IMPACT OF FOLIAR APPLICATIONS OF NANO-NITROGEN, POTASSIUM AND CALCIUM ON GROWTH, YIELD AND QUALITY OF APPLE (*Malus × domestica* Borkh.)

Thesis

by

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CERTIFICATE-I

This is to certify that the thesis titled **"Impact of foliar applications of nano-nitrogen, potassium and calcium on growth, yield and quality of apple (*Malus x domestica* Borkh.)"** submitted in partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** in the discipline of **SOIL SCIENCE** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173 230 is a bonafide research work carried out by **Mr. Abhinav Rathi (F-2020-52-D)** son of Shri Naveen Kumar Rathore under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation have been fully acknowledged.

Place: Nauni-Solan
Dated:

Dr. Pardeep Kumar
Major Advisor

CERTIFICATE-II

This is to certify that the thesis entitled, **"Impact of foliar applications of nano-nitrogen, potassium and calcium on growth, yield and quality of apple (*Malus x domestica* Borkh.)"**, submitted by **Mr. Abhinav Rathi (F-2020-52-D)** son of Shri Naveen Kumar Rathore to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) – 173 230 India in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** in the discipline of **SOIL SCIENCE** has been approved by the student's advisory committee after an oral examination of the student in collaboration with an External Examiner.

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Needless to say errors and omissions are mine.

Place: Nauni, Solan
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CONTENTS

ABBREVIATIONS USED

Abbreviation		Description
%	:	Per cent
/	:	Per
µg	:	Microgram
^{0}C	:	Degree Celsius
Amsl	:	Above mean sea level
ANOVA	:	Analysis of Variance
Ca	:	Calcium
CD	:	Critical difference
cm	:	Centimetre
cm^2	:	Centimetre square
cm^3	:	Cubic centimeter
cmol (p$^+$) kg^{-1}	:	Centimole proton per kilogram
Cu	:	Copper
cv.	:	Cultivar
DF	:	Degree of freedom
dS m^{-1}	:	Deci Siemens per meter
DTPA	:	Diethylene Triamine Penta Acetic Acid
EC	:	Electrical conductivity
et al.	:	Co-workers
etc	:	et cetera
Fig	:	Figure
Fe	:	Iron
gm	:	gram
g kg^{-1}	:	gram per kilogram
ha	:	Hectare (10,000 m^2)
HP	:	Himachal Pradesh
i.e.		that is
K	:	Potassium
kg	:	Kilogram
kg cm^{-2}	:	Kilogram per centimetre square
kg ha^{-1}	:	Kilogram per hectare

kg tree^{-1}	Kilogram per tree
m	Metre
m^2	metre square
m^3	Cubic metre
mg	Milligram
Mg	Magnesium
ml	Millilitre
mm	Millimetre
Mn	Manganese
MT	Metric tons
N	Nitrogen
nano- N	Nano-Nitrogen
nN	nano- nitrogen
NS	Non Significant
OC	Organic carbon
OPSTAT	Operational Statistics
P	Phosphorus
pH	*Puissance de Hydrogen*
ppm	Parts per million
RBD	Randomized Block Design
S	Sulphur
viz.	Videlicet (namely)
Zn	Zinc

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Chapter-1

INTRODUCTION

The agriculture sector in India is regarded as the backbone of the Indian economy, with over 50 per cent of the workforce relying on agriculture for a livelihood. The growth in the Indian agricultural sector has had its moments of glory nonetheless. “The Green Revolution” has been the major contributor to self-sufficiency in food grain production in India. It occupies centre stage in Indian economy embarking thrust areas as to promote inclusive growth, to enhance rural income and to sustain food security. Of late, horticulture has evolved as a vital aspect of agriculture for nutritional health of mankind and cash crop production with a wide range of crop diversification options (Bhat 2019).

Apple (*Malus x domestica* Borkh.) is the premier table fruit of the world known as “King of temperate fruits.” Botanically, it is a member of family Rosaceae and sub-family Pomoidae with a basic chromosome number of x=17. Area and production of apple in World stands out to be 4825.729 thousand hectares and 95835.964 thousand tonnes, respectively (FAOSTAT, 2024). In India, apple is being grown in an area of 315 thousand hectares with an annual production of 2589 thousand tonnes. It is largely cultivated in states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand and to a small extent in Arunachal Pradesh, Nagaland and Sikkim. In Himachal Pradesh, the apple crop is being grown in an area of 1,15,680 hectares with an annual production 6,72,343 MT for the year 2022- 2023 (DoH 2024).

Apple grows best on well-drained, loamy soils having a pH range of 5.5-6.5. The soil should be free from hard substrata and water-logged conditions. Soils with heavy clay or compact subsoil are to be avoided. Recommendations for chemical fertilizers are generally based on the soil and leaf nutrient status. In case of perennial crops like apple, it is an essential practice to maintain higher levels of soil fertility for a longer time to sustain continuous cultivation both under irrigated and rainfed conditions (Bangroo et al. 2017).

Both soil-applied and foliar-applied nutrients have a place in modern agricultural production systems. Historically, majority of the nutrients were applied to the soil either as manures/organic materials or as synthetic fertilizers. Whereas, foliar feeding is a technique of applying nutrients through liquid fertilizers directly to leaves of plants. Most of the modern foliar fertilizers have been formulated to ensure quick penetration into the foliage, which can speed this process even further.

Foliar application of agrochemicals has long been used in agriculture as a quick, low-cost, and efficient method of increasing the growth and production of many crops under water stress to correct nutritional deficiencies in plants caused by improper supply of nutrients to roots (Fan and Silberbush 2002). This technique is adopted and important for crops to achieve maximum yield when crop nutrient demand is not fully fulfilled through soil during the crop growth period. The main mechanisms by which plants take up the foliar applied nutrients are through leaf stomata (Eichert et al. 1999) and hydrophilic pores within the leaf cuticle. This also helps in reducing the indiscriminate use of fertilizers in soil which otherwise increases economic cost of product and dents the farmer's income.

Lately, nanotechnology has emerged as an effective alternative solution for addressing crop nutritional deficiencies through enhanced availability of nutrients and limited losses to the environment (Mousavi and Rezaei 2011; Ditta et al. 2015). Nanotechnology has provided new opportunities to meet the challenges posed by low or declining nutrient use efficiencies. Loading of nanoparticles with nutrient fertilizer is one of these innovations which are done in three ways: (i) Nutrient can be encapsulated inside nanoporous materials, (ii) coated with thin polymer film, or (iii) delivered as particle or emulsions of nanoscale dimensions (Rai et al. 2012). Foliar application of nanoscale materials can meet the crop nutrient requirement effectively as per its need with enhanced fertilizer use efficiency. Notably, nanomaterials enhance the productivity of crops by increasing the efficiency of agricultural inputs by site-targeted controlled delivery of nutrients, thereby ensuring the minimal use of agri-inputs.

Traditional urea reaches the atmosphere or water sources and pollutes them and damages biodiversity, soil as well as human health. While, nano urea fertilizers have shown potential for higher nutrient use efficiency of nitrogen because of the size-dependent qualities and high surface-volume ratio besides decreased environmental pollution. Experimental trials of Nano Nitrogen (liquid urea) undertaken during Rabi/Zaid 2019-20 through National Agriculture Research System (NARS) at 7 ICAR research institute/state agricultural universities on different crops like paddy, wheat, mustard, maize, tomato, cabbage, cucumber, capsicum, onion indicated that nano nitrogen (Nano Urea) enhanced crop yields besides saving nitrogen to the extent of 50 per cent. As such, nano nitrogen (Nano Urea) holds great promise for foliar application in fruit crops like apple in terms of a better quality of harvested produce and higher crop productivity without harming soil health.

Potassium (K) is one of the most important macro-elements which is highly mobile in plants at all levels, from individual cell to xylem and phloem transport. It is involved in quality-related characteristics of fruit and is called a quality element (Ahmad et al. 2018). It is crucial for many biochemical reactions that are essential for enzyme activation and physiological processes in cell (Anees et al. 2016). These reactions play a major role in ion transport between cells and stomatal conductance under different climatic variables (temperature, light, humidity), thus affect fruit quality (Eisenacha and Angeli 2017). Furthermore, K is important for the fixation of molecular nitrogen by root nodules. Fruit size, appearance, color, soluble solids, acidity, vitamin content, taste, as well as shelf-life are significantly influenced by an adequate supply of K (Tohidloo et al. 2018). There is a wide scope for the foliar application of potassium to plants that ensure healthy growth and high yield (Adhikari et al. 2020).

Calcium (Ca) is an essential macronutrient for plant growth and development, and is considered as an important intracellular messenger, mediating responses to hormones, stress signals and a variety of developmental processes. Furthermore, Ca is an important component in the structure of cell walls and cell membranes (Hepler and Winship 2010). Ca plays a role in the regulation of various mechanisms of plants under environmental conditions such as water stress, heat, cold and salinity. In addition, calcium signaling is required for acquisition of tolerance or resistance to the stress (Cousson 2009). Positive effect of calcium in improving stress tolerance can be attributed to regulate of water status, antioxidant systems activity, osmolytes accumulation, improving photosynthetic pigment content, and nutritional balances (Kurtyka et al. 2008). Ca plays an important role in oxidative stress signaling, linking H_2O_2 perception and induction of antioxidant genes in plants (Rentel and Knight 2004).

Potassium (K) and calcium (Ca) have a profound effect on marketable yield and quality of apple crop. Potassium affects fruit quality by influencing size, color, soluble solids, acidity, and vitamin content (Bhargava et al. 1993). Potassium uptake is proportional to vegetative growth, reaching its maximum in early summer and accumulates subsequently in fruit tissue (Johnson and Uriu 1989). In plants, K shortage induces several responses at different levels: morphological, physiological, biochemical, and molecular. Activation of signalling cascades including reactive oxygen species, phytohormones (ethylene, auxin, and jasmonic acid), Ca^{2+}, and phosphatidic acid is also triggered (Hafsi et al. 2014). In contrast, K deficiency produces small fruits with thin peel. Whereas, Ca deficiency expresses itself in the form of cork spot, which develop primarily during the early part of the growing season, bitter pit, which develops during the latter part of the growing season and senescent breakdown, which forms during and after storage. Ca may affect disease sensitivity during the growing season, and may affect the development of scald and decay during storage. Therefore, it becomes essential to supplement soil application of potassium and calcium with foliar sprays which are reliable and economical.

In recent times, a lot of emphasis is being given on foliar application of nano-nitrogen (urea), potassium (K) and calcium (Ca) for better crop quality and productivity in fruit crops. However, a glimpse of the literature reveals that there is little information on these aspects in case of apple which is a major cash crop in Himalayan region of India. Keeping in view these facts, the present investigations titled **"Impact of foliar applications of nano- nitrogen, potassium and calcium on growth, yield and quality of apple (*Malus x domestica* Borkh.)"** were carried out with the following objectives:

1. To study the effect of nano- nitrogen (urea) applications on growth, yield, and quality of apple
2. To study the effect of foliar applications of potassium and calcium on growth, yield, and quality of apple

Chapter-2

REVIEW OF LITERATURE

Nano fertilizers undoubtedly represent a tempting frontier for agricultural technology, with potential benefits capable of significantly increasing crop production and sustainability in meaningful ways. One of their primary advantages is its ability to improve nutritional efficiency. By using nanotechnology, such fertilization solutions can efficiently provide nutrients to crops where and when they are needed, reducing waste through leaching or vaporization. This focused supply ensures that nutrients are acquired at the appropriate timing and locations, optimizing nutrition absorption and utilization. Occasionally, the small size of nano fertilizers allows for precise nutrient delivery straight to plant roots, improving nutrient usage efficiency and reducing fertilizer application required to meet crop demands.

Nano fertilizers are eco-friendly because their small size allows them to lessen environmental impact, resulting in safer and more stable farming. They limit the discharge of excess nutrients into soil and water bodies, reducing pollution and protecting natural resources from depletion. Several scientific investigations have demonstrated that nano-fertilizers not only boost nutrient availability, but also improve plant growth, yield and crop quality when compared to synthetic fertilizers. This contributes significantly to tackling global food security issues by optimizing the use of agricultural resources.

However, the application of nanofertilizers demands an extensive evaluation of safety, environmental impact, and economic feasibility. Continued study and suitable implementation are necessary to fully realize their potential benefits while preserving sustainable agricultural methods for future generations. As a result, nano fertilizers are a potential discovery that might revolutionize crop production by addressing nutrient efficiency, sustainability and resilience in modern agriculture.

Furthermore, foliar potassium and calcium treatment is advantageous because it eliminates soil-related issues that may restrict nutrient absorption, such as soil pH or nutrient interactions. It permits the targeted delivery of these nutrients directly to the leaves, where they may be easily absorbed and distributed throughout the plant. This targeted delivery can be especially useful in conditions when root absorption is limited, such as in damp soils or during the early stages of plant growth when root systems are still developing.

To conclude, foliar potassium and calcium treatment is a rapid and effective technique to replenish these essential minerals in plants, correcting deficiencies and promoting healthy growth and development. Foliar treatments improve nutrient availability and absorption efficiency, resulting in healthier plants with greater stress tolerance and output potential, making them an important tool in modern agricultural operations.

The available literature pertaining to foliar application of graded levels of nano-nitrogen (nN), potassium (K) and calcium (Ca) in fruit crops particularly apple is relatively scarce. However, in the light of this knowledge gap, efforts were made to compile a comprehensive review of relevant literature focusing on various key topics under the following sub-heads:

2.1 Effect of nano- nitrogen (nN) applications on growth, yield, and quality of apple

2.1.1 Effect of nano- nitrogen (nN) on chemical properties of soil
2.1.2 Effect of nano- nitrogen (nN) on leaf nutrient content of plant
2.1.3 Effect of nano- nitrogen (nN) on plant growth parameters
2.1.4 Effect of nano- nitrogen (nN) on fruit quality attributes
2.1.5 Effect of nano- nitrogen (nN) on tree physiology and yield traits

2.2 Effect of foliar applications of potassium (K) and calcium (Ca) on growth, yield, and quality of apple

2.2.1 Effect of foliar application of K and Ca on leaf nutrient content of plant
2.2.2 Effect of foliar application of K and Ca on plant growth parameters
2.2.3 Effect of foliar application of K and Ca on fruit quality attributes
2.2.4 Effect of foliar application of K and Ca on tree physiology and yield traits

2.1.1 Effect of nano- nitrogen (nN) on chemical properties of soil

Nibin and Ushakumari (2019) conducted a field experiment with bhindi crop (Cv. Varsha Upahar) in sandy clay loam soil at College of agriculture, Vellayani during 2017-18 and discovered the ideal soil pH (6.70), EC (0.013 dS m^{-1}), organic carbon (1.650%), available nitrogen (179.77 kg ha^{-1}), phosphorus (112.7 kg ha^{-1}), potassium (209.63 kg ha^{-1}), calcium (413.33 mg kg^{-1}), magnesium (132.00 mg kg^{-1}) and sulphur (10.85 mg kg^{-1}) with the combined application of FYM @ 12 t ha^{-1} + nano NPK (12.5 kg ha^{-1}) + nano NPK (0.4%).

Al-Jabri et al. (2020) conducted an experiment in Al-Khidr District, AlMuthanna Governorate, during the 2019-20 agricultural season in loam soil and reported a considerable increase in soil nitrogen (49.00 mg kg^{-1}), phosphorus (10.51 mg kg^{-1}) and potassium (234.8 mg kg^{-1}) levels after applying nano-N @ 3.1 kg ha^{-1}.

El-Sayed et al. (2020) conducted a field experiment in Gelban village, Egypt, to assess the effects of foliar application of NPK nano fertilizers and compost with or without mineral fertilizers on soybean in 2018 and 2019. The soil pH ranged from slightly to moderately alkaline, with a value of 7.95 to 8.08. The mean EC value ranged from 5.87 to 4.43. Under NPK nano fertilizers, soil had the greatest mean value of available nitrogen (43.55 mg kg^{-1}), phosphorus (5.19 mg kg^{-1}), potassium (210.00 mg kg^{-1}), iron (3.10 mg kg^{-1}), manganese (2.22 mg kg^{-1}) and zinc (0.75 mg kg^{-1}).

Chandana et al. (2021) investigated the effect of various foliar amounts of bulk and nano-nitrogen treatment on nutrient absorption in rice fields at Wetland farms of Tamil Nadu Agricultural University, Coimbatore. Twelve treatments with three replications were laid out in randomized complete block design. They achieved the highest nitrogen absorption (106.48 kg ha^{-1}) by applying 75 percent bulk nitrogen and 25 percent nano nitrogen by fertigation at 45 and 60 days after transplantation.

Sharaf-Eldin et al. (2022) studied the effects of various combinations of mineral and nano-nitrogen fertilizers on soil parameters in lettuce patches at the experimental farm of the Faculty of Agriculture, Kafrelsheikh University, Egypt. The study found that implementing 75 percent bulk nitrogen and 25 percent nano-nitrogen through fertigation at 45 and 60 days after transplanting in 2017 led to a nitrogen uptake of 168.2 kg ha^{-1}, nitrogen use efficiency of 22.5 kg_{yield} kg_N^{-1}, soil pH of 7.5, electrical conductivity of 1.9 dS m^{-1} and available nitrogen at 42 mg kg^{-1}. In 2018, nitrogen uptake increases to 188.7 kg ha^{-1}, with nitrogen use efficiency 25.5 kg_{yield} kg_N^{-1}, soil pH remaining at 7.5, electrical conductivity at 1.9 dS m^{-1} and available nitrogen at 40.6 mg kg^{-1}.

2.1.2 Effect of nano- nitrogen (nN) on leaf nutrient content of plant

A study was conducted to compare the effects of foliar fertilization with a nitrogen (N) fertilizer containing nanoparticles (nN) with those of foliar fertilization with urea. Foliar nitrogen injection at 0.50 g N/l enhanced leaf N concentrations in pomegranate fruit (cv. Ardestani) by 2.13 and 2.04%, respectively, over two years (Davarpanah et al. 2017).

