.2
18-04-2022	40	28	37.0	12	0	5.5
19-04-2022	40	29	37.0	34	0	6.4
20-04-2022	37	30	31.5	12	0	6.7
21-04-2022	38	30	32.0	10	0	6.5
22-04-2022	39	29	33.0	14	0	6.2
23-04-2022	40	28	32.0	4	0	6
24-04-2022	42	30	30.5	22	0	5.7
25-04-2022	41	32	31.0	6	0	5
26-04-2022	42	31	30.5	12	0	4.5
27-04-2022	40	31	26.0	2	0	5
28-04-2022	42	32	26.0	10	0	4.8
29-04-2022	41	32	26.0	10	0	4.5
30-04-2022	41	32	25.5	10	0	4.7
01-05-2022	41	30	29.0	0	0	6.5
02-05-2022	42	31	27.5	8	0	8
03-05-2022	40	30	27.0	12	0	8
04-05-2022	34	31	28.5	20	0	8
05-05-2022	41	27	30.5	6	0	8
06-05-2022	40	29	30.0	8	0	6.3
07-05-2022	42	30	28.5	18	0	6.5
08-05-2022	43	30	29.0	10	0	7.1
09-05-2022	36	30	26.5	22	0	7.3
10-05-2022	40	30	29.0	22	0	6
11-05-2022	42	32	33.0	24	0	7.6

12-05-2022	40	33	38.0	16	0	18.2
13-05-2022	38	32	37.0	26	0	9.3
14-05-2022	37	30	31.5	10	0	9.8
15-05-2022	42	32	30.5	12	0	11.6
16-05-2022	42	31	34.0	18	0	11.6
17-05-2022	40	32	30.0	18	0	11.6
18-05-2022	41	32	28.5	6	0	9.7
19-05-2022	37	31	32.5	24	0	10.5
20-05-2022	42	33	29.5	10	0	12.6
21-05-2022	40	32	27.5	24	0	15.7
22-05-2022	42	30	31.5	12	0	14.2
23-05-2022	42	27	33.5	16	11.2	6.4
24-05-2022	36	26	34.0	4	0	9.1
25-05-2022	40	24	36.0	4	0	10.1
26-05-2022	39	28	37.5	8	0	8.4
27-05-2022	42	30	39.0	0	0	6.5
28-05-2022	40	32	39.5	0	0	10.2
29-05-2022	40	32	39.0	46	0	18.4
30-05-2022	36	33	41.0	0	0	12.7
31-05-2022	38	30	40.5	10	0	11.4
01-06-2022	32	31	38.5	4	0	12.6
02-06-2022	38	30	39.0	0	0	14.5
03-06-2022	40	31	36.0	22	0	16
04-06-2022	41	32	37.0	8	0	12.4
05-06-2022	43	30	36.0	0	0	8.5
06-06-2022	40	32	35.5	4	0	12.5
07-06-2022	40	31	36.5	5	0	13.8
08-06-2022	48	34	34.5	6	0	14.4
09-06-2022	38	32	34.0	12	0	18.5
10-06-2022	39	34	32.0	14	0	20.4
11-06-2022	40	33	55.0	26	0	14.5
12-06-2022	38	28	52.5	17	0	13.2
13-06-2022	39	34	31.5	6	0	32.6
14-06-2022	40	35	31.0	0	0	18.6
15-06-2022	36	30	55.0	21	0	3.5
16-06-2022	40	30	52.5	12	0	10.5
17-06-2022	38	34	38.5	11	0	5.5
18-06-2022	44	35	46.5	9	0	6.3
19-06-2022	40	31	39.0	13	0	2.1
20-06-2022	34	29	46.0	0	65.4	0
21-06-2022	38	29	46.5	24	5.2	4.1
22-06-2022	42	28	46.5	12	0	2.6
23-06-2022	40	27	47.0	26	0	10.8
24-06-2022	40	28	47.0	16	0	18.6
25-06-2022	41	30	46.5	0	0	24.8
26-06-2022	40	32	53.5	5	0	15.5
27-06-2022	38	34	48.5	1	0	38.6