Abd El-baset (2018) conducted a field trial at Nursery of Ornamental and Medicinal Plants at Laboratory of the Vegetable and Ornamental Plants Dept., Mansoura University, Egypt to investigate the response of concentration and number of foliar sprays of nano material. He observed highest leaf N (2.90 and 2.98%), P (0.27 and 0.27%) and K (3.10 and 2.97%) in purple cornflower after three application cycles of the nanofertilizer 'lithovit' @ 2 g l^{-1} over two consecutive years.

Abdel-Hak et al. (2018) investigated the response of 'Flame Seedless' grape to nano carbon and nitrogen fertilization and concluded that the application of 80% N + 0.6% carbon nano tubes resulted in significant increases in leaf nitrogen (1.56 and 1.43%), phosphorus (0.21 and 0.25%), potassium (2.16 and 1.93%), magnesium (0.58 and 0.45%), iron (136.40 and 138.73 ppm), zinc (49.20 and 49.9 ppm) and manganese (117.43 and 118.8 ppm) over two consecutive years.

Abdel-Salam (2018) carried out studies on lettuce plants, (*Lactuca sativa var. longifolia* cv. Balady), grown on a heavy clay torrifluvent soil, during two successive seasons at the Experimental Farm, Faculty of Agriculture, Moshtohor, Benha University and found that combining nano urea with mycrorrhiza resulted in significant increases in N (31.62 and 44.27 g μg^{-1}), P (4.967 and 6.497 g μg^{-1}), and K (59.87 and 81.97 g μg^{-1}) content in fresh and dry leaves after three foliar sprays of 3750 mg N l^{-1} nano urea at 30, 40, and 50 days after transplant.

A trial was put out in one-year-old olive seedlings cv. Aggizi in Giza, Egypt, by taking different rates (0, 50 and 75%) of the prescribed dose (1 gm/seedling/$week^{-1}$) of conventional fertilizers and substituting them with a spray of nano fertilizers (0.05, 0.1, 1.5 and 2%) at various levels. The highest quantity of leaf NPK was discovered in samples with a high concentration of nano NPK (Hagagg et al. 2018a).

Hegab et al. (2018) studied the effects of application for nitrogen fertilizer (urea), nano urea and biofertilization (*Azotobacter chroococcum*), on the chemical composition and productivity of sage plant at Baloza Research Station of Desert Research Center, North

Sina. They found that foliar treatment of 500 ppm nano urea to salvia plants (*Salvia officnalis* L.) resulted in highest plant nitrogen (0.807 and 0.834%), phosphorus (0.266 and 0.380%), and potassium (2.716 and 2.756%) levels throughout two consecutive seasons.

Vishekaii et al. (2019) noticed a substantial rise in leaf N (1.67 and 2.04%), P (0.13 and 0.15%), and B (35.61 and 57.03 ppm) with foliar application of 8 g N l^{-1} of water over two consecutive years when examining the influence of nitrogen nano-chelated fertilizer in olive orchards using Cv. ‘Zard’, located in Guilan province of Iran.

El-Sayed et al. (2020) conducted a field experiment in Gelban village, Egypt, to compare the effects of foliar application of NPK nano fertilizers and compost with or without mineral fertilizers on soybean in 2018 and 2019. The average mean values for the various treatments under Nano-NPK fertilizers for leaf nitrogen (4.25%), phosphorus (0.39%), potassium (2.52%), iron (65.69%), manganese (39.05%) and zinc (35.17%) were found.

Abd EL-Rahman and Abd-Elkarim (2022) performed an experiment during 2017 and 2018 growth seasons to investigate the influence of nano N fertilizer against traditional fertilizer on Zaghloul date palm cultivated in Qena, Egypt conditions. The observed findings show that by applying 80% RDN as nano (1600 g palm^{-1}) via. Foliar spray raises leaf nitrogen, phosphorus, and potassium levels over both years of research.

Sharaf-Eldin et al. (2022) applied 75 percent bulk nitrogen + 25 percent nano nitrogen to lettuce at 45 and 60 days after transplanting using fertigation and foliar sprays, and observed significant increases in leaf nitrogen (5.66 and 5.86%), phosphorus (0.55 and 0.57%) and potassium (5.52 and 5.20%) through fertigation and nitrogen (3.56 and 3.52%), phosphorus (0.51 and 0.52%), and potassium (4.40 and 4.69%) through foliar sprays over two years at the Experimental farm of the Faculty of Agriculture, Kafrelsheikh University, Egypt.

2.1.3 Effect of nano- nitrogen (nN) on plant growth parameters

Mishra et al. (2020) investigated the influence of nanofertilizers on tomato growth, yield and economics (cv. Arka Rakshak). The study's findings revealed that using a treatment containing (50% N + 100% PK + 50% Zn) + (1st spray Nano N + 2nd spray Nano

Zn) + (3rd spray Nano Cu) resulted in the highest plant height (122.45cm), number of branches per plant (12.4), fruit length (7.15cm), fruit girth (5.32cm), maximum number of fruits per plant (64.03) and individual fruit weight (66.48g).

Abd EL-Rahman and Abd-Elkarim (2022) executed an experiment over two growth seasons, 2017 and 2018, to determine the influence of nano N fertilizer vs traditional fertilizer on Zaghloul date palm cultivated in Qena, Egypt. The observed findings show that applying 80% RDN as nano (1600 g palm^{-1}) via. Foliar spray increased leaf area, fruit weight, fruit length, fruit diameter and flesh percentage in both years of research.

El-Ghobashi and Ismail (2022) investigated the effects of mineral and nano-nitrogen fertilizer on a soybean and maize intercropping system at the El-Serw Agricultural Research Station in Damietta Governorate, Egypt, measuring maximum plant height (339.89 and 311.81 cm), stem diameter (4.47 and 4.93 cm), number of green leaves plant^{-1} (14.92 and 13.47) and leaf area (885.17 and 879.60 cm^{2}) in maize with a combination of 75% mineral urea + 25% nano-N over two consecutive years.

Abobatta and Ahmed (2023) experimented with Volkamer lemon (*Citrus volkameriana*) and Sour orange (*Citrus aurantium* L.) seedlings planted in the Horticulture Research Institute's citrus seedling nursery in Giza, Egypt. Two nitrogen sources (urea and nano particles) at two doses (500 and 750 ppm) were foliar sprayed three times during a one-month period. Spraying nitrogen nano (Nn) at 750 ppm in both rootstocks for two consecutive sessions resulted in an increase in stem length, stem diameter, number of leaves per seedling, leaf area, shoot fresh weight, shoot dry weight, leaves fresh weight and leaves dry weight.

Bhatti et al. (2023) carried out an field experiment at Junagadh Agricultural University, Gujarat to study the effect of different levels of urea and nano urea with their interaction effect and also control vs rest on growth parameters of guava (*Psidium guajava* L.) cv. Lucknow-49. The results showed that the maximum incremental plant height (0.83 m) and plant spread (E-W) (0.91 m) were found in 100% RDN + 0.6% nano-urea and maximum incremental plant spread (N-S) (1.43 m) was noted in 80% RDN + 0.6% nano-urea.

Mirji et al. (2023) explored the effect of nano NPK fertilizers on growth and quality of sapota [*Manilkara achrus* (Mill.). Fosberg] cv. Kalipatti. The experiment was designed as a randomized complete block design (RCBD) with 12 treatments and three replications. The treatment 50% RDF + 0.3% Nano NPK fertilizer foliar spray produced the highest plant height (3.78 m). In contrast, treatment 50 percent RDF plus foliar application of 0.2% nano NPK fertilizer produced the highest fruit length (6.53 mm), fruit width (5.43 mm) and pulp weight (26.67g).

Rajesh et al. (2023) conducted a field investigation on the growth characteristics of oats (*Avena sativa* L.) with nano urea fertilizer. They discovered that 100% RDN through urea produced the greatest increase in plant height, total number of leaves per plant, leaf length, leaf width, and plant population, followed by 75% RDN + 25% N through Nano-N, 50% RDN + 50% N through Nano-N, and 25% RDN + 75% N through Nano-N.

Al-Mohammadi and Al-Dolaimi (2024) carried out a field trial on date palm (cv. Khastawi) in Anbar Governorate during the growing season 2023 to assess the role of adding nano-fertilizer (20:20:20) at dosages of 0, 50, and 100 g of palm trees and the EM1 bio fertilizer at concentrations of 0 and 20 ml L^{-1}, and spraying with algae extract (SEFLEFF ORIGIN) at concentrations of 0, 1, and 2 ml L^{-1} for growth characteristics. The results demonstrated that there was a spike in leaf area, percentage of dry matter in the leaves, fruit diameter and length, fruit weight, cluster weight and yield at a concentration of 100 g (F2), 20 ml L^{-1} (E1) and 2 ml L^{-1} (A2).

Beniwal et al. (2024) investigated the influence of nano urea, boron, and zinc sulphate foliar spray on strawberry development characteristics (cv. Winter Dawn). The two treatments that performed the best were Nano urea 1.5% + Zinc Sulphate 0.6% + Boron 0.6% and Nano urea 1.5% + Zinc Sulphate 0.4% + Boron 0.4%. These treatments showed the highest values for all the parameters, including petiole length 90 DAT (10.00 cm), number of leaves per plant (36.95), plant spread N-S (35.69 cm), plant spread E-W (32.11 cm), runner production per plant (8.56), fruit length (62.50 mm), fruit width (39.67 mm), fresh weight (31.86 g) and number of fruits per plant (17.52).

Fadhil and Balaket (2024) investigated the effects of spraying with nano-fertilizer at three levels (0, 2 and 3 gm/liter) and ground application in the lathhouse of Al-Furat Al-

Awsat Technical University / Al-Musayyib Technical College in Babylon province. Three mandarin seedlings were treated with nanofertilizer at concentrations of 0, 0.5, and 1 g anvil^{-1}. The salient findings were: The Clementine cultivar had the best seedling height and average leaf area (96.36 cm, 1715.4 cm^2 seedling^{-1}). Spraying shoots with 3 g L^{-1} nano-fertilizer and 1 g plot^{-1} enhanced seedling height and leaf area.

Fadzil et al. (2024) performed a field trial in a netted rainhouse shelter at the Department of Agriculture in Serdang, Malaysia. Sakata Glamour, a Rock Melon F_1 hybrid, was employed in this study. The impacts of rock melon vegetative development on different application frequencies (T_1=0, T_2=2, T_3=4, T_4=6, and T_5=8 times) of MARDI nanofertilizer via foliar treatment were investigated in this study. The results indicated that the vegetative development of the rock melon, including plant height, stem diameter, relative chlorophyll content and leaf area, were considerably ($p \leq 0.05$) enhanced by 15.07, 7.8, 41.5 and 41.5%, respectively at T_3.

Kumar et al. (2024) investigated the effects of nano urea, boron and zinc sulphate foliar application on the development characteristics of Guava (*Psidium guajava* L.) cv. Allahabad Surkha. The best treatments were Nano urea 2.0% + zinc sulphate 0.6% + boron 0.6% and Nano urea 2.0% + zinc sulphate 0.4% + boron 0.4%, which had the highest values in all parameters, including number of flowers tree^{-1} (86.47), days to fruit harvesting (49.19), fruit set (74.00%), number of fruit/tree (63.25), fruit length (7.42 cm), fruit weight (178.73g) and fruit diameter (7.12 cm).

2.1.4 Effect of nano- nitrogen (nN) on fruit quality attributes

Davarpanah et al. (2017) investigated the effects of nitrogen-containing nanoparticle (nN) foliar feeding on the properties of pomegranate fruit cv. Ardestani. Two foliar sprays of nN (0.25 and 0.50 g N L^{-1}, corresponding to about 1.3 and 2.7 g N tree^{-1} or 0.9 and 1.8 kg N ha^{-1}; nN_1 and nN_2, respectively were used). The treatment with nN_2 (0.50 g N L^{-1}) enhanced aril juice, total soluble solids (TSS), maturity index, total phenolic compounds, total sugars, and antioxidant activity in both seasons, but only in the first.

Nabi et al. (2017) studied the effect of magnetic water irrigation (normal water and magnetic water), foliar spraying with nano material water as well as their interactions and found that foliar application of nano lithovit at 0.5 g l^{-1} at the Experimental Station Farm, Faculty of Agriculture, Mansoura University, Egypt, during seasons of 2015/2016 and 2016/2017 resulted in the highest TSS (5.06 and 4.75%), total sugars (8.29 and 8.21%), in head lettuce over two seasons.

Abd El-baset (2018) worked with purple cornflower and observed that after three foliar treatments of the nano fertilizer "lithovit" at a rate of 2 g l^{-1}, the largest total sugars (18.98 and 18.77%) were achieved over the two years.

Panda et al. (2020) investigated the impact of nano-fertilizer on tomato (*Solanum lycopersicum* L.) at the experimental field of Institute of Agricultural Sciences, Bhubaneswar (India) and discovered that foliar spraying with nano fertilizer 'Pramukh' @ 5 g l^{-1} + RDF @ 125 N: 60 P_2O_5: 100 K_2O kg ha^{-1} considerably enhanced fruit length (5.84 cm) and girth (14.13 cm).

Gaiotti et al. (2021) investigated the effect of urea-doped calcium phosphate nanoparticles (U-ACP) on the quality of 'Pinot Gris' grapevines under semi-controlled settings. They discovered that the sugar content, titratable acidity and aromatic content of berries improved dramatically after applying U-ACP.

Weber et al. (2021) evaluated the effect of nano fertilizer (Lithovit) on strawberry (*Fragaria* × *ananassa* Duch.) at the experimental station of the Agricultural Institute of Slovenia, located in Brdo pri Lukovici and discovered that total phenolic content, aroma and fruity esters in strawberries rose considerably with foliar application of nano fertilizer lithovit @ 5 g l^{-1} water.

Abd EL-Rahman and Abd-Elkarim (2022) conducted an experiment over two growing seasons (2017 and 2018), to investigate the effect of nano N fertilizer vs traditional fertilizer on Zaghloul date palm cultivated in Qena (Egypt). The observed findings showed that by applying 80% RDN as nano (1600 g $palm^{-1}$) via. foliar spray increased TSS, total sugars and lowering sugars over both years of research.

Rahman and Naglaa (2022) conducted an experiment over two growing seasons, 2017 and 2018, to investigate the effects of nano-N fertilizer versus conventional fertilizer on the development, yield and nutritional value of the fruits of Zaghloul date palm planted in Qena, Egypt. Palm trees that were fertilized with nano-N at 80% of the specified dose by spraying and subsequently soil application had the greatest fruit weight, dimensions, flesh percentage, TSS% and sugar content.

Mirji et al. (2023) explored the effect of nano NPK fertilizers on growth and quality of sapota [*Manilkara achrus* (Mill.). Fosberg] cv. Kalipatti'. The trial followed a randomized complete block design (RCBD) with 12 treatments and three replications. The greatest TSS (22.33 °Brix), decreasing sugar (9.31%) and total sugars (22.18%) were observed in treatment 50 percent RDF and 0.2% nano NPK fertilizer applied foliar.

Ekka et al. (2024) investigated how nano-chitosan, nano-micronutrients, and bio-capsules affected the production and quality of Kinnow mandarin (*Citrus nobilis* x C. *deliciosa*) during 2021-22 and 2022-23. Based on pooled data, treatment consisted of NPK soil soaking with nano-chitosan at a concentration of 100 ppm, bio-capsules at 500 ppm and foliar spray of nano-micronutrients (Zinc oxide and Iron oxide), outperformed in qualitative metrics such as total soluble solids (TSS) of 11.62%, titratable acidity of 1.09%, ascorbic acid content of 26.69 (mg $100g^{-1}$), juice content of 50.06% and fruit pulp weight of 50.0 (g).

Hussein et al. (2024) investigated the efficacy of conventional vs nano-micronutrients as foliar fertilizers for improving the quality of pomegranate (cv. Manfalouty) fruits. Foliar micronutrients and nano-micronutrients significantly improved TSS% compared to the control, with the highest values observed in pomegranate trees treated with nano-micronutrients at 1500 µg mL^{-1} and 1000 µg mL^{-1}, respectively. During the two examined seasons, the greatest TA% of juice (1.14 and 1.07%, respectively) was attributable to control (unsprayed), while the minimum acidity was 0.88% and 0.90%, respectively, owing to foliar spraying with nano-micronutrients at 500 µg mL^{-1}.

2.1.5 Effect of nano- nitrogen (nN) on tree physiology and yield traits

Davarpanah et al. (2017) evaluated the effects of foliar fertilization with nano-nitrogen fertilizers and urea on the pomegranate cultivar 'Ardestani' at the Razavi Khorasan province in northeastern Iran. They used nano-nitrogen at 0.25 and 0.50 g N l^{-1} and urea at 4.6 and 9.2 g N l^{-1}, and found that foliar spraying with nano-N at 0.25 and 0.50 g N l^{-1} considerably boosted fruit production when compared to urea treatments. While researching the reaction of 'Keitte' mango to nano fertilizer sprays, Saied (2018) sprayed nano NPK-Mg fertilizer to mango plants at concentrations of 0.05, 0.1, 0.2, 0.4 and 0.5%. He reported that foliar spraying with nano NPKMg at 0.1% increased mango fruit output by 38.0 kg tree^{-1}.

Abdel-Hak et al. (2018) investigated the impact of nano-C and nitrogen fertilization levels on grape cv. 'Flame Seedless' and concluded that applying 80% of the recommended dose of N + 0.6% carbon nano tubes (CNTs) significantly enhanced total leaf chlorophyll content (34.80 and 36.36 SPAD), total leaf carbohydrates (6.08 and 6.61%), and grape yield (15.00 and 15.79 kg vine^{-1}) over two consecutive years.

Hagagg et al. (2018b) studied the effect of nano-NPK spraying on the growth efficiency and nutritional status of olive seedlings of the Kalamat cultivar in Giza, Egypt. When Nano-NPK @ 0.2% was applied in foliar sprays at varied intensities (0.5, 1, 1.5, and 2%), total chlorophyll content increased by 87.7 SPAD units.

Sohair et al. (2018) administered various dosages of NPK nano-fertilizers to Egyptian cotton (*Gossypium barbadense* L.) via soil and foliar sprays, including 100, 50, 25, and 12.5% of the recommended fertilizer dose (RFD) at the Agricultural Experimental and Research Station, Faculty of Agriculture, Cairo University, Giza (Egypt) in the two successive summer seasons (2016 and 2017). They found that applying 50% RFD foliar nanofertilizer boosted total bolls plant^{-1} (21.65), open bolls plant^{-1} (15.35), boll weight (2.24 g) and seed cotton production (28.50 g plant^{-1}).

Al-Juthery et al. (2019) studied the effect of foliar application of nano fertilizers and nano amino acids on wheat at the Extension farm in Province 41 of Husseiniya, Babylon Governorate, Iraq and found that plants treated with foliar spray of nano chelated super fertilizer (NCSF) @ 1000 ml g^{-1} had considerably higher total chlorophyll content (51.99 SPAD).

Khan et al. (2019) investigated the effect of nano-NPK fertilizer on the production of 'Red Delicious' (*Malus* × *domestica* Borkh.) apples of village Kanelwan of District Anantnag, (J&K, India) during the year 2017 and 2018. They used varied amounts of nano NPK fertilizer and found that foliar application of nano-NPK @ 300 ppm N + P @ 50 ppm considerably enhanced fruit output (28.15 and 29.89 kg ha^{-1}) over two years.

Zargar et al. (2019) investigated the potential effectiveness of foliar treatment of macronutrients, micronutrients and growth regulators on pear (cv. Talgar Beauty) and apple (cv. Ranet Simirenko and Starkrimson) at the Russian Research Institute of Arid Agriculture in Russia. Total of five agrochemicals were used in which “Plantafol” outperformed all other agrochemicals, as pear (cv. Talgar Beauty) production (116.6 kg tree^{-1}) and yield (34.4 t ha^{-1}) being 152.8% greater than the control. Similar findings were found for apple cultivars, with Renet Simirenko productivity (57.5 kg tree^{-1}) and yield (47.9 t ha^{-1}) being 67.5% greater than the control, and Starkrimson productivity (33.6 kg tree^{-1}) and yield (28.0 t ha^{-1}) 57.3% being higher than the control.

Al-Juthery et al. (2020) achieved the highest chlorophyll content (60.55 SPAD), protein yield (970.32 kg ha^{-1}) and protein (14.52%) in wheat by applying nano-chelated NPK 20:20:20 fertilizer + nano-chelated complete micro fertilizer (NCM) + yeast extract, respectively in Husseinieh province, Babylon Governorate, Iraq.

Sayah and Jameel (2020) carried out an experiment at Diwaniyah Governorate Center in Iraq during the autumn season (2019-2020) to find the effect of treatment with nano NPK balanced fertilizer (20-20-20) on Cucurbita pepo L and observed that the plants fed with 4 g l^{-1} nano NPK fertilizer produced considerably more fruits (10.91 fruits plant^{-1}) and had a dry weight of 45.52 g.

Aly et al. (2022) examined the effects of nano silver (Ag NPs) and nano zinc (Zn NPs) on apples. They reported the greatest chlorophyll content (50.05 SPAD), maximum yield (64.81 kg tree^{-1}), and productivity (7.29 t ha^{-1}) with foliar sprays of nano zinc @ 300 ppm before the blooming stage, full bloom, and one month later.

Bedrech and Farroh (2022) applied foliar spray of chitosan nano particles in different concentrations (100, 150 and 200 ppm) on ‘Crimson Seedless’ grapevine and recorded maximum total leaf chlorophyll content (44.9 and 44.65 SPAD) during two consecutive years with the application of 200 ppm nano chitosan urea foliar sprays, whereas, maximum carbohydrates (6.802 and 7.328%), fiber content (1.33 and 1.40%) and L-ascorbic acid (64.74 and 69.08%) were observed with foliar sprays of nano chitosan urea @ 150 mg l^{-1}. They reported that foliar application of nano chitosan particles @ 200 ppm significantly improved berry yield (14.8 and 14.9 kg vine^{-1}) during two consecutive years.

The growth, production, and nutritional content of fruits from a 20-year-old Zaghloul date palm planted in Qena, Egypt, were compared to those acquired using traditional methods during two growing seasons (2017 and 2018). Different amounts of nano N fertilizer (20-40-60-80% dosage) were administered as soil surface and foliar sprays. The findings revealed that an 80% foliar application of nano nitrogen was ideal for fruit establishment, fruit retention, and yield (Rahman and Naglaa 2022).

Hussein et al. (2024) investigated the efficacy of conventional vs nano-micronutrients as foliar fertilizers for improving the quality of pomegranate (cv. Manfalouty) fruits. The experiment was conducted in 2021 in an experimental orchard at the Faculty of Agriculture University in Egypt, and was repeated in 2022. In the first and second seasons, spraying nano-micronutrients at 1000 and 1500 µg mL^{-1} (35.44 and 30.98; 34.04 and 26.67 kg) and micronutrients at 1000 µg mL^{-1} (26.74 and 25.70 kg) resulted in the greatest increase in yield compared to untreated trees.

Vishekaii et al. (2024) investigated the effects of fertilizers on olive tree cv. 'Zard' in Manjil, Guilan province (Iran). The treatments involved the application of two quantities of pure nitrogen and potassium from each fertilizer source: 1.02g and 0.81g (nano-N_1K_1 and N_1K_1), and 1.36 g and 1.08 g (nano-N_2K_2 and N_2K_2). The results revealed that the trees treated with N_2K_2 produced the maximum yield. Nano-N_1K_1 foliar spray influenced leaf chlorophyll content, whereas nano-N_1K_1 affected carbohydrate content during the pit hardening stage and nano-N_2K_2 shortly after harvest of table olive.

2.2.1 Effect of foliar application of K and Ca on leaf nutrient content of plant

Kadir (2005) investigated the response of "Jonathan" apple trees (*Malus domestica*, Borkh.) grafted on EMLA 111 to repeated calcium chloride ($CaCl_2$) applications at Kansas orchards in Topeka, Emporia, and Conway Springs in 2002. Calcium chloride was sprayed on trees foliarly one to eight times at a rate of 8.971 kg ha^{-1}. Fruits in Topeka, Emporia, and Conway Springs, with diameters of 1.4, 0.9 and 1.6 cm, respectively, were sprayed for the first time. Fruit quality during harvest was enhanced by more than six treatments of $CaCl_2$. Out of the three sites, the leaf Ca content from control trees in Emporia was the lowest. But when $CaCl_2$ was applied often, the leaf Ca concentrations increased similarly in all three locations. Compared to Emporia or Conway Springs, the growth was more noticeable at

Topeka. Furthermore, after four Ca applications, leaf N or K concentrations rose; however, greater N concentrations were only seen in the peels of samples that received eight applications as opposed to the control leaf, and leaf P concentrations rose by 30, 23 and 34%, respectively, after eight $CaCl_2$ applications.

Korkmaz and Aşkın (2015) investigated the impact of foliar application of calcium nitrate and boric acid on the leaf nutrient content of pomegranate (*Punica granatum* L. var. Hicaz Nar) trees in an established orchard in Ortaca, Mugla, Turkey. The study revealed that the application of 2% calcium nitrate significantly enhanced the concentrations of key nutrients in the leaves, including iron (ranging from 62.57 to 143.3 ppm), zinc (8.54 to 15.81 ppm), copper (7.1 to 14.23 ppm), manganese (11 to 24 ppm), phosphorus (0.07 to 0.13%), potassium (0.56 to 1.01%), calcium (0.84 to 4.86%), magnesium (0.3 to 1.92%) and nitrogen (1.82 to 2.45%). Furthermore, the application of 4% calcium nitrate resulted in notable increases in the concentrations of potassium (0.74 to 0.99%), calcium (0.99 to 5.66%) and iron (56.77 to 128.7 ppm).

Mosa et al. (2015) conducted a study in Egypt on seven-year-old "Anna" apple trees (*Malus x domestica* L.) during 2012 and 2013 to assess the effects of various foliar treatments. The treatments included: a water-sprayed control, potassium sulfate (2%), calcium chloride (0.2%), boric acid (0.2%), humic acid (5%), and combinations of these substances. The study found that the combination of potassium sulfate, calcium chloride, boric acid and humic acid significantly increased leaf concentrations of calcium (1.46% and 1.48%), phosphorus (0.38% and 0.37%), potassium (2.20% and 2.25%) and nitrogen (2.20% and 2.22%) compared to the control in both years.

In northeastern Iran's Razavi Khorasan province, Davarpanah et al. (2018) investigated the effects of foliar applications of calcium nanoparticles (nano-Ca) and calcium chloride ($CaCl_2.2H_2O$) on pomegranate fruit quality and yield for two consecutive years (2014-2015). The nano-Ca was applied at concentrations of 0.25 and 0.50 g Ca L^{-1}, while $CaCl_2.2H_2O$ was used at 1% and 2% (2.73 and 5.45 g Ca L^{-1}). Applications were made twice, once at full bloom and again one month later. The control trees showed average leaf concentrations of N (1.79%), P (0.11%), K (0.90%) and Ca (2.40%), with Fe, Mn and Zn levels at 113.16, 74.35 and 14.07 mg kg^{-1} DW, respectively. Calcium treatments increased leaf Ca concentrations by 13-21% compared to controls in the first season, with 1% $CaCl_2$

resulting in the highest Ca concentrations. However, no treatments significantly affected N, P, K, Fe, Zn or Mn levels. Additionally, the highest concentration of $CaCl_2$ (2%) caused leaf burn in both seasons.

Norozi et al. (2019) investigated the impact of zinc and potassium foliar sprays on the nutritional content and quality of pistachio cv. "Chrokeh" leaves and fruit. The study, conducted during 2017-2018, included nine treatments with three replications, featuring varying concentrations of K_2SO_4 (0, 1, and 2%) and $ZnSO_4$ (0, 0.5, and 1%). Applications were made twice, during bud swell and green tip stages. Results indicated that K_2SO_4 and $ZnSO_4$ significantly influenced leaf concentrations of phosphorus (0.39- 0.93%), potassium (1.41- 2.21%), magnesium (0.35- 0.83%), zinc (12.47- 26.09 ppm), manganese (31.03- 38.74 ppm) and iron (102.63- 145.91 ppm). However, no significant changes were observed in leaf nitrogen (1.76- 1.87 ppm).

Hagagg et al. (2020) conducted a study on the impact of foliar calcium treatments on the vegetative growth and mineral content of olive cultivars Kalmata and Manzanillo in Ismailia Governorate, Egypt, during the 2017 and 2018 growing seasons. The results demonstrated that foliar application of two calcium sources significantly influenced the Fe, Zn and Mn content in the leaves of both cultivars. In the Kalmata cultivar, trees treated with chelated calcium showed the highest levels of Fe (298.67 and 194.33 ppm) and Zn (25.29 and 30.52%) across the two seasons, while those treated with $CaCl_2$ exhibited the highest Mn content (26.94 and 15.37 ppm). In contrast, untreated trees consistently showed the lowest levels of these nutrients. For the Manzanillo cultivar, chelated calcium applications resulted in the highest Fe (265.50 and 171.21 ppm) and Zn (25.33 ppm) concentrations during the first season, while $CaCl_2$ applications led to the highest Mn (24.58 and 33.26 ppm) and Zn (18.19 ppm) concentrations in the second season.

Sürücü and Küçükyumuk (2023) conducted a study to evaluate the effects of foliar potassium (K) and calcium (Ca) fertilizers, both individually and combined, on two apple varieties- Red Chief and Golden Delicious. Significant differences were observed in nutrient concentrations due to the variety*application interaction. Red Chief leaves had higher nitrogen (N) levels (24.6 g kg^{-1}) compared to Golden Delicious (19.5 g kg^{-1}), with the highest N concentration seen in the control and Ca-treated Red Chief. Golden Delicious leaves showed higher potassium (13.9 g kg^{-1}) and calcium (16.6 g kg^{-1}) levels, particularly under the

K+Ca treatment, while Red Chief had lower levels of these nutrients. Additionally, magnesium (Mg) content was highest in Golden Delicious leaves treated with K+Ca (5.0 g kg^{-1}) compared to the Red Chief variety. These findings highlight the differential nutrient uptake and response of these apple varieties to K and Ca fertilization.

2.2.2 Effect of foliar application of K and Ca on plant growth parameters

Korkmaz and Aşkın (2015) conducted an investigation on *Punica granatum* L. var. Hicaz Nar, involving forty-five trees from a well-established orchard in the Ortaca region of Mugla province, Turkey. The study focused on evaluating the effects of foliar applications of calcium and boron on the growth parameters of these pomegranate trees. The researchers applied 2% calcium nitrate (CN_1) and 3% boric acid (B_2) and observed an increase in the number of fruits per tree, with the CN_1 treatment yielding the highest fruit count at 85 fruits per tree, followed by the B_2 treatment with 80 fruits per tree. Although the increase in fruit count was not statistically significant, the findings suggest that foliar applications of calcium and boron have the potential to enhance the growth and fruit production of pomegranate trees, indicating their beneficial role in horticultural management practices.

Hagagg et al. (2020) aimed to enhance vegetative growth in two olive cultivars, Kalmata and Manzanillo, through foliar application of calcium. The study revealed that spraying trees with chelated calcium significantly increased leaf area in both cultivars. For the Kalmata cultivar, leaf area improved from 4.00 and 4.10 cm^2 in the control to 4.80 and 4.94 cm^2 in the first and second seasons, respectively. Similarly, the Manzanillo cultivar exhibited an increase in leaf area from 4.11 and 4.08 cm^2 in the control to 4.50 and 4.79 cm^2 when treated with chelated calcium.

Ibrahim et al. (2021) conducted a field experiment at PICO farm in the EL-Beheira Governorate of Egypt to assess the impact of varying levels of calcium (Ca), boron (B), and zinc (Zn) on the growth parameters of three strawberry cultivars: Red Merlin (029), Elyana, and Fortuna (116). The experiment, carried out over two consecutive seasons (2016-17 and 2017-18), revealed that Fortuna exhibited the highest sensitivity to Ca:B levels. Among the treatments, Fortuna and Elyana cultivars showed the largest leaf areas when treated with Ca:B at a ratio of 1.5:0.5:1.5 g, with leaf area averages of 23.67 cm^2 and 24.67 cm^2, respectively, across both seasons.

Yathish et al. (2021) conducted a field experiment in 2017 at the College of Agriculture, Vishweshwaraiah Canal Farm, Mandya, to evaluate the impact of foliar applications of calcium nitrate, boron and humic acid on the growth and yield of transplanted pigeonpea. The study demonstrated that various treatments applied at different growth stages significantly influenced plant height and leaf area. The highest plant height at harvest (307.33 cm) was recorded with the foliar application of humic acid (6 ml L^{-1}) at flowering initiation and 15 days later, in combination with recommended doses of fertilizers (RDF) and farmyard manure (FYM). This was closely followed by the treatment with a 2.0% $Ca(NO_3)_2$ foliar spray, which achieved a plant height of 304 cm. In contrast, the control group, which only received RDF and FYM, exhibited a significantly lower plant height of 268.67 cm. For leaf area, the treatment with humic acid (6 ml L^{-1}) at flowering initiation and 15 days afterward, along with RDF and FYM, resulted in a significantly larger leaf area per plant (5110.33 cm^2). This was comparable to the treatment with a 2.0% $Ca(NO_3)_2$ foliar spray, which resulted in a leaf area of 5007.33 cm^2. The control group, however, showed a considerably smaller leaf area of 3999.00 cm^2 at harvest.

2.2.3 Effect of foliar application of K and Ca on fruit quality attributes

Tzoutzoukou and Bouranis (1997) conducted a study to assess the effect of preharvest calcium (Ca) foliar treatment on the fruit firmness of 'Bebekou' apricots over two years (1991 and 1992). The study involved applying calcium chloride ($CaCl_2$) at different concentrations and timings: 0.5% $CaCl_2$ was applied 21, 17, and 13 days before harvest in 1991, and 0.8% and 0.7% $CaCl_2$ were applied 16 and 12 days before harvest in 1992, respectively. The results showed a significant reduction in firmness as the fruits ripened. However, the apricots treated with calcium were notably firmer than the control fruits at 83 and 89 days after anthesis in 1991 and at 78 and 84 days after anthesis in 1992. The positive effect of calcium on fruit firmness was evident even after three weeks of storage in 1991 and four weeks in 1992 at 0°C. This suggests that preharvest calcium treatment can significantly enhance fruit firmness and extend its storage quality.

In a study conducted in the autumn of 1999, Hao and Papadopoulos (2003) examined the effects of varying calcium (Ca) and magnesium (Mg) concentrations on the firmness of tomato fruits grown on rockwool. They tested two Ca concentrations (150 and 300 mg L^{-1}) combined with four Mg concentrations (20, 50, 80 and 110 mg L^{-1}). The results indicated that a higher Ca concentration (300 mg L^{-1}) led to a decrease in fruit firmness compared to the lower Ca concentration (150 mg L^{-1}). Interestingly, at the lower Ca concentration, an increase in Mg concentration was found to enhance fruit firmness, particularly towards the end of the growing season. Furthermore, at the higher Ca concentration, fruit firmness was greater when the Mg concentration was 80 mg L^{-1} compared to 50 mg L^{-1}. These findings suggest that for optimal fruit firmness in greenhouse tomatoes, the Mg content should begin at 50 mg L^{-1} and be gradually increased to 80 mg L^{-1} as the season progresses, particularly when higher levels of Ca were used.

Kadir (2005) investigated the impact of repeated foliar applications of calcium chloride ($CaCl_2$) on "Jonathan" apple trees (*Malus domestica*, Borkh.) grafted on EMLA 111 in Kansas orchards in 2002. Calcium chloride was applied at a rate of 8.971 kg ha^{-1}, with treatments ranging from one to eight applications. The study found that fruit weight, size, and appearance improved with an increasing number of $CaCl_2$ applications. Fruits from trees receiving eight treatments were significantly larger compared to those from untreated control plants. In Emporia and Conway Springs, fruit weight increased by 20% and 23%, respectively, with eight treatments compared to controls, while at Topeka, fruit weight improved after at least six treatments. Additionally, apple firmness was highest with eight $CaCl_2$ applications, showing increases of 30%, 12% and 11% in firmness at Topeka, Emporia and Conway Springs, respectively. At Conway Springs, a minimum of five treatments were needed to enhance firmness, whereas four applications were sufficient at Topeka and Emporia.