28-06-2022	43	34	53.0	32	0	12.4
29-06-2022	44	32	55.0	12	0	18.2
30-06-2022	40	30	53.0	14	0	6.4
01-07-2022	38	32	61.0	40	0	18.1
02-07-2022	42	30	58.0	14	0	14.6
03-07-2022	44	32	57.5	18	35.2	11.2
04-07-2022	44	29	59.0	4	4.2	13.2
05-07-2022	42	32	63.5	10	0	14.4
06-07-2022	43	31	60.5	8	0	0
07-07-2022	45	32	64.5	0	0	0
08-07-2022	44	32	66.5	4	0	4.8
09-07-2022	40	33	63.0	0	0	4.7
10-07-2022	39	30	60.0	10	0	3.2
11-07-2022	36	33	63.0	18	0	4.7
12-07-2022	37	33	62.5	4	0	2
13-07-2022	37	30	60.0	20	0	0
14-07-2022	38	32	59.5	26	0	4.6
15-07-2022	32	32	57.5	4	6.2	2.4
16-07-2022	37	30	57.0	2	0	4.8
17-07-2022	36	31	55.0	0	4.7	4.6
18-07-2022	35	32	59.5	4	2.6	2.7
19-07-2022	36	32	61.5	10	8.4	2.9
20-07-2022	34	31	74.5	23	47.4	0.9
21-07-2022	29	25	78.0	8	142.6	0.8
22-07-2022	35	26	68.0	18	0	0.8
23-07-2022	36	28	73.0	9	0	1
24-07-2022	37	27	70.5	12	0	1.6
25-07-2022	34	27	63.0	14	0	2.8
26-07-2022	37	28	67.0	9	0	3.2
27-07-2022	37	27	73.0	9	1.4	3
28-07-2022	37	25	71.0	5	1	3.2
29-07-2022	30	26	67.5	13	0.5	2.9
30-07-2022	29	25	68.0	8	0.9	2.6
31-07-2022	34	24	70.5	4	0.7	2.5
01-08-2022	35	24	68.5	11	0	7.4
02-08-2022	36	26	73.0	1	0	7.2
03-08-2022	36	27	73.0	13	0	7.5
04-08-2022	35	26	73.0	11	0	7.6
05-08-2022	34	25	71.0	9	0	7.1
06-08-2022	34	26	70.0	4	0.1	6.6
07-08-2022	35	26	70.5	4	0	0
08-08-2022	36	25	67.5	9	0	0
09-08-2022	39	28	67.0	5	0	7.3
10-08-2022	39	29	70.0	5	0	6.2
11-08-2022	26	24	69.5	16	8.3	7.5
12-08-2022	37	25	65.5	5	0	7
13-08-2022	35	26	66.0	10	0	8.1

14-08-2022	35	27	69.5	9	4.6	0
15-08-2022	29	25	68.5	18	3.2	0
16-08-2022	34	25	68.0	3	0	7.4
17-08-2022	34	26	73.5	15	0	7.5
18-08-2022	33	26	73.0	8	0	7.5
19-08-2022	35	28	67.5	5	1.2	6.3
20-08-2022	34	27	69.0	3	0.5	6.1
21-08-2022	35	25	69.5	5	0.5	0
22-08-2022	33	26	71.0	5	1.4	0
23-08-2022	33	26	70.5	10	3.3	7.1
24-08-2022	35	26	65.5	10	0.8	7.3
25-08-2022	33	25	71.0	6	0.7	7.6
26-08-2022	34	26	70.5	8	0.1	7.4
27-08-2022	34	25	73.0	5	0	7.2
28-08-2022	34	25	73.5	7	0	7.5
29-08-2022	34	27	70.5	6	1.6	0
30-08-2022	35	25	66.5	9	1.7	0
31-08-2022	37	26	69.0	9	0.1	7.1
01-09-2022	36	27	69.5	9	0	4
02-09-2022	36	26	70.0	7	1	6
03-09-2022	36	26	68.0	6	0.1	6
04-09-2022	36	26	69.5	4	0	0
05-09-2022	38	25	65.5	11	0	0
06-09-2022	37	25	64.5	12	0	5.2
07-09-2022	38	25	68.0	10	0	5.5
08-09-2022	38	26	65.5	11	0	6
09-09-2022	39	26	63.5	12	0	4.3
10-09-2022	38	25	67.0	1	0	4.2
11-09-2022	38	26	75.5	10	0	4
12-09-2022	35	25	70.5	9	0.2	0
13-09-2022	36	23	68.0	12	0.5	0
14-09-2022	36	24	65.5	11	0	0
15-09-2022	33	25	68.5	8	0.4	4.5
16-09-2022	32	24	69.5	11	1.4	6
17-09-2022	33	21	64.5	19	2.6	4
18-09-2022	38	24	71.0	13	0	6.3
19-09-2022	38	24	67.5	17	0	0
20-09-2022	37	25	66.5	10	0	0
21-09-2022	39	25	66.0	14	0	4
22-09-2022	35	25	68.0	10	0.5	4
23-09-2022	34	23	66.5	14	0.1	6.2
24-09-2022	30	23	70.5	10	2.1	6.2
25-09-2022	23	21	69.5	9	2.4	4
26-09-2022	35	20	63.5	12	0	4
27-09-2022	35	22	65.5	10	0	2
28-09-2022	35	23	69.5	12	0	4.5
29-09-2022	36	23	67.0	9	0	5.5