Ramezanian et al. (2009) investigated the impact of calcium chloride and urea, both separately and in combination, on pomegranate (*Punica granatum* L. cv. Malase-Yazdi) fruit quality and quantity over two years at the Agricultural Research Centre in Yazd, Iran. Treatments included aqueous solutions of calcium chloride at 0%, 2% and 4% and urea at 0%, 0.5%, 1% and 2%, applied at full bloom (FB) and one month after full bloom (1MAFB). Urea applications at 1% and 2% significantly increased fruit diameter, length, and aril size, with the most substantial effects observed when applied post-bloom. Calcium chloride alone had minimal impact on fruit size, but its combination with urea at higher concentrations enhanced average fruit weight. The most significant increase in fruit weight was noted with 2% calcium chloride combined with urea above 1%. Additionally, 2% calcium chloride significantly reduced titratable acidity (TA) during the initial application, though no notable effect was observed with the second application.

Ramezani and Shekafandeh (2011) investigated the effects of spraying potassium nitrate (KNO_3) and zinc sulfate ($ZnSO_4$) on the fruit characteristics of olive trees cv. Amygdalifolia. The experiment involved applying various concentrations of KNO_3 (0%, 0.5%, 1.0% and 1.5%) and $ZnSO_4$ (0%, 0.25%, 0.50% and 0.75%) to the trees in August, approximately midway through the fruit growth period. The results indicated that the highest fruit weight was achieved with a combination of 0.5% $ZnSO_4$ and 0.5% KNO_3. Different concentrations of $ZnSO_4$, particularly when combined with KNO_3, significantly affected fruit length (39.01 to 48.76 mm) and diameter (17.29 to 20.02 mm).

The effects of urea and potassium nitrate (KNO_3) on the fruit size of nine-year-old mango trees (*Mangifera indica* L.) cv. Amrapali were evaluated by Sarker and Rahim (2013) at the BAU Germplasm Centre from September 2006 to July 2007. Treatments with potassium nitrate at 4%, 6% and 8%; urea at 2% and 4%; and a water spray control were included. The results showed that the control plants produced the smallest fruit size, measuring 175.00 g, while the urea at 4% produced the biggest fruit weight, measuring 202.83 g. Potassium nitrate at 4% proved helpful in improving overall fruit quality and size, even though it did not produce the largest fruit.

Korkmaz and Aşkın (2015) conducted research on pomegranate (*Punica granatum* L. var. Hicaz Nar) trees in an established orchard in Ortaca, Mugla, Turkey. Their study revealed that treatments with 2% calcium nitrate (CN_1) and 3% boric acid (B_2) significantly enhanced key fruit parameters. Specifically, these treatments improved fruit weight (565.4 g with CN_1 and 580.2 g with B_2), diameter (105.3 cm with CN_1 and 104 cm with B_2) and length (90.4 cm with CN_1 and 91.5 cm with B_2) compared to the control.

Aly et al. (2015) conducted a study to assess the impact of various foliar sprays on the yield and fruit quality of Washington navel orange trees. The experiment, carried out over two consecutive seasons (2013 and 2014) in Abou–EL Matamier, Beheira Governorate, Egypt, involved applying calcium chloride ($CaCl_2$), zinc sulphate ($ZnSO_4$), and potassium sulphate (K_2SO_4) at different concentrations. The results indicated that the highest average fruit volumes were observed with the 3% and 2% K_2SO_4 treatments, yielding 275.40 and

277.96 cm^3 and 260.48 and 259.20 cm^3 in the respective seasons. These were followed by the 1.5% $CaCl_2$ and 1% K_2SO_4 treatments. The 3% K_2SO_4 treatment also resulted in the highest average fruit diameter (8.23 and 8.20 cm) and average fruit length (8.48 and 8.60 cm) in both seasons. Conversely, the lowest average values were recorded with the 0.5% $ZnSO_4$ treatment. The study concluded that 1.5% $CaCl_2$ and 3% K_2SO_4 significantly enhanced fruit volume and size compared to the control and other treatments, highlighting the effectiveness of these concentrations in improving orange fruit yield.

Korkmaz et al. (2016) studied the effects of calcium nitrate, boric acid and GA_3 applications on the fruit weight of pomegranate cv. Hicaznar in a commercial orchard in Ortaca, Turkey. The treatments were applied during the flowering phase and a month later. In the first year, all treatments positively influenced fruit weight, with the highest weight of 582.4 g achieved in the GA_3 application. However, in the second year, only calcium nitrate (CN_1, 481.7 g) and boric acid (B_2, 521.1 g) treatments increased fruit weight compared to the control.

Maji et al. (2017) investigated the impact of foliar applications of calcium and boron on the growth and quality of young pomegranate plants cv. BHAGWA. The study involved testing various concentrations of calcium (3% and 5%) and boron (0.25% and 0.5%), both individually and in combination, across three replications. The results revealed that the combination treatment, which included 3% calcium and 0.25% boron, significantly enhanced fruit quality. Under this treatment, fruits exhibited the highest average weight (77.0 g), length (6.1 cm), and diameter (6.00 cm). Furthermore, quality indicators such as total sugars (6.66%) and reducing sugars (4.73%) were notably higher compared to other treatments.

Solhjoo et al. (2017) conducted a study in south-central Iran to evaluate the effects of foliar applications of potassium (K) and calcium (Ca), both individually and in combination, on the quality characteristics of 'Red Delicious' apples over two growing seasons (2013 and 2014). The trees were sprayed five times with 5 g L^{-1} calcium chloride ($CaCl_2$) at 3-week intervals starting three weeks after full bloom and three times with 2.5 g L^{-1} K sources (potassium chloride [KCl], potassium sulphate [K_2SO_4], and potassium nitrate [KNO_3]) at 9, 12 and 15 weeks after full bloom. The study found that all treatments increased fruit weight (ranging from 148.6 to 166.17 g in 2013 and 145.20 to 149.60 g in 2014), with the combination of K and $CaCl_2$ producing the highest mean fruit weight (166.17 g) in 2013.

Additionally, $CaCl_2$ and KCl treatments significantly improved fruit firmness (43.54 and 46.5 N), anthocyanin concentration (31.50 and 29.70 mg g^{-1} FW), and total sugar content (15.30 and 12.40 mg g^{-1} DW), with KCl alone yielding the highest anthocyanin (32.40 and 33.00 mg g^{-1} FW) and sugar levels (16.00 and 14.52 mg g^{-1} DW) in both years, respectively.

In order to assess the effects of foliar sprays of potassium (K), calcium (Ca), and their combination on the fruit quality and red skin colour of 'Red Delicious' apples, Solhjoo et al. (2017) carried out a study in south-central Iran. During the growing seasons of 2013 and 2014, apple trees were sprayed with 2.5 g L^{-1} potassium chloride (KCl), potassium sulphate (K_2SO_4), or potassium nitrate (KNO_3) at 9, 12, and 15 weeks after full bloom; and 5 g L^{-1} calcium chloride ($CaCl_2$) at three-week intervals beginning three weeks after full bloom. Results showed significant improvements in fruit weight (166.15- 166.17 and 149.16- 149.57 g), sugar content (13.08- 15.30 and 12.40- 12.75 mg g^{-1} DW), anthocyanin concentration (31.50- 32.20 and 29.70- 30.50 mg g^{-1} FW) and firmness (43.50- 44.63 and 46.51- 47.10 N), particularly when $CaCl_2$ was combined with K sources.

The study by Vijay et al. (2017) assessed the effects of potassium foliar applications and spray schedules on fruit quality parameters in sweet orange cv. Jaffa., conducted at the Department of Horticulture, CCS Haryana Agricultural University, Hisar, during 2014-15, the research aimed to determine optimal potassium treatments for improving fruit production. KNO_3 at 4% enhanced average fruit weight (157.62 g) and fruit diameter (6.72 cm).

Ranjbar et al. (2018) conducted a study on 15-year-old apple trees (*Malus domestica* L. cv. Red Delicious) in Shiraz, Iran, where they evaluated the effects of different concentrations of calcium chloride ($CaCl_2$) and nano-calcium (Nano-Ca) on fruit firmness. The trees were sprayed with four concentrations of $CaCl_2$ (0, 1, 1.5 and 2% @ 35% Calcium) and four concentrations of Nano-Ca (0, 1.5, 2 and 2.5% @ 7% Calcium) across five applications, with two-week intervals starting 70 days after full bloom. The study found that fruit firmness naturally decreased during storage, but the calcium treatments significantly slowed this decline compared to the control group, which received no calcium treatment.

The effects of potassium fertilisation on the fruit quality and nutrient content of 'Brown Turkey' fig trees were studied by Soliman et al. (2018) at King Saud University in Dirab, Riyadh, during the 2015 and 2016 seasons. Results indicated that applying K_2O at 400 g per tree significantly increased fruit weight (38.2 g), volume (39.4 cm) and dimensions (length: 4.8 cm; diameter: 5.5 cm). While non-reducing sugars (6.2%) peaked at 200 g K_2O per tree, higher potassium rates @ K_2O at 400 g per tree also resulted in increased total soluble solids (23.2%), total sugars (22.0%) and reducing sugars (18.3%).

In the study by Bamouh et al. (2019), the effect of foliar potassium fertilization on fruit size was evaluated for strawberries and blueberries. For strawberries, foliar potassium application at the fruit-growing stage enhanced fruit size by 4%. In blueberries, a foliar potassium application during the fruit-growing stage increased fruit size by 19%, while an application at early flowering increased fruit size by 13%.

The study by Bibi et al. (2019) explored the impact of potassium (K), calcium (Ca), and boron (B) on quality of Mango cv. Summer Bahisht (SB) Chaunsa. The research hypothesized that a combined application of these nutrients would enhance mango production. The experiment involved applying two sources of calcium ($CaCl_2$ and $Ca(NO_3)_2$) and three sources of potassium (KNO_3, K_2SO_4, and K-Citrate) at 1% concentration, along with boric acid (BA) at 0.2%. The results showed significant improvements in various parameters compared to the control. Specifically, the combination of KNO_3 (1.0%) + BA (0.2%) led to substantial increases in total soluble solids (35.1% in 2016 and 40.6% in 2017), and overall fruit yield (52.5% in 2016 and 49.2% in 2017).

Shinde et al. (2019) conducted a study to assess the impact of various foliar potassium forms and micronutrients on the quality attributes of sweet orange (*Citrus sinensis* L. Osbeck) over two years (2016-17 to 2017-18) at the Horticulture Research Scheme, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The treatments included potassium nitrate (1%), mono potassium phosphate (1.5%), potassium sulfate (1%), chelated zinc (0.5%), and ferrous (0.4%). The findings showed that potassium sulfate at 1% significantly increased reducing sugars (7.84%, 7.87% and 7.86%) and total sugars (11.39%, 11.34% and 11.37%), with the lowest acidity (0.40%, 0.40% and 0.40%) among the potassium forms.

Sinha et al. (2019) investigated the impact of pre-harvest calcium nitrate $Ca(NO_3)_2$ sprays on the storability and quality of plum fruits (cv. Satluj Purple) at Punjab Agricultural University, Ludhiana. The study involved applying $Ca(NO_3)_2$ at concentrations of 1.0%, 1.5%, and 2.0% to six-year-old plum trees during the second and third weeks of April.

Results showed that two sprays of 2.0% $Ca(NO_3)_2$ significantly preserved fruit firmness (25.72 N at harvest, 11.61 N after 35 days of storage) compared to the control (20.78 N at harvest, 4.42 N after storage). The total sugar content peaked at 9.36% after 28 days of storage in fruits treated with 2.0% $Ca(NO_3)_2$, while anthocyanin content increased over time, with control fruits initially having the highest levels. The study concluded that applying 2.0% $Ca(NO_3)_2$ before harvest enhances firmness, sugar content and anthocyanin stability during cold storage.

Yahmed and Mimoun (2019) examined the impact of several potassium (K) treatments on the 'Superior Seedless' grapevine's' fruit quality and yield. Potassium treatments resulted in notable improvements in the weight and diameter of the grapes and berries. The Nitrate of Potash (NOP) fertiliser was shown to significantly increase the weight and diameter of the fruit. Furthermore, potassium fertilisation raised the berries' total soluble solids (TSS). The maximum TSS levels were obtained by combination of 75% K requirement by fertigation and 25% by foliar spray with either NOP or K Leaf fertilizers.

Chidananda et al. (2020) conducted a field study at the College of Horticulture, Hiriyur, Karnataka, during the 2019- 2020 growing season to assess the impact of foliar potassium application on the quality of pomegranate cv. Bhagwa. The study utilized a randomized block design with 13 treatments, finding that a 3% K_2SO_4 foliar application significantly enhanced several quality attributes. These included total soluble solids (TSS) at 16.40 °Brix, reducing sugars at 14.51%, non-reducing sugars at 1.55%, total sugars at 16.14%, and anthocyanin content at 8.98 mg $100g^{-1}$ fresh weight (FW), while also decreasing acidity to 0.45%. In contrast, the control treatment, which involved water spray, resulted in lower values for these quality parameters and a higher acidity of 0.72%.

Elakkuvan et al. (2021) conducted a study to evaluate the effects of foliar applications of potassium nitrate (KNO_3) and ethephon on the yield characteristics of papaya (*Carica papaya* L.) cv. Red Lady. The research took place at a farmer’s field in Idappadi, Salem district, Tamil Nadu, from 2018 to 2020 with nine different treatments and was replicated thrice. The treatments involved various concentrations and combinations of KNO_3 and ethephon. The study found that the foliar application of KNO_3 at 2% combined with ethephon at 800 ppm significantly improved several parameters such as number of fruits per plant (52.63), fruit length (26.29 cm), fruit diameter (18.65 cm) and fruit weight (2440.65 g).

Hosseini et al. (2021) evaluated the impact of foliar applications of potassium nitrate (KNO_3) and calcium nitrate $Ca(NO_3)_2$ on seedless barberry shrubs in Birjand, Southern Khorasan, Iran, during the 2017 and 2018 growing seasons. The study involved 28-year-old shrubs categorized as ON (fruitful) and OFF (unfruitful). In 2017, after 30 days of storage, fruits from treated plants with 0.5% KNO_3 and $Ca(NO_3)_2$ were brighter in color compared to the control, which exhibited a redder hue, indicating that the calcium and nitrogen in the treatments delayed coloring. However, in 2018, the treatments did not affect the color properties of the seedless barberry.

Moradinezhad and Dorostkar (2021) conducted a study to evaluate the effects of foliar spraying potassium nitrate (KNO_3) and calcium chloride ($CaCl_2$) on the biochemical and physical characteristics of apricot fruits. The study was conducted in Birjand, Iran, on a commercial apricot orchard over the 2019 and 2020 growing seasons. The experiment tested the impact of 1% and 2% KNO_3, as well as 0.5% and 1% $CaCl_2$, on the fruit characteristics of apricot cultivar "Shahroudi." The results revealed that KNO_3 application at both concentrations significantly improved fruit dimensions and weight. Specifically, fruit width increased by 150%, fruit length by 160% and fresh fruit weight by 180% compared to the control. In addition to the physical improvements, the treatments also enhanced biochemical attributes. Fruit pulp calcium content increased by 35% and fruit firmness improved by 25% with either 1% or 2% KNO_3 and 1% $CaCl_2$ treatments compared to the control.

Morwal and Das (2021) investigated effects of boron and calcium nitrate on the weight of pomegranate fruits in Sindhuri (Bhagwa). The treatments applied were T_1 (farmers' practices), T_2 (FYM 25 kg per plant + NPK 625:250:250 g per plant and micronutrient 25 g per plant), and T_3 (RDF with foliar spraying of calcium nitrate @ 0.2% and boron as borax @ 0.3% at full blossoming and one month after). The study found that the T_3 treatment resulted in a significantly higher fruit weight (190.92 g) compared to the other treatments. In contrast, the lowest fruit weight (177.00 g) was observed under farmers' practices (T_1). This indicates that the combined application of calcium nitrate and boron during key growth stages positively influences the fruit weight of pomegranates.

Mosa et al. (2015) conducted an experiment on seven-year-old "Anna" apple trees (*Malus domestica* L.) in Egypt between 2012 and 2013. It included ten foliage spraying treatments as follows: control, water, K at 2% as potassium sulphate, Ca at 0.2% as calcium chloride, B at 0.2% as boric acid, H.A. at 5% as humic acid, potassium sulphate+ humic acid, calcium chloride+ humic acid, boric acid+ humic acid, potassium sulphate+ calcium chloride+ boric acid, and potassium sulphate+ calcium chloride+ boric acid+ humic acid. According to the findings, the combination of potassium sulphate+ calcium chloride+ boric acid+ humic acid significantly increased fruit firmness (14.77 and 14.63 Ib inch^{-2}), diameter (5.84 and 5.97 cm), and length (5.92 and 6.03 cm) in both seasons when compared to the control.

Okba et al. (2021) investigated the effects of various potassium sources on the yield, size and firmness of 'Canino' apricots in Elisha village, EL-Nubaria city, Behaira governorate, Egypt, during the 2019 and 2020 seasons. The study applied 0.2% solutions of potassium humate, potassium sulfate, potassium nitrate, potassium silicate and potassium citrate, along with a water control treatment. The results indicated that potassium nitrate treatments produced the largest fruit size (42.28 and 42.32 cm^3) and highest fruit weight (43.28 and 42.98 g) compared to other treatments, including potassium citrate, which also showed notable improvements. The control treatments generally resulted in smaller fruit sizes and lower weights. In terms of fruit firmness throughout storage, most potassium treatments showed better firmness retention than the control, with potassium silicate and sulfate exhibiting the highest firmness values, followed by potassium nitrate. However, potassium humate and citrate treatments initially performed similarly to the control in the first growing season.

Al-Saif et al. (2022) examined the fruit quality and yield in 2020 and 2021 to determine whether kaolin (aluminium silicate), potassium nitrate, and calcium nitrate affected pomegranate cv. Wonderful. They found that potassium nitrate at 3% and 2% increased fruit volume to 150.33 and 129.33 cm^3 (first season) and 150.33 and 177.67 cm^3 (second season), respectively. Kaolin at 6% and 4% resulted in fruit volumes of 62 and 46.66 cm^3 (first season) and 74.33 and 62.67 cm^3 (second season). Calcium nitrate at 4% and 3% achieved volumes of 91.66 and 67.66 cm^3 (first season) and 93 and 59 cm^3 (second season). Fruit length increased to 2.41 and 1.85 cm (potassium nitrate at 3% and 2%), 1.42 and 1.11 cm (kaolin at 6% and 4%), and 1.84 and 1.7 cm (calcium nitrate at 4% and 3%) in the first season, with similar trends in the second season. Fruit diameter was also enhanced with potassium nitrate at 3% and 2% (2.98 and 2.51 cm), kaolin at 6% and 4% (2.45 and 1.81 cm), and calcium nitrate at 4% and 3% (2.15 and 1.91 cm). Fruit firmness increased to 31.00 and 32.67 lb in^{-2} with kaolin at 6% and 32.33 and 35.33 lb in^{-2} with calcium nitrate at 3% and 4%, respectively. The total sugar content was higher with potassium nitrate at 3% and 2% (3.4% and 2.64%; 3.1% and 2.22%) and kaolin at 6% (2.26% and 1.97%). Reduced sugars were elevated with potassium nitrate at 3% and 2% (1.8% and 1.68%; 1.36% and 1.23%) and kaolin at 6% (1.32% and 1.09%), while non-reduced sugars were increased with potassium nitrate at 3% and 2% (1.6% and 0.95%; 1.74% and 0.99%) and kaolin at 6% (0.94% and 0.88%) compared to the control.

Sajid et al. (2022) conducted a study at the Horticulture Research Farm and Postharvest Laboratory, The University of Agriculture, Peshawar, Pakistan, during 2018-19, to evaluate the effect of foliar application of potassium nitrate and copper sulfate on 'Le Conte' pear production and quality. They tested different concentrations of potassium nitrate (0, 1, 2 and 3%) and copper sulfate (0, 0.2, 0.4, 0.6 and 0.8%). The application of 2% potassium nitrate resulted in the heaviest fruit (188.30 g), highest fruit volume (203.80 cm^3), and greatest yield per tree (60.13 kg), with a minimal fruit drop (8.52%). Maximum fruit firmness (7.66 kg cm^{-2}) and total soluble solids (12.40 °Brix) were observed with 3% potassium nitrate, along with the lowest titratable acidity (0.41%). Conversely, the 0.6% copper sulfate treatment yielded the highest fruit weight (192.04 g) while the 0.8% treatment enhanced fruit firmness (7.53 kg cm^{-2}) and overall quality parameters.

Al-Saif et al. (2023) conducted the experiment during the 2021-2022 to investigate the effect of foliar yeast extract (YE), fulvic acid (FA), moringa leaf extract (MLE), seaweed extract (SWE), and nano-potassium (K NPs) alone or in combination with K NPs on fruit physical and chemical characteristics of date palm cv. Samani. The application of 0.2% YE + 0.02% K NPs had highest results in fruit weight (35.80 ± 0.77 and 36.74 ± 0.77 g), total sugars (44.67 ± 0.50 and 48.49 ± 0.79%) and reduced sugars (38.68 ± 0.45 and 41.11 ± 0.73%). Furthermore, the data showed that 0.4% SWE + 0.02% K NPs, 0.4% FA + 0.02% K NPs and 6% MLE improved every parameter when compared to other treatments.

2.2.4 Effect of foliar application of K and Ca on tree physiology and yield traits

Hao and Papadopoulos (2003) conducted a study in the autumn of 1999 to evaluate the effects of different calcium (Ca) and magnesium (Mg) concentrations on plant growth and fruit yield of tomatoes grown on rockwool. The researchers tested two Ca concentrations (150 and 300 mg L^{-1}) combined with four Mg concentrations (20, 50, 80, and 110 mg L^{-1}). Their findings indicated that fruit yield was higher at the higher Ca concentration of 300 mg L^{-1} compared to the lower concentration of 150 mg L^{-1}. However, at Mg concentration of 20 mg L^{-1}, fruit yield decreased during the late growth stage, suggesting that appropriate Mg levels are crucial for maintaining high yield in tomato crops. The study concluded that the ideal Ca/Mg concentration for maximizing fruit yield in an autumn greenhouse tomato crop is 300/50-80 mg L^{-1}.

A study conducted by Jifon and Lester (2008) examined the effects of six different foliar potassium sources on fruit quality parameters of field-grown muskmelon 'Cruiser' in Weslaco, south Texas. The potassium sources tested included potassium chloride (KCl), potassium nitrate (KNO_3), monopotassium phosphate (MKP), potassium sulfate (K_2SO_4), potassium thiosulfate (KTS) and potassium metalosate (KM). In 2006, additional foliar potassium sprays did not affect fruit yields, but in 2007, significant differences in yields were observed between the foliar potassium sources. Treated plots generally yielded higher than control plots, with potassium thiosulfate showing the highest yields in both years, producing 166.9 and 573.9 40-lb boxes per acre, respectively.

Sarker and Rahim (2013) investigated the impact of potassium nitrate (KNO_3) and urea on yield and harvesting time of nine-year-old mango trees (*Mangifera indica* L.) cv. Amrapali. Conducted at the BAU Germplasm Centre, Department of Horticulture, Bangladesh Agricultural University, from September 2006 to July 2007, the experiment involved five treatments: potassium nitrate at 4%, 6% and 8%; urea at 2% and 4%; and a control with water spray. The results revealed that potassium nitrate at 4% significantly enhanced fruit production, with the highest number of fruits per plant (136.67 kg $plant^{-1}$) compared to the control (62.67 kg $plant^{-1}$). Additionally, potassium nitrate at 4% resulted in the highest total yield per plant (23.14 kg $plant^{-1}$), whereas the control plants had the lowest yield (9.12 kg $plant^{-1}$). Overall, potassium nitrate at 4% was the most effective treatment for increasing yield.

Aly et al. (2015) conducted a study in Abou-EL Matamier, Beheira Governorate, Egypt, during 2013 and 2014 to evaluate the impact of spraying calcium chloride and zinc sulfate at 0.5%, 1% and 1.5%, as well as potassium sulfate at 1%, 2% and 3%, on the yield and fruit quality of Washington navel orange trees. The study found that all treatments significantly increased the number of fruits per tree compared to the control. Specifically, the average number of fruits per tree was highest with the 2% and 3% potassium sulfate treatments, yielding 348.00 and 355.60 fruits in 2013 and 355.40 and 367.80 fruits in 2014, respectively. The control treatment resulted in the lowest average number of fruits per tree in both seasons.

Korkmaz and Aşkın (2015) examined the effects of foliar applications of calcium and boron on the physiological and yield characteristics of *Punica granatum* L. var. Hicaz Nar trees in Ortaca, Mugla province, Turkey. The study revealed that the highest fruit yield was achieved with a 2% calcium nitrate (CN_1) treatment, which produced 38.338 kg per tree. In contrast, the lowest yield was observed with a 1.5% boron application, yielding 20.76 kg per tree. Additionally, the study found that treatments with 2% calcium nitrate (CN_1), 4% calcium nitrate (CN_2), and 3% boric acid (B_2) were all effective in enhancing fruit yield.

The study conducted by Mosa et al. (2015) on seven-year-old "Anna" apple trees (*Malus domestica* L.) in Egypt during 2012 and 2013 evaluated ten different foliar spray treatments, including a control with water, potassium sulfate + humic acid, calcium chloride + humic acid, boric acid + humic acid, potassium sulfate + calcium chloride + boric acid, and potassium sulfate + calcium chloride + boric acid + humic acid. Among these treatments, the combination of potassium sulfate + calcium chloride + boric acid + humic acid was found to be the most effective, resulting in the highest improvement in yield, with values of 58.47 kg tree^{-1} and 60.27 kg tree^{-1} in both years, respectively.

Korkmaz et al. (2016) conducted a study on the cv. Hicaznar variety of pomegranate, grown in a commercial orchard in Ortaca, Turkey. The study involved treatments with control, calcium nitrate $Ca(NO_3)_2$ at 2% (CN_1) and 4% (CN_2), boric acid (H_3BO_3) at 1.5% (B_1) and 3% (B_2), and gibberellic acid (GA_3) at 50 ppm (GA_31) and 75 ppm (GA_32). These treatments were applied to five-year-old pomegranate trees during and one month after blossoming. The results showed that the yield per tree was higher in the first year compared to the second year. In the first year, CN_1 treatment achieved the highest yield (38.34 kg tree^{-1}), followed by B_2 (38.11 kg tree^{-1}) and CN_2 (35.55 kg tree^{-1}). In the second year, only the GA_31 treatment yielded a higher result (36.60 kg tree^{-1}) compared to the control (28.24 kg tree^{-1}).

Shen et al. (2016) examined the effects of foliar application of different potassium (K) fertilisers on 'Kousui' Japanese pear (*Pyrus pyrifolia*) trees over three growing seasons (2012-2014). The fertilisers included potassium phosphate monobasic (KH_2PO_4), potassium nitrate (KNO_3) and humic acid potassium (HAK). The study found that KNO_3 treatment increased average yield by 16%, while HAK treatment enhanced yield by 26% in 2014. Both KNO_3 and HAK treatments significantly elevated potassium accumulation in leaves and fruits, as well as increased concentrations of fructose, malate, and aspartic acid. These findings suggest that KNO_3 effectively boosts yield, while HAK improves fruit quality.

Maji et al. (2017) conducted a field experiment to evaluate the effects of foliar applications of calcium and boron on the growth and fruit quality of young pomegranate plants cv. BHAGWA. The study tested various concentrations of calcium (3% and 5%) and boron (0.25% and 0.5%), both individually and in combination, across three replications. The results indicated that the combination of 3% calcium and 0.25% boron (T_6) significantly accelerated higher flower production, which positively impacted fruit yield. Specifically, T_6 achieved the highest fruit yield of 359.5 kg ha^{-1}.

Ibrahim et al. (2017) conducted two field experiments in 2013/2014 and 2014/2015 at Horticulture Research Station, El-Kanater, El Kaluobia Governorate, to investigate the effects of various calcium sources on the productivity, quality, and storability of local Jerusalem artichokes. The study included treatments with calcium sulfate ($CaSO_4$) at 0.5 and 1 ton fed^{-1}, calcium nitrate ($CaNO_3$) at 20 and 40 units fed^{-1}, chelated calcium at 1000, 1500, and 2000 ppm, and Cal-Bor-Nova compound (12% Ca^{2+} & 1% B_3^{+}) at 3 cm lit^{-1}. The results indicated that applying 0.5 tons fed^{-1} of $CaSO_4$ and 40 units fed^{-1} of $CaNO_3$, followed by 20 units fed^{-1} of $CaNO_3$, positively affected the weight of Jerusalem artichoke plants. Among the treatments, the highest tuber yield was achieved with either 0.5 tons fed^{-1} of $CaSO_4$ or 40 units fed^{-1} of $CaNO_3$, followed by the Cal-Bor-Nova compound.

In a study conducted by Vijay et al. (2017), the impact of potassium foliar treatments and spray schedules on yield in sweet orange cv. Jaffa was evaluated. The research, carried out during the 2014-15 season at CCS Haryana Agricultural University, Hisar, aimed to identify the most effective potassium treatments for enhancing fruit yield. The study found that the highest yield of 76.90 kg $plant^{-1}$ was achieved with two applications of potassium nitrate (KNO_3) at 4%- one in the latter weeks of April and another in August. This yield was comparable to the results from treatments with a second spray in May.

Bamouh et al. (2019) conducted on-farm trials in the Gharb region of Morocco to assess the impact of foliar potassium (K) fertilization on the yield of strawberries, raspberry and blueberries during the 2017 growing season. The study involved four treatments: no foliar application, a single application of 1.6% K_2SO_4 at flowering, a single application at the fruit-growing stage, and two applications at both stages. The results revealed that a single foliar potassium application at flowering increased strawberry yield by 10%, while two applications resulted in a 7% increase. In blueberries, foliar potassium applied during the fruit-growing stage improved yield by 13%. A single treatment of potassium sulphate during the fruit-growing stage in raspberry improved yield by 29%, but two sprays increased yield by 40%.

The effect of potassium (K), calcium (Ca), and boron (B) on the yield of Mango cv. Summer Bahisht (SB) Chaunsa was investigated in the study conducted by Bibi et al. (2019). The study claimed that increasing the combined application of these nutrients will improve mango yields. Two calcium sources- [$CaCl_2$ and $Ca(NO_3)_2$] and three potassium sources (KNO_3, K_2SO_4 and K-Citrate) were applied at 1% concentration for the experiment, along with 0.2% of boric acid (BA). In comparison to the control, the results demonstrated a number of significant improvements in several parameters. For example, the addition of BA (0.2%) and KNO_3 (1.0%) significantly increased the overall yield of fruit (52.5% in 2016 and 49.2% in 2017).

Norozi et al. (2019) investigated the effects of zinc and potassium foliar sprays on the nutritional content of pistachio cv. "Chrokeh" leaves, as well as on fruit quantity and quality. The study included nine treatments with three replications each, involving three levels of K_2SO_4 (0, 1 and 2%) and three levels of $ZnSO_4$ (0, 0.5 and 1%). During the 2017-2018 growing season, the trees were sprayed twice with these solutions during the bud swell and green tip stages. Results showed that nutrient treatments, especially 2% K_2SO_4 combined with 1% $ZnSO_4$, significantly increased the levels of chlorophyll a (2.85 ± 0.05 mg g^{-1} FW), chlorophyll b (1.72 ± 0.37 mg g^{-1} FW) and total chlorophyll (3.55 ± 0.56 mg g^{-1} FW) in the leaves. This treatment also led to substantial improvements in both fresh yield (up to 65%) and dry yield (up to 67%) compared to control trees.

Tejashvini and Thippeshappa (2019) conducted a polyhouse experiment at the Zonal Agricultural and Horticultural Research Station (ZAHRS) in Navile, Shivamogga, during the kharif season of 2016 to evaluate the impact of different calcium sources and levels on tomato fruit. The study utilized three calcium sources for foliar application: calcium chloride ($CaCl_2$), calcium nitrate ($CaNO_3$) and calcium ammonium nitrate (CAN), each at three concentrations (0.20%, 0.50% and 0.80%). The results demonstrated that foliar applications of calcium from these sources significantly increased tomato yield compared to the control treatment (water spray). The improved yield was attributed to enhanced nutrient uptake and utilization in the plants.

Yahmed and Mimoun (2019) evaluated the impact of various potassium (K) treatments on the yield and fruit quality of grapevine (‘Superior Seedless’) and reported that potassium fertilization slightly increased yield compared to the control group. Among the different treatments, the application of 75% of the K requirement by fertigation combined with 25% by foliar spray using K Leaf fertilizer proved to be the most effective, showing the best yield results.

Hagagg et al. (2020) conducted a study to enhance vegetative growth and mineral content in two olive varieties by applying a 0.5% solution of calcium chloride (21% Ca) and chelated calcium. For the Kalmata cultivar, spraying with chelated calcium led to a significant increase in total chlorophyll content in leaves, recording 94.27 and 97.90 (SPAD units) in the first and second seasons, respectively, compared to 72.27 and 82.21 (SPAD units) in the control treatment. Similarly, for the Manzanillo cultivar, the application of chelated calcium resulted in the highest total chlorophyll levels, with values of 86.10 and 96.21 (SPAD units), compared to the unsprayed trees which had total chlorophyll levels of 82.44 and 87.43 (SPAD units) in both seasons.

Abbas et al. (2021) conducted two trials at Cairo University Research Station in Giza, Egypt, in 2018 and 2019 to evaluate the impact of calcium foliar sprays on maize production and grain chemical composition under drought stress. The trials utilized water regimes of 100% (control), 75%, and 50% of projected evapotranspiration. Calcium levels of 0 and 50 mg L^{-1} were applied to the subplots, and three maize cultivars (SC-P3444, Sammaz 35 and EVDT) were included in the study. The results revealed that drought conditions led to a significant reduction in overall yield. However, foliar application of calcium (50 mg L^{-1}) significantly enhanced maize production across all irrigation conditions. Under a full water regime (100% evapotranspiration), the SC-P3444 cultivar achieved the highest grain yield of

8061 kg ha^{-1}, followed by Sammaz 35 with 7570 kg ha^{-1} and EVDT with 7191 kg ha^{-1}. At 75% of projected evapotranspiration, calcium foliar treatment increased grain yield by 16% for SC-P3444, 13% for Sammaz 35, and 14% for EVDT. At 50% of projected evapotranspiration, the increases were 17% for SC-P3444, 16% for Sammaz 35, and 13% for EVDT.

A study by Elakkuvan et al. (2021) assessed how foliar sprays of ethephon and potassium nitrate (KNO_3) affected the yield parameters of papaya (*Carica papaya* L.) cv. Red Lady. From 2018 to 2020, nine distinct treatments were used in a farmer's field in Idappadi, Salem district, Tamil Nadu. Different KNO_3 and ethephon concentrations and combinations were used in the treatments. In comparison to other treatments, the study indicated that the foliar spray of KNO_3 at 2% along with ethephon at 800 ppm produced the most yield per plant (49.67 kg).

Morwal and Das (2021) conducted research to determine the impact of boron and calcium nitrate on the yield of pomegranate cultivars in Sindhuri (Bhagwa). The study included three treatments: T_1 (farmers' practices), T_2 (FYM 25 kg per plant + NPK 625:250:250 g plant^{-1} and micronutrient 25 g plant^{-1}), and T3 (RDF and foliar spraying of calcium nitrate @ 0.2% and boron as borax @ 0.3% at full blossoming and one month after). The findings revealed that foliar application of borax @ 0.3% + calcium nitrate @ 0.2% (T_3) led to a significantly higher fruit yield per plant (8.82 kg) and total yield (73.45 q ha^{-1}). In contrast, the lowest fruit yield per plant (6.82 kg) and total yield (54.70 q ha^{-1}) were observed under farmers' practices (T_1).