30-09-2022	37	23	68.5	12	0	5.5
01-10-2022	37	23	50.5	6	0	5.1
02-10-2022	36	23	51.0	12	0	4.5
03-10-2022	37	23	49.5	12	0	4
04-10-2022	37	22	46.5	10	0	4.8
05-10-2022	37	21	48.0	7	0	4.6
06-10-2022	34	22	46.0	9	0	5
07-10-2022	32	21	50.5	8	0	5.2
08-10-2022	32	21	51.0	9	0	3.5
09-10-2022	32	21	49.0	8	0	3.8
10-10-2022	30	19	60.0	3	0	3.6
11-10-2022	31	20	58.5	2	0	4.1
12-10-2022	36	24	46.0	6	0	4.8
13-10-2022	32	23	51.0	2	0	4
14-10-2022	32	20	49.0	2	0	4.2
15-10-2022	36	24	51.5	4	0	4.8
16-10-2022	34	20	46.5	2	0	5
17-10-2022	32	23	50.0	4	0	4.4
18-10-2022	32	20	49.0	0	0	4.8
19-10-2022	32	21	50.5	2	0	4.4
20-10-2022	31	20	51.0	2	0	4.2
21-10-2022	31	19	47.5	3	0	4.6
22-10-2022	30	19	45.5	2	0	4.4
23-10-2022	30	20	50.0	2	0	4.5
24-10-2022	30	19	49.5	2	0	4.6
25-10-2022	29	18	51.5	3	0	4.7
26-10-2022	30	18	47.0	8	0	5.2
27-10-2022	29	18	48.0	3	0	4.5
28-10-2022	30	19	49.5	3	0	4.4
29-10-2022	29	16	47.5	2	0	4.5
30-10-2022	29	19	46.5	0	0	4
31-10-2022	30	19	46.5	2	0	4.2
01-11-2022	30	19	48.0	4	0	3.5
02-11-2022	28	18	49.5	2	0	3.4
03-11-2022	28	19	53.0	6	0	3.4
04-11-2022	29	17	48.0	2	0	3.3
05-11-2022	27	18	49.5	2	0	3.4
06-11-2022	29	18	49.0	2	0	3.5
07-11-2022	29	16	49.5	2	0	3.4
08-11-2022	28	14	51.0	0	0	3.5
09-11-2022	28	14	48.5	2	0	3.4
10-11-2022	27	14	48.0	3	0	3.4
11-11-2022	27	16	47.5	3	0	3.5
12-11-2022	27	13	48.0	2	0	3.6
13-11-2022	27	13	51.5	2	0	3.2
14-11-2022	27	14	50.0	2	0	3.3
15-11-2022	26	14	52.5	4	0	3.5

16-11-2022	27	13	52.5	2	0	3.4
17-11-2022	26	14	53.0	2	0	3.3
18-11-2022	27	14	52.0	2	0	3.2
19-11-2022	26	14	53.0	3	0	3.1
20-11-2022	25	13	54.0	3	0	3.3
21-11-2022	24	14	49.5	2	0	3.2
22-11-2022	24	12	53.5	4	0	3.2
23-11-2022	23	12	50.0	2	0	3.3
24-11-2022	24	15	50.0	0	0	3.4
25-11-2022	24	14	51.0	2	0	3
26-11-2022	21	12	52.0	0	0	2
27-11-2022	21	10	49.5	0	0	1.7
28-11-2022	22	10	46.5	0	0	1.9
29-11-2022	22	10	50.0	0	0	2
30-11-2022	23	11	48.0	0	0	1.8
01-12-2022	25	11	83.0	0	0	1.5
02-12-2022	24	13	84.0	2	0	2
03-12-2022	26	14	74.0	5	0	1.7
04-12-2022	28	12	72.0	8	0	1.5
05-12-2022	27	13	70.5	2	0	2
06-12-2022	27	8	77.0	0	0	1.3
07-12-2022	27	9	74.5	4	0	1.8
08-12-2022	26	9	75.0	4	0	1.5
09-12-2022	28	11	71.0	0	0	1.5
10-12-2022	28	14	76.5	10	0	1.3
11-12-2022	29	13	73.0	12	0	1.7
12-12-2022	27	11	67.5	4	0	1.5
13-12-2022	27	12	83.5	10	0	1.5
14-12-2022	26	10	84.0	8	0	1.3
15-12-2022	25	10	81.0	10	0	1.5
16-12-2022	25	10	82.0	5	0	1.8
17-12-2022	27	10	87.5	5	0	1.2
18-12-2022	26	10	79.5	2	0	1
19-12-2022	25	11	81.5	4	0	0.5
20-12-2022	23	10	85.0	6	0	0.3
21-12-2022	25	10	84.0	5	0	0
22-12-2022	24	9	84.5	5	0	0.1
23-12-2022	22	9	86.0	5	0	0.1
24-12-2022	23	7	84.0	5	0	0.2
25-12-2022	19	7	86.0	6	0	0.1
26-12-2022	21	9	85.5	5	0	0.2
27-12-2022	22	9	87.0	10	0	0
28-12-2022	23	8	89.5	10	0	0.5
29-12-2022	21	9	93.0	6	2	0
30-12-2022	22	12	84.0	6	0	0
31-12-2022	22	8	83.0	10	0	0

LIST OF CONFERENCES & WORKSHOPS

- Oral Presentation in International Conference on "*Global Initiatives in Agricultural, Forestry and Applied Sciences*" on 17 to 18 October 2021 organized by Shri Guru Ram Rai University, Dehradun, Uttarakhand, India.

- Oral Presentation in International Conference on "*International Conference on Advances in Agriculture Technology and Allied Sciences"* on 19 to 21 June 2023 organized at Loyola Academy, Secunderbad, Telangana, India.

PAPER FOR Ph.D

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