During the 2019 and 2020 seasons in Egypt, Okba et al. (2021) treated 'Canino' apricots with a 0.2% solution of five different potassium sources- potassium humate, potassium sulfate, potassium nitrate, potassium silicate, and potassium citrate- as well as water as a control treatment. The results indicated that all potassium sources had the potential to increase yield compared to the control. Among the treatments, potassium citrate ($K_3C_6H_5O_7$) and potassium nitrate (KNO_3) led to the highest yields, outperforming the other potassium forms and the control treatment.

Yathish et al. (2021) conducted a field experiment in Mandya, Karnataka, in 2017 to assess the effects of foliar sprays of calcium nitrate, boron and humic acid on transplanted pigeonpea growth and production. The study found that the treatment with 1.0% calcium nitrate $Ca(NO_3)_2$ at flower commencement, in addition to recommended dose of fertilizers (RDF) and farmyard manure (FYM), resulted in the highest grain yield of 1670.00 kg ha^{-1}. This yield was significantly higher compared to the control (T_2), which received RDF and FYM alone and yielded 1540.00 kg ha^{-1}. Additionally, the treatment with 0.50% borax applied at flower initiation and 15 days after flower initiation (T_2) produced a grain yield of 2093.00 kg ha^{-1}, which was also significantly higher than the control but less than the calcium nitrate treatment.

To investigate the effects of kaolin (aluminium silicate), potassium nitrate and calcium nitrate on pomegranate cv. Wonderful, Al-Saif et al. (2022) assessed fruit quality and yield during the 2020 and 2021 growing seasons. The study involved spraying trees with various formulations: water (control), calcium nitrate (2%, 3% and 4%), potassium nitrate (1%, 2% and 3%), and kaolin (2%, 4% and 6%). The results revealed that potassium nitrate at 2% and 3% significantly increased fruit yield to 7.19 and 11.43 tons ha^{-1}, and 8.02 and 12.41 tons ha^{-1}, respectively. Similarly, kaolin at 4% and 6% boosted yields to 4.15 and 5.86 tons ha^{-1}, and 4.25 and 6.57 tons ha^{-1}, respectively. Calcium nitrate at 2% and 3% resulted in yields of 4.38 and 7.08 tons ha^{-1}, and 4.71 and 7.85 tons ha^{-1}, respectively, compared to the control.

Roosta et al. (2023) investigated the impact of foliar spraying nano calcium carbonate and different cultivation systems-soil cultivation, hydroponic cultivation in greenhouse settings, and hydroponic vertical cultivation in plant factories- on pennyroyal plants. After planting, the plants were treated with nano calcium carbonate at 7-day intervals for a total of three applications. The study found that plants grown in greenhouse hydroponic systems exhibited the highest levels of total chlorophyll, while those in field hydroponic systems showed the lowest. Additionally, no significant differences in total chlorophyll were observed among plants grown in vertical cultivation systems under various LED light spectrums.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled **“Impact of foliar applications of nano- nitrogen, potassium and calcium on growth, yield and quality of apple (*Malus x domestica* Borkh.)”** was undertaken during two consecutive years 2022 and 2023 at Experimental farm of Krishi Vigyan Kendra, Shimla at Rohru, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Himachal Pradesh. The details of the experiments undertaken and methodologies employed for the investigation are presented in this chapter under the following heads:

3.1 Experimental site
3.2 Experimental details
3.3 Observations recorded
3.4 Statistical analysis

3.1 EXPERIMENTAL SITE

3.1.1 Geographical location

Field trials were executed at Krishi Vigyan Kendra, Shimla at Rohru, Himachal Pradesh. The experimental area is located at an altitude of 1720 m above mean sea level and lies between 31°45’30’’ N latitude and 77°25’30’’ E longitude. Figure 3.1 shows the exact location of the experimental site.

3.1.2 Climate and Weather

Himachal Pradesh is situated in the Western Himalayas covering an area of 55673 kms. It is a mountainous state with elevation ranging from about 350 m - 6000 meters. The climate of state varies with altitude and agro- climatically it is divided into 4 zones. Shimla has a subtropical highland climate (Cwb) under the Köppen climate classification. The climate in Shimla is predominantly cool during winters and a relatively warm during summer.

The study area Krishi Vigyan Kendra, Shimla at Rohru falls under wet temperate high hill zone of H.P. Mean annual temperature ranges from 9.1 to 20 °C and rainfall ≥1500 mm. The meteorological data of temperature (max. and min.), rainfall (mm), RH I and RH II (%) and bright sunshine (hrs.) recorded at Reginal Horticultural Research and Training Station, Mashobra, (situated 102 kms away from the experimental site) Dr. Yashwant Singh Parmar University of Horticulture and Forestry was procured on weekly distribution during the experimental period (January - October) i.e. 1- 40 standard meteorological weeks for both the years (Fig 3.2 and 3.3). Similarly, the maximum temperature observed during the experimental year was 27.5 and 24.5 °C for both years. The minimum temperature recorded in 2022 and 2023 were -1.4 and 0.2 °C, respectively.

Summer temperatures average between 4.3°C and 27.5 °C for the year 2022 and 9.0°C to 24.5°C for the year 2023, whereas, winter temperatures range between -0.1°C to 17.9 °C for the year 2022 and 0.2°C to 16.2°C for the year 2023. The precipitation ranges from 0 to 135.7 mm in 34th week of 2022 and 0 to 258.6 mm in 28th week of 2023. A total of 1240.5 mm and 1778.4 mm rainfall was received during the experimental period in the year 2022 and 2023, respectively (Appendix-I).

3.1.3 Soil Characteristics

The soil of the experimental site was classified as sandy loam in texture. Prior to the execution of the experiment, representative soil samples from two depths viz. 0-15 and 15-30 cm were collected. The samples were air dried, processed and kept at muslin cloth bags for further analysis of the soils' physical and chemical characteristics (Table 3.1) using established protocols.

Table 3.1: Physico-chemical characteristics of the experimental soil before the start of Experiment

Soil Property	Depth	
	0-15 cm	15-30 cm
Soil texture	Sandy loam	Sandy loam
Bulk density (g cm^{-3})	1.22	1.25
Particle density (g cm^{-3})	2.83	2.86
Porosity (%)	56.89	56.29
pH (soil: water suspension 1: 2)	5.78	5.76
EC (dS m^{-1})	0.46	0.44
Organic carbon (g kg^{-1})	17.35	17.58
Available N (kg ha^{-1})	296.85	284.94
Available P (kg ha^{-1})	74.93	70.67
Available K (kg ha^{-1})	426.86	415.43
Exchangeable Ca [cmol (p^+) kg^{-1}]	6.37	6.24
Exchangeable Mg [cmol (p^+) kg^{-1}]	3.19	3.04
Available S (kg ha^{-1})	24.26	21.59
DTPA Extractable - Fe (mg kg^{-1})	18.28	16.57
DTPA Extractable - Cu (mg kg^{-1})	1.83	1.77
DTPA Extractable - Zn (mg kg^{-1})	2.36	2.31
DTPA Extractable - Mn (mg kg^{-1})	19.58	19.28

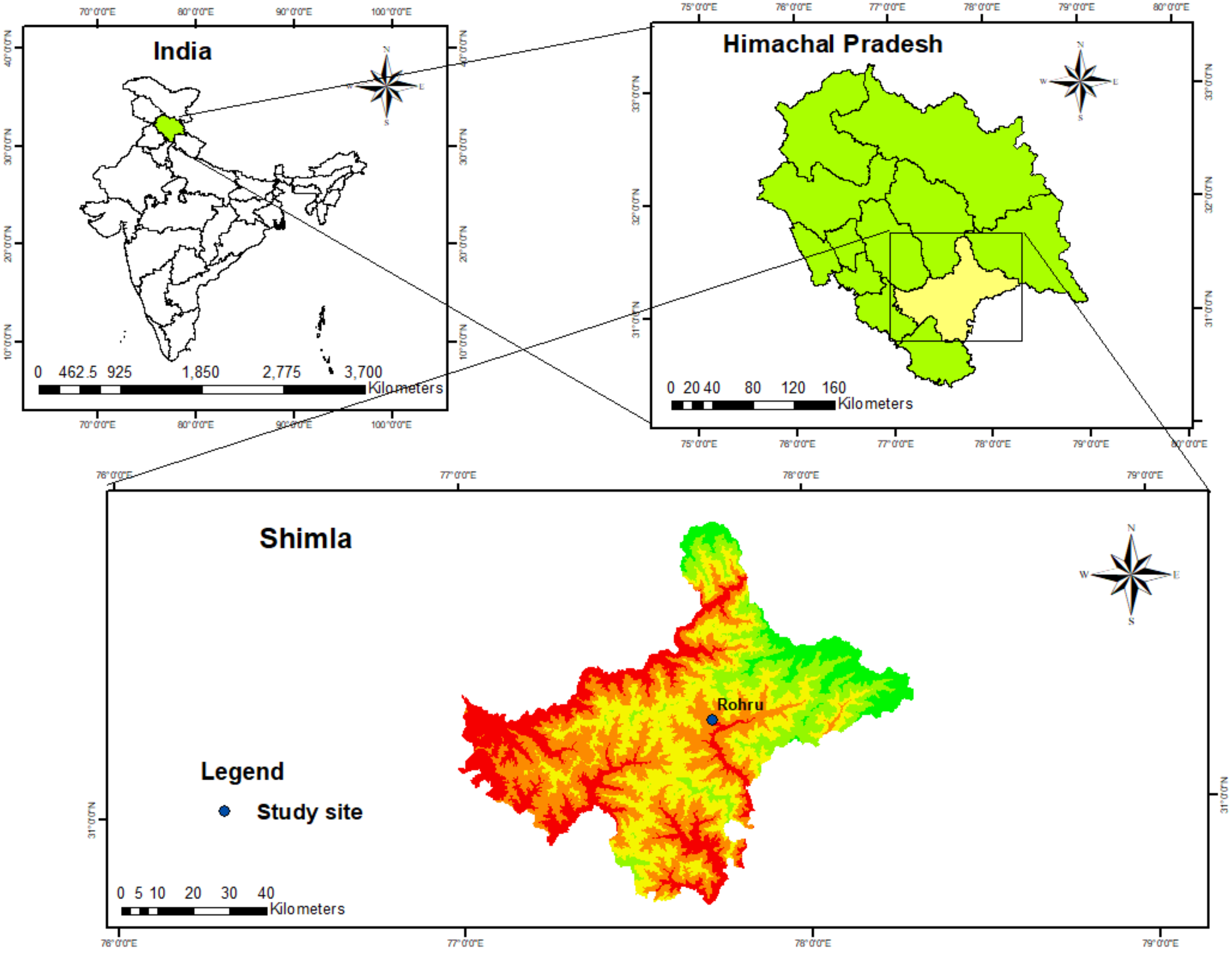


Fig. 3.1 Study area map of the experimental area.

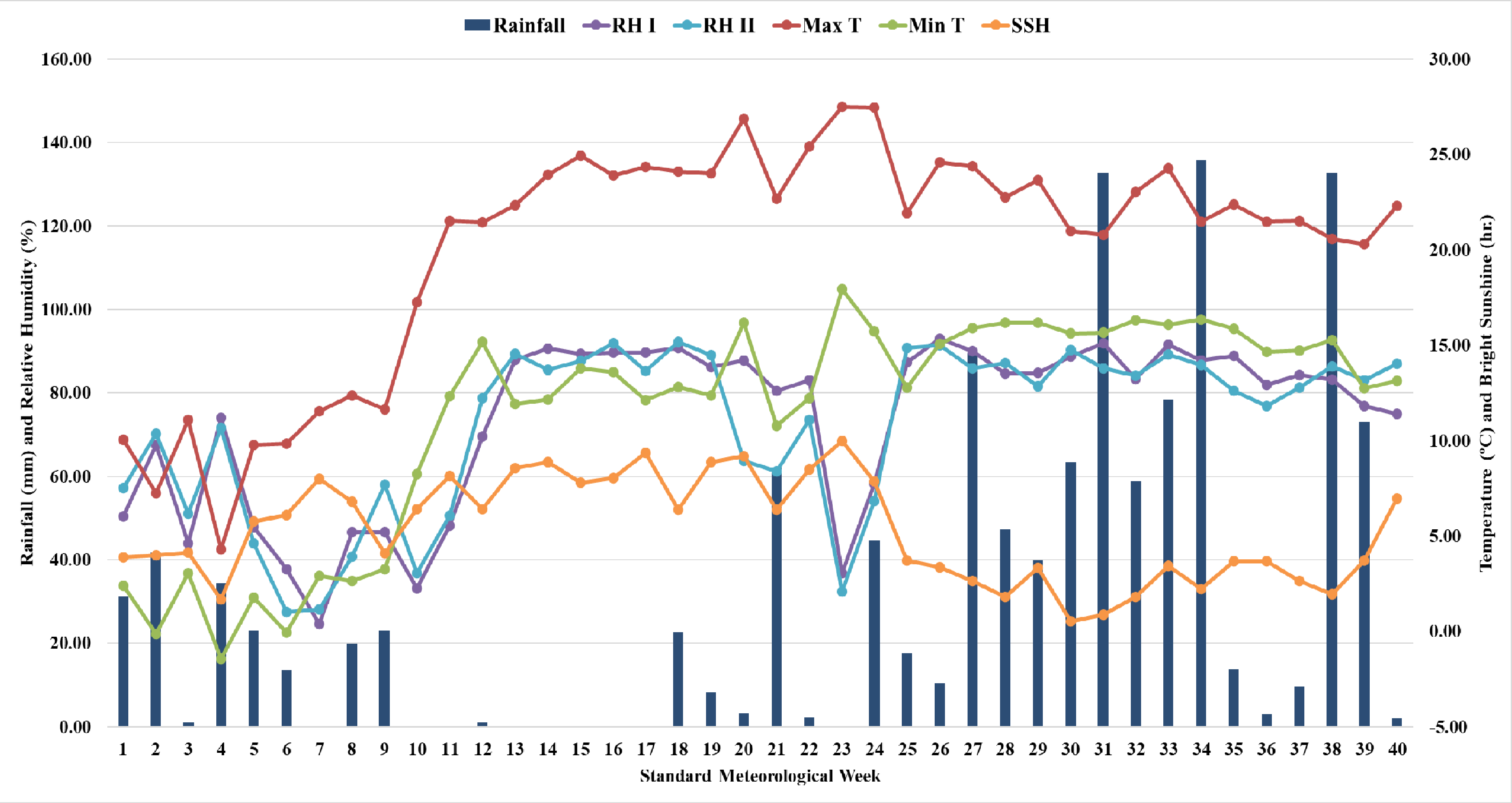


Fig. 3.2 Meteorological data during experimental period (January- October, 2022) i.e. 1- 40 standard meteorological weeks

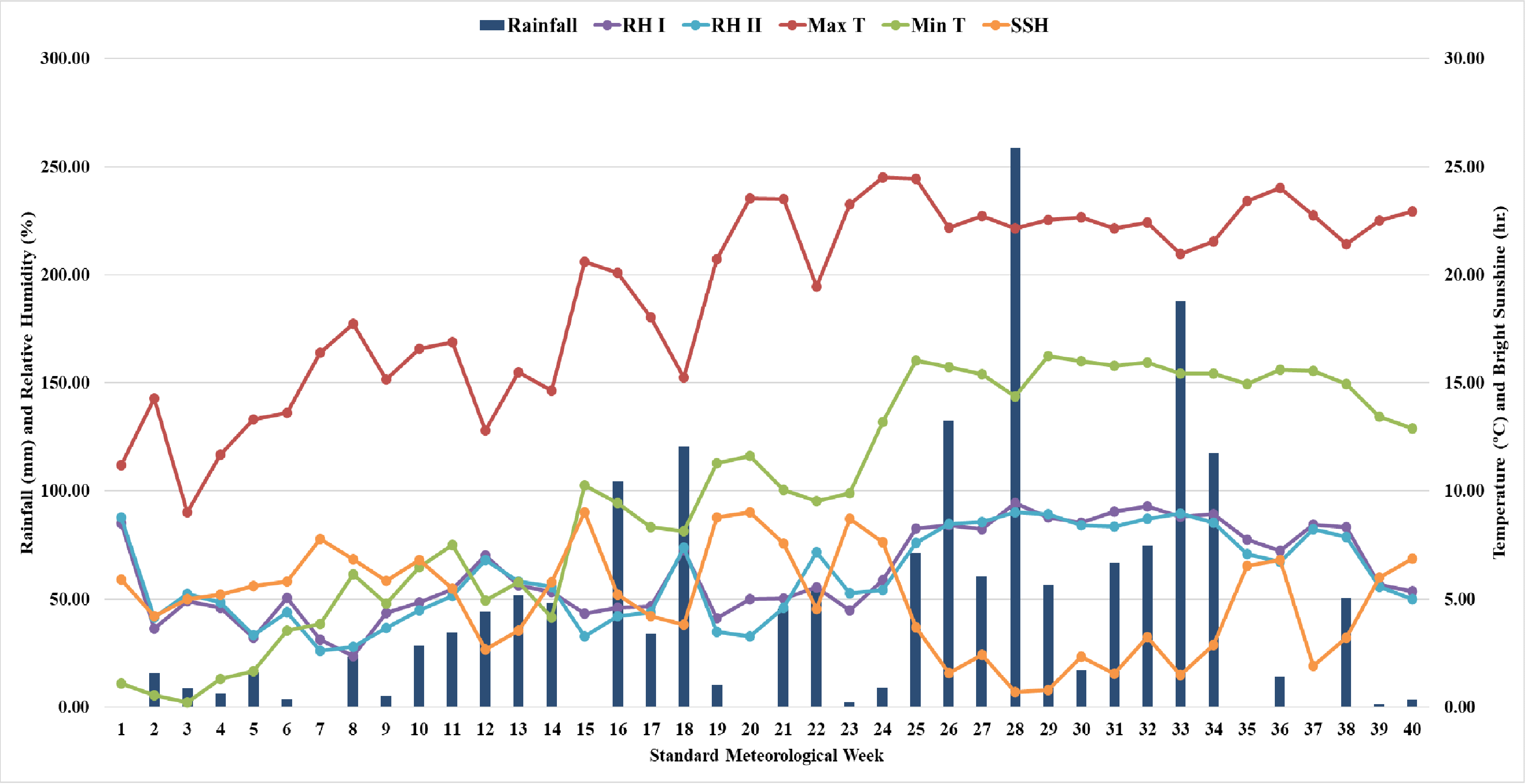


Fig. 3.3 Meteorological data during experimental period (January- October, 2023) i.e. 1- 40 standard meteorological weeks

3.2 EXPERIMENTAL DETAILS

3.2.1 Layout and experimental design

The present investigation was carried out on 20 years old apple orchard for two consecutive years. Apple (c.v. Red Chief) trees having uniform growth and vigor and being kept under uniform cultural practices during the course of experimentation. Two field trials were conducted simultaneously in same orchard and was laid out in Randomized Block Design (RBD) with eleven treatments and each treatment replicated thrice. The plants were planted at East- West direction of the experimental site with a spacing of 3.5m x 3.5m. According to the package and practices (PoP) recommended by Dr. YSPUHF, Solan, for apple plantations, the recommended dose of fertilizer is 700:350:700 g tree^{-1} (N: P_2O_5: K_20) for >10 years of plantation.

3.2.2 Treatments details

3.2.2.1 Experiment- 1

Objective: - To study the effect of nano- nitrogen (nN) applications on growth, yield and quality of apple

Treatment Code	Treatment details
T_1	Soil application of 100% RDN + 0.5% urea at Pink bud stage- **Control**
T_2	Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage
T_3	Soil application of 25% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage
T_4	Soil application of 25% RDN + nN @ 500 ppm split at Pink bud and Fruit Set stage
T_5	Soil application of 25% RDN + nN @ 500 ppm split at Pink bud, Fruit Set and Walnut stage
T_6	Soil application of 50% RDN + nN @ 175 ppm split at Pink bud and Fruit Set stage
T_7	Soil application of 50% RDN + nN @ 175 ppm split at Pink bud, Fruit Set and Walnut stage
T_8	Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage
T_9	Soil application of 50% RDN + nN @ 250 ppm split at Pink bud, Fruit Set and Walnut stage
T_{10}	Soil application of 50% RDN + nN @ 350 ppm split at Pink bud and Fruit Set
T_{11}	Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage

*RDN- Recommended dose of nitrogen

3.2.2.1.1 Time and Method of fertilizer application

Before the execution of experiment, every year tree basins were ploughed with spade to make them weed free and were thoroughly mixed with the farm yard manure (FYM) and fertilizers. The application of farm yard manure was done during the months of January-February throughout both years of study. Recommended dose of phosphorus (P_2O_5) through single super phosphate (SSP) and potassium (K_2O) through muriate of potash (MOP) was applied in January and was kept constant for application in all the treatments. Respective doses of nitrogen (soil application) through Urea as per treatments were imposed in two split doses. The first half of the nitrogen dose was applied two weeks prior to flowering, while the remaining half was applied one month after the first application. The calculated amount of fertilizers for each treatment was evenly spread in the basin around each tree 25 cm away from tree trunk and thoroughly mixed into the soil. All experimental trees received consistent and recommended cultural practices throughout the entire duration of the study. Nano-nitrogen was applied through IFFCO nano urea as foliar spray at different phenological stages of crop as mentioned in treatment details.

3.2.2.2 Experiment- 2

Objective: - To study the effect of foliar applications of potassium and calcium on growth, yield and quality of apple

Treatment Code	Treatment details
T_1	Water spray- **Control**
T_2	KNO_3 @ 0.5% at Walnut stage
T_3	K_2SO_4 @ 0.5% (45 days before harvesting)
T_4	$CaCl_2$ @ 0.5% (45 and 60 days before harvesting)
T_5	KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting)
T_6	KNO_3 @ 0.5% at Walnut stage + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)
T_7	K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)
T_8	KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)
T_9	KNO_3 @ 0.5% at Walnut stage + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)
T_{10}	K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)
T_{11}	KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)

3.2.2.2.1 Time and Method of fertilizer application

Before the execution of experiment, every year tree basins were ploughed with spade to make them weed free and were thoroughly mixed with the farm yard manure (FYM) and fertilizers. The application of farmyard manure (FYM) was done during the months of January-February throughout both years of study. Recommended dose of phosphorus (P_2O_5) through single super phosphate (SSP) and potassium (K_2O) through muriate of potash (MOP) was applied in January and was kept constant for application in all the treatments. Recommended doses of nitrogen as soil application were applied uniformly in all the treatments with two split doses. The first half of the nitrogen dose was applied two weeks prior to flowering, while the remaining half was applied one month after the first application. Foliar applications of KNO_3 (Potassium nitrate), K_2SO_4 (Potassium sulphate) and $CaCl_2$ (Calcium chloride) were carried out as per treatments.

3.2.3 Crop Physiological Stages

The spray schedule for the apple crop was determined by the phenological stages of the crop which may vary from time to time as it may have governed by weather parameters such as temperature, rainfall, relative humidity, wind speed, sunshine hours etc. The following spray schedule was followed for the experimentation (Table 3.2) and each stage was represented in Plate 1.

Table 3.2: Physiological growth stages for apple plantation at experimental site

Sr. No.	Physiological growth stage	Year(s)	
		2022	2023
1.	Pink bud	22/03/2022- 29/03/2022	30/03/2023- 01/04/2023
2.	Fruit set	22/04/2022- 24/04/2022	01/05/2023- 04/05/2023
3.	Walnut stage	01/06/2022- 03/06/2022	16/06/2023- 18/06/2023
4.	Harvesting	13/09/2022- 17/09/2022	30/09/2023- 02/10/2023

3.3 OBSERVATIONS RECORDED

3.3.1 Soil Analysis

3.3.1.1 Collection and preparation of soil samples

Representative soil samples were collected during both the years of study. All the samples were collected with stainless steel auger, spade, shovel and spatula to avoid any contamination. The soil samples were air dried, grounded with wooden pestle and mortar, passed through 2 mm sieve and finally stored in plastic containers for further analysis.

3.3.1.2 Soil Chemical Properties

3.3.1.2.1 Soil pH

Soil pH was determined by using pH meter by making soil: water suspension (1:2) by following the procedure as described by Jackson (1973).

3.3.1.2.2 Electrical conductivity (dSm^{-1})

EC of soil was estimated using the electrical conductivity meter in supernatant solution obtained from 1:2 soil water suspension by keeping it overnight (Jackson 1973).

3.3.1.2.3 Organic carbon (g kg^{-1})

Soil organic carbon was determined by wet digestion method of Walkley and Black (1934). This is based on reduction of chromic acid by organic matter, wherein unreduced amount of chromic acid is determined by titration.

3.3.1.2.4 Available Nitrogen (kg ha^{-1})

The available nitrogen was estimated by alkaline potassium permanganate method as given by Subbiah and Asija (1956) and expressed in kg ha^{-1}.

3.3.1.2.5 Available Phosphorus (kg ha^{-1})

Available phosphorus was determined by Stannous Chloride reduced ammonium molybdate method using Olsen's extractant (Olsen et al. 1954) and determined on spectronic 20 D+ at 660 nm wave length and expressed in kg ha^{-1}.

3.3.1.2.6 Available Potassium (kg ha^{-1})

1N Ammonium acetate was used as extractant and was determining by feeding the extract to flame photometer as per the procedure given by Merwin and Peach (1951).

3.3.1.2.7 Exchangeable Calcium [cmol (p^{+}) kg^{-1}]

Exchangeable calcium was extracted with the neutral normal ammonium acetate and determined by using Flame Photometer (Merwin and Peach 1951) and expressed in [cmol (p^{+}) kg^{-1}].

(A) Pink bud stage of apple

(B) Flowering stage of apple

(C) Walnut stage of apple

(D) Harvesting of apple

Plate 1: Physiological growth stages of apple for spray scheduling

3.3.1.2.8 Exchangeable Magnesium [cmol (p^+) kg^{-1}]

Exchangeable magnesium was extracted with the neutral normal ammonium acetate and determined on Atomic Absorption Spectrophotometer (Merwin and Peach 1951) and expressed in [cmol (p^+) kg^{-1}].

3.3.1.2.9 Available Sulphur (kg ha^{-1})

Sulphate sulphur was extracted with 0.15% $CaCl_2$ extractant and determined turbidimetrically as per the procedure of Chesnin and Yein (1950).

3.3.1.2.10 DTPA Extractable- Fe, Cu, Zn and Mn (mg kg^{-1})

The extractable micronutrient content of the soil was determined using the method described by Lindsay and Norvell (1978). Ten gram of soil was shaken with 20 ml of DTPA extractant at pH 7.3 for two hours. The mixture was then filtered and the extract obtained was used for further analysis. The DTPA extractable iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn) in the extract were quantified using an Atomic Absorption Spectrophotometer. The results were expressed in parts per million (ppm) on a dry weight basis.

3.3.2 Leaf Analysis

3.3.2.1 Collection and preparation of leaf samples

During the first week of August, leaves including petioles were taken from the middle section of mid-terminal shoots of the current season's growth along the periphery of each experimental tree. This collection approach was based on the study by Kenworthy (1964).

Composite samples were generated by combining each replication samples, and this process was done over both the years of study. The obtained leaf samples were immediately transported to the laboratory. To assure cleanliness, the leaves were carefully washed according to the Chapman (1964) process. They were washed with tap water, then 0.1 N HCl, and finally distilled water. Following washing, the leaf samples were spread out on filter paper sheets to allow for surface drying. After drying, the samples were packed into paper bags and dried in a hot air oven at 65 ± 5°C for 48 hours to completely remove moisture. The dried samples were crushed and grinned to a fine powder, which was stored in butter paper bags. These dried and crushed leaf samples were later employed for the digestion and estimation of several nutrient elements in subsequent laboratory examination.

3.3.2.2 Digestion of leaf samples

The leaf samples were digested in a di-acid mixture obtained by combining concentrated HNO_3 and $HClO_4$ in a 4:1 ratio, using all necessary procedures as outlined by Piper (1966) for measuring P and K levels. To estimate nitrogen (N), a separate digestion was performed using concentrated H_2SO_4 and a mixture of potassium sulfate (400 parts), copper sulphate (20 parts), mercuric oxide (3 parts) and selenium powder (1 part), as described by Jackson (1973).

3.3.2.3 Analysis of nutrient elements

3.3.2.3.1 Nitrogen (%)

Total nitrogen was estimated by micro-Kjeldhal method as outlined by A.O.A.C. (1975) and results were expressed in per cent nitrogen on the basis of dry weight in leaves.

3.3.2.3.2 Phosphorus (%)

Total phosphorus was estimated by Vanado-molybydate phosphoric yellow colour method (Jackson, 1973). 5ml of aliquot (digested) was pipette out in 25 ml of volumetric flask and 5ml of vanado-molybydate reagent was added. Solution was then diluted to 25 ml with distilled water and allowed to develop colour for half an hour. After the development of colour, concentration of phosphorus in solution was recorded on spectrophotometer at 470 nm wavelength and blank was run simultaneously to adjust zero absorbance and was expressed in per cent on dry weight basis.

3.3.2.3.3 Potassium and Calcium (%)

Plant potassium and calcium in the Di-acid extract was determined by feeding the extractant to Flame Photometer (Jackson 1973) and results were expressed in percent dry weight basis.

3.3.2.3.4 Sulphur (%)

Plant sulphur was determined by feeding the extractant to spectrophotometer and results were expressed in percent dry weight basis.

3.3.2.3.5 Magnesium (%) and plant micronutrients (ppm)

Magnesium and micronutrient cations (viz., iron, manganese, zinc and copper) in the Di-acid extract were analysed on Atomic Absorption Spectrophotometer (Sarma et al. 1987; Vogel 1978).

3.3.3 Vegetative growth parameters

3.3.3.1 Increase in tree height (%)

The height of the plants from the ground level to the terminal apex was measured in meters with a meter tape. The percent increase in plant height was obtained from the length increased divided by the length taken at initial observation.

$$\text{Increase in tree height (\%)} = \frac{\text{Tree height}_2 \text{ - Tree height}_1}{\text{Tree height}_1} \times 100$$

Whereas,

Tree height_2 = Tree height at the end of experiment.
Tree height_1 = Tree height before application of treatments.

3.3.3.2 Increase in trunk girth (%)

The girth of the tree trunk was measured in centimeters with the help of measuring tape at a height of 15 cm from the ground level. The percent increase in plant girth was obtained from the girth increase divided by the girth taken at initial observation.

3.3.3.3 Increase in tree spread

The estimation of tree spread was conducted in two directions: East-West (E-W) and North-South (N-S). Initially, the tree spread was determined at the start of experiment and subsequently at the end of each growing season. A measuring tape was used to carefully assess the spread at a height where it was maximum. To calculate the tree spread, the values obtained for the E-W and N-S directions were averaged. The increase in spread was then calculated by subtracting the initial values from the final values recorded at the end of the growing season and was thereby expressed in centimeters (cm).

3.3.3.4 Increase in tree volume

The calculation of tree or canopy volume was performed using the formula given by Westwood (1978), which incorporates the tree height and tree spread as key components.

i. For trees taller than their width: Tree volume = $4/3 \pi ab^2$

ii. For trees wider than their height: Tree volume = $4/3 \pi a^2b$

The tree canopy volume was subsequently determined using these formulas, and the values were expressed in cubic meters (m^3).

Whereas,

In the formulas:
$\pi = 3.14$
a = Half the length of the major axis (height)
b = Half the length of the minor axis (width)
Tree volume_2 = Tree volume at the end of experiment.
Tree volume_1 = Tree volume before application of treatments.

3.3.3.5 Annual shoot growth

Shoots from the current season's growth in the four cardinal directions (North, South, East and West) were randomly chosen from the outer edges of each designated tree in the experiment. The length of these selected shoots was subsequently determined using a measuring tape at the conclusion of each growing season. The average annual growth of the shoots was then quantified and expressed in centimetres (cm).

3.3.3.6 Leaf area

Leaf area data was obtained by randomly selecting ten fully expanded leaves from the middle portion of current season's growth of each experimental tree in the month of July. The leaf area of each selected leaf was then measured using CI-202 Portable Laser Area Meter. The recorded values were averaged to determine average leaf area, which was expressed in square centimetres (cm^2).

3.3.4 Fruit quality parameters

3.3.4.1 Fruit length

Fruit length was measured using digital Vernier caliper, starting from the calyx (the stem end) to the styler end (opposite end) of the fruit. The measurements were taken in millimetres (mm) to ensure accuracy. Measuring the fruit length provides valuable information about the size and elongation of the fruit, which is an important parameter for evaluating fruit quality.

3.3.4.2 Fruit diameter

Diameter of the same fruits, which were previously measured for their length, was determined by measuring the distance between the cheeks of the fruits using digital Vernier caliper. This measurement was carried out in millimetres (mm) to ensure precision and accuracy.

3.3.4.3 Fruit weight

The fruits selected for recording fruit size were weighed using an electronic top pan balance. The weight of each fruit was measured individually and then the average fruit weight was calculated by taking the sum of all the individual fruit weights and dividing it by the total number of fruits. The average fruit weight was expressed in grams (g).

3.3.4.4 Fruit volume

Fruit volume was computed using the water displacement method. Fruits which were taken for recording fruit weight were submerged in known volume of water filled in measuring beaker to obtain certain graduation. The difference between initial and final readings gave the measurement of fruit volume which was expressed in cubic centimetres (cc).

3.3.4.5 Fruit firmness

Fruit firmness was deliberated using Digital Fruit Pressure tester (Type ACSY4) which measured the pressure necessary for the plunger to penetrate the peeled flesh of fruits. Five fruits were tested from each tree and results were expressed as kilogram per square centimetres (kg cm^{-2}).

3.3.4.6 Total soluble solids

To determine the total soluble solids (TSS) content of the fruits, a Milwaukee MA-871 digital refractometer with a range of 0- 85°B was employed. Prior to use, the refractometer was calibrated using distilled water to ensure accurate measurements. When the temperature deviated from 20°C, a temperature correction, as outlined by A.O.A.C. (1980), was applied. A few drops of fruit juice were placed on the prism of the refractometer and the readings were recorded. The readings were then averaged and the results were expressed in degrees Brix (°B).

3.3.4.7 Titratable acidity

Titratable acidity, a measure of the fruit's acidity, was estimated following the standard procedure outlined by Ranganna (1995). Initially, 25 grams of fruit pulp was thoroughly homogenized with distilled water using pestle and mortar. The final volume was adjusted to 250 ml in a volumetric flask. From this mixture, 50 ml of extract was separated for acidity estimation, while the remaining portion was reserved for determining total and reducing sugars. The 50 ml extract obtained was then filtered through Whatman No. 1 filter paper. Subsequently, 25 ml of the filtered juice was titrated against N/10 NaOH solution, employing phenolphthalein as an indicator. The titration continued until a pink end point was observed. The titratable acidity was calculated in terms of malic acid, considering that 1 ml of 0.1N NaOH solution being equivalent to 0.0067 g anhydrous malic acid and expressed in terms of acidity A.O.A.C. (1980) guidelines. Acidity was calculated as malic acid by using the following formulae:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times 0.1\text{N NaOH} \times \text{volume made} \times \text{Eq. weight of acid}}{\text{Volume of sample for estimation} \times \text{volume of aliquot} \times 1000} \times 100$$

3.3.4.8 Total sugars

To estimate total sugars content of fruit, volumetric method based on hydrolyzing sucrose to glucose and fructose in the presence of hydrochloric acid was employed, following the procedure outlined by Ranganna (1995). The remaining 200 ml of the fruit extract, obtained after the titratable acidity estimation, was transferred to a 250 ml volumetric flask. To this, 5 ml of 45% standard lead acetate was added and allowed to react for 5-10 minutes. Subsequently, 5 ml of 22% potassium oxalate was added to precipitate any excess lead acetate, and the volume was adjusted to 250 ml. The solution was then filtered. 50 ml of the filtrate was taken and hydrolyzed by adding 5 ml of concentrated hydrochloric acid (HCl). This hydrolysis process was allowed to occur overnight at room temperature. The following day, the excess HCl was neutralized by adding saturated sodium hydroxide (NaOH) solution, and the final volume was adjusted to 250 ml with distilled water. To estimate the total sugars, a boiling mixture of 5 ml each of Fehling A and Fehling B solutions was titrated against the hydrolyzed fruit juice. Methylene blue was used as an indicator and the end point was indicated by the appearance of a brick red colour. Total sugars content was expressed as a percentage of fresh weight of the fruit pulp.

$$\text{Total sugar (\%)} = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre value} \times \text{Weight or Volume of the sample taken}} \times 100$$

*Factor = 0.05

3.3.4.9 Reducing sugars

Estimation of reducing sugars content in the fruit was performed using the method proposed by Ranganna (1995). After hydrolysis and neutralization steps described in total sugars, the remaining unhydrolyzed, deleaded, and clarified solution was used for this analysis. A boiling solution containing 5 ml each of Fehling A and Fehling B solutions was prepared. To this solution, the clarified fruit extract was added drop by drop until the appearance of a brick red colour, indicated by methylene blue indicator. The volume of the fruit extract required to achieve the endpoint was noted. Reducing sugars content was then calculated as a percentage of the fresh weight of the fruit pulp, based on the volume of fruit extract used in titration and the known concentration of the Fehling solutions.

$$\text{Reducing sugars (\%)} = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre value} \times \text{Weight of the sample taken}} \times 100$$

*Factor = 0.05

3.3.4.10 Non-reducing sugars

Non-reducing sugars content in the fruit was determined by subtracting the reducing sugars content from the total sugars content. The difference between the total sugars and reducing sugars was then multiplied by a standard factor of 0.95. The calculated value represents the non-reducing sugars content in the fruit, expressed as a percentage of the total fruit pulp weight.

Non-reducing sugars (%) = (Total sugars - Reducing sugars) × 0.95

3.3.4.11 TSS: acid ratio

The ratio mentioned is obtained by dividing the values of Total Soluble Solids (TSS) of the fruit juice by its malic acid content. This ratio provides an indication of the relationship between the sweetness (TSS) and acidity (malic acid) of the fruit juice. By comparing these values, it is possible to assess the balance between sweetness and acidity in the fruit.

$$\text{TSS: acid} = \frac{\text{TSS}}{\text{Titratable acidity}}$$

3.3.4.12 Fruit color

After the fruits were harvested, their colour expression was visually observed using a colour chart provided by the Royal Horticultural Society, London (Wilson 1941). This colour chart serves as a reference guide, allowing the observer to compare the fruit's color to the standardized color on the chart. By matching the fruit's color to the corresponding color on the chart, valuable information about the fruit's maturity and quality can be obtained. Visual assessment of fruit color is a common practice in determining the stage of fruit maturity and helps in determining the optimal time for harvesting.

3.3.4.13 Anthocyanin content

The determination of anthocyanin pigment in apple skin involves the following steps, as described by Harborne (1973). One gram of apple skin was taken and macerated in a known quantity of methanol containing 1 per cent hydrochloric acid. Maceration helped to extract anthocyanin pigment from the apple skin. After maceration, the content was kept overnight at 0°C in a deep freezer. This step was performed to enhance the extraction and stability of anthocyanin. The next day, the red-coloured solution was obtained from the macerated mixture. This solution contained the extracted anthocyanin pigment. Using Nukes UV-VIS spectrophotometer, the absorbance of the red-coloured solution was measured at 535 nm in this case. This wavelength was chosen because it corresponds to the maximum absorbance of anthocyanin. The absorbance value recorded at 535 nm represents the concentration of anthocyanin in the solution.

Finally, the amount of anthocyanin was expressed as absorption mg/100 g. This allowed for the comparison of anthocyanin content among different samples.

$$\text{Total anthocyanin content (mg/100g)} = \frac{\text{Total OD/100mg}}{\text{E}}$$

Whereas,

E (Extinction Coefficient) = 98.20 and OD = Optical density

$$\text{Total OD/100mg} = \frac{\text{OD} \times \text{Volume made up for colour measurement} \times \text{Total Volume}}{\text{Volume of extract used} \times \text{weight of sample taken}} \times 100$$

The E value for 1 per cent solution of cyanidin-3-glucoside (i.e. 10 mg per 1 ml) at 535 nm is equal to 982 (Ranganna 1997). Therefore, the absorbance of a solution containing 1 mg per ml is equal to 98.2.

3.3.5 Physiological and yield parameters

3.3.5.1 Leaf Chlorophyll content

Twenty-five fully expanded and mature leaves from the current season's growth of each tree were collected in the month of July during morning hours, following the method described by Halfacre et al. (1968). The leaves were carefully harvested and immediately placed in an icebox to maintain their freshness during transportation to the laboratory. Upon arrival at the laboratory, the leaves from each sample were finely chopped under subdued light to ensure minimal degradation of the leaf samples. A total of 100 mg of the chopped leaf samples were then transferred to vials containing 7 ml of Dimethyl Sulphoxide (DMSO), which served as the extraction solvent. The vials containing the leaf samples and DMSO were then incubated at a temperature of 65˚C for a period of 30 minutes. This incubation process allowed for the extraction of various compounds present in the leaves into the DMSO solution.

After the incubation period, the extract was adjusted to a final volume of 10 ml using Dimethyl Sulphoxide (DMSO), following the protocol outlined by Hiscox and Israelstam (1979). This extraction process is crucial for studying the composition and concentration of various compounds present in the leaves, which can provide insights into their physiological and biochemical properties.

Estimation

The optical density (OD) values of the extract were recorded in spectrophotometer (Nukes UV-VIS Spectrophotometer) at 645 and 663 nm wavelength against a dimethyl sulphoxide blank. The total chlorophyll content was calculated by using the following formula:

$$\text{Total chlorophyll} = \frac{[20.2\ (A_{645}) + 8.02\ (A_{663})]}{A \times 1000 \times W} \times V$$

Whereas,

V = Volume of the extract made

A = Length of the light path in cell (usually 1 cm)

W = Weight of the sample (g)

A_{645} = Absorbance at 645 nm

A_{663} = Absorbance at 663 nm

The results thus obtained were expressed as mg g^{-1} of fresh weight.

3.3.5.2 Yield (kg tree^{-1})

The yield under each replication was recorded at the time of harvest by weighing the total fruits harvested from an individual tree and total fruit yield per plant was expressed in kilogram per tree (kg tree^{-1}).

3.4 STATISTICAL ANALYSIS:

The observations recorded during the course of investigation were analyzed by using MS-Excel and software OPSTAT. The mean values of data were subjected to Analysis of Variance as per the procedure outlined by Panse and Sukhatme (2000) for using Randomized Block Design. The table for Analysis of Variance (ANOVA) was calculated as follows:

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean sum of squares (M)**	**F. Cal.**
Replications	(r-1)	S_r	$S_r/(r-1)= M_r$	M_r/ M_e
Treatments	(t-1)	S_t	$S_t/(t-1)= M_t$	M_t/ M_e
Error	(r-1) (t-1)	S_e	$S_e/(r-1)(t-1)= M_e$	
Total	(rt-1)	S_T		

Whereas,

r = Number of replications,

t = Number of treatments

Sr = Sum of square due to replications

St = Sum of square due to treatments

Se = Sum of square due to error

S_T = Total sum of squares

Mr = Mean sum of square due to replications

Mt = Mean sum of square due to treatments

Me = Mean sum of square due to error

The calculated 'F' values were compared with the tabulated 'F' values at 5% level of significance. If the calculated 'F' value were higher than the tabulated, it was considered significant i.e. one of the treatment pair differ significantly and CD was calculated to find out the superiority of one treatment over the others.

The standard error of mean SE (m) and critical difference (CD) for comparing the means of error were calculated as below:

SE (m) = ± $(M_e/r)^{1/2}$

SE (d) = ± $(2\ M_e/r)^{1/2}$

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

SE (m) ± = Standard error of mean

SE (d) ± = Standard error of differences

$CD_{0.05}$ = Critical difference at 5 per cent level of significance

Chapter-4

RESULTS AND DISCUSSION

The results pertaining to the present investigation entitled **"Impact of foliar applications of nano-nitrogen, potassium and calcium on growth, yield and quality of apple (*Malus x domestica* Borkh.)"** are presented in this chapter. To achieve this objective field experiments were conducted for two consecutive years 2022 and 2023 at the Experimental farm of Krishi Vigyan Kendra, Shimla at Rohru, Himachal Pradesh (India). The results thus obtained are presented and discussed under the following heads with the help of appropriate tables, suitable illustrations and explanation below:

4.1 Experiment-1: Effect of nano- nitrogen (nN) applications on growth, yield and quality of apple

- 4.1.1 Effect of nano- nitrogen on chemical properties of soil
- 4.1.2 Effect of nano- nitrogen on leaf nutrient content of plant
- 4.1.3 Effect of nano- nitrogen on plant growth parameters
- 4.1.4 Effect of nano- nitrogen on fruit quality attributes
- 4.1.5 Effect of nano- nitrogen on tree physiological and yield traits

4.2 Experiment-2: Effect of effect of foliar applications of potassium (K) and calcium (Ca) on growth, yield and quality of apple

- 4.2.1 Effect of foliar application of K and Ca on leaf nutrient content of plant
- 4.2.2 Effect of foliar application of K and Ca on plant growth parameters
- 4.2.3 Effect of foliar application of K and Ca on fruit quality attributes
- 4.2.4 Effect of foliar application of K and Ca on tree physiological and yield traits

4.1 Experiment-1: Effect of nano- nitrogen (nN) applications on growth, yield and quality of apple

4.1.1 Effect of nano- nitrogen on chemical properties of soil

4.1.1.1 Soil pH

The data with respect to soil pH for 2022 and 2023 are cited in Table 4.1. The perusal of data showed that various treatments exerted a non- significant effect on soil pH during both the years of study.

It is evident from the data presented in Table 4.1 that during 2022 and 2023, highest soil pH (5.93 and 5.94) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest soil pH (5.74 and 5.73) was recorded under T_5 (Soil application of 25% RDN + nN @ 500 ppm split at Pink bud, Fruit Set and Walnut stage).

Pooled analysis of the data also revealed same trend with highest soil pH (5.94) being recorded under $T_{11.}$ Whereas, lowest soil pH (5.73) was recorded under T_5. The data on effects of treatment (T), year (Y) and their interaction (Y×T) were found to be non-significant.

4.1.1.2 Electrical Conductivity

The data with respect to soil electrical conductivity for 2022 and 2023 are cited in Table 4.1. The perusal of data showed that various treatments exerted a non- significant effect on soil electrical conductivity during both the years of study.

It is evident from the data presented in Table 4.1 that during 2022 and 2023, highest soil EC (0.55 dS m^{-1} and 0.56 dS m^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest soil EC (0.41 dS m^{-1} and 0.41 dS m^{-1}) was recorded under T_6 (Soil application of 50% RDN + nN @ 175 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with highest soil EC (0.56 dS m^{-1}) being recorded under $T_{11.}$ Whereas, lowest soil EC (0.41 dS m^{-1}) was recorded under T_6. The data on effects of treatment (T), year (Y) and their interaction (Y×T) were found to be non- significant.

4.1.1.3 Organic Carbon

The data with respect to soil organic carbon for 2022 and 2023 are cited in Table 4.1. The perusal of data showed that various treatments exerted a non- significant effect on soil OC during both the years of study.

It is evident from the data presented in Table 4.1 that during 2022 and 2023, highest soil OC (19.63 and 19.74) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest soil OC (18.48 and 18.57) was recorded under T_5 (Soil application of 25% RDN + nN @ 500 ppm split at Pink bud, Fruit Set and Walnut stage).

Table 4.1: Effect of graded levels of N and nano-N on soil pH, electrical conductivity and organic carbon

Treatment Code	**pH**			**EC (dS m^{-1})**			**OC (g kg^{-1})**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	5.91	5.93	5.92	0.54	0.55	0.55	19.59	19.77	19.68
T_2	5.78	5.79	5.78	0.46	0.47	0.47	18.93	19.06	18.99
T_3	5.82	5.80	5.81	0.44	0.45	0.45	18.99	19.02	19.00
T_4	5.77	5.78	5.78	0.46	0.46	0.46	19.32	19.48	19.40
T_5	5.74	5.73	5.73	0.43	0.44	0.43	18.48	18.57	18.52
T_6	5.81	5.82	5.82	0.41	0.41	0.41	18.87	19.03	18.95
T_7	5.82	5.83	5.83	0.42	0.43	0.42	19.05	19.20	19.13
T_8	5.89	5.87	5.88	0.52	0.53	0.53	19.22	19.27	19.24
T_9	5.86	5.87	5.86	0.45	0.46	0.46	19.44	19.59	19.51
T_{10}	5.92	5.93	5.92	0.53	0.54	0.54	19.18	19.37	19.27
T_{11}	5.93	5.94	5.94	0.55	0.56	0.56	19.63	19.74	19.69
Mean	5.83	5.84		0.47	0.48		19.15	19.28	
CD (0.05)	NS	NS		NS	NS		NS	NS	
Year (Y):			NS			NS			NS
Treatment (T):			NS			NS			0.47
Y×T:			NS			NS			NS

Pooled analysis of the data also revealed same trend with significantly highest soil OC (19.69) being recorded under $T_{11.}$ Whereas, lowest soil OC (18.52) was recorded under T_5. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) on soil OC were found.

Increase in soil organic carbon contents might be due to the application of organic matter through FYM and organic manures besides recycling of crop residue like roots and leaf fall over a considerable period of time. Similar results were reported by Verma et al. (2010). Soil organic carbon contents were increased through application of FYM in orange orchard (Abd El-Migeed et al. 2007) and apple orchard (Reganold et al. 2001; Verma and Bhardwaj 2005; El-Boray 2006; Verma 2008; Verma et al. 2009).

4.1.1.4 Available Nitrogen

The data with respect to soil available nitrogen for 2022 and 2023 are cited in Table 4.2. The perusal of data showed that various treatments exerted a significant effect on soil available nitrogen during both the years of study.

It is evident from the data presented in Table 4.2 that during 2022 and 2023, significantly highest soil available nitrogen (354.70 kg ha^{-1} and 362.12 kg ha^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_1, T_6, T_7, T_8, T_9 and T_{10}. Whereas, significantly lowest available nitrogen (317.17 kg ha^{-1} and 325.80 kg ha^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest soil available nitrogen (358.41 kg ha^{-1}) being recorded under T_{11} which was statistically at par with treatments T_6, T_7, T_8, T_9 and $T_{10.}$ Whereas, significantly lowest available nitrogen (321.48 kg ha^{-1}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on available soil nitrogen contents were found.

The available nitrogen content in orchard soils under study significantly increased in treatments with higher urea application rates with statistically at par values being observed under treatments of soil application of 50% and 100% recommended dose of nitrogen (RDN) (Control) as compared to treatments of 25% of RDN. This could be attributed to the enhanced rates of urea hydrolysis resulting into higher concentration of NH_4^+ ions and their subsequent conversion to NO_3^- ions through bacterial nitrification. Sharma et al. (2016) reported that application of 50%, 100%, and 150% of the recommended nitrogen dose in wheat led to increases in soil nitrogen availability by 5.3%, 11.8%, and 15.0%, respectively. Bhickta et al. (2018) also observed in case of apple that increasing nitrogen levels significantly enhanced available nitrogen content in the soil. Garhwal et al. (2014) reported a similar increase in soil nitrogen content with continuous application of higher nitrogen doses in Kinnow mandarins. Similar findings have been reported by Sharma (1987) and Singh (1992) for peach, El-Wakeel (2005) for mango and Sun et al. (2020) for banana.

4.1.1.5 Available Phosphorus

Data pertaining due to different treatments on soil available phosphorus during 2022 and 2023 and pooled analysis are presented in Table 4.2. It is clear from the data that different treatments significantly affected the available phosphorus at experimental soil.

The data enumerated in Table 4.2 revealed that during 2022 and 2023, significantly highest soil available phosphorus (86.89 kg ha^{-1} and 91.69 kg ha^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_1, T_5, T_6, T_7, T_8, T_9 and T_{10}. Whereas, significantly lowest available phosphorus (80.44 kg ha^{-1} and 84.98 kg ha^{-1}) was recorded under T_3 (Soil application of 25% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage).

Pooled analysis of the data also revealed same trend with significantly highest soil available phosphorus (89.29 kg ha^{-1}) being recorded under T_{11} which was statistically at par with treatments T_6, T_8, T_9 and T_{10}. Whereas, significantly lowest available phosphorus (82.71 kg ha^{-1}) was recorded under T_3. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on available soil nitrogen contents were found.

Table 4.2: Effect of graded levels of N and nano-N on available nitrogen, phosphorus and potassium in soil

Treatment Code.	**Available N (kg ha^{-1})**			**Available P (kg ha^{-1})**			**Available K (kg ha^{-1})**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	347.91	355.13	351.52	83.89	87.66	85.78	460.97	472.50	466.73
T_2	317.17	325.80	321.48	81.02	85.21	83.12	459.65	470.46	465.05
T_3	324.38	330.99	327.68	80.44	84.98	82.71	458.38	469.99	464.18
T_4	319.09	326.17	322.63	81.98	86.32	84.15	459.99	471.68	465.84
T_5	322.87	331.96	327.42	83.12	87.53	85.32	458.82	470.39	464.61
T_6	348.47	356.09	352.28	85.22	88.63	86.92	462.89	473.64	468.27
T_7	348.19	356.21	352.20	83.37	89.32	86.35	461.53	472.56	467.05
T_8	351.43	358.67	355.05	84.86	88.32	86.59	460.87	472.68	466.77
T_9	349.98	356.50	353.24	85.26	89.65	87.45	465.86	477.69	471.77
T_{10}	353.80	361.93	357.86	84.00	89.33	86.67	463.23	474.88	469.05
T_{11}	354.70	362.12	358.41	86.89	91.69	89.29	466.72	478.91	472.82
Mean	339.81	347.41		83.63	88.05		461.71	473.21	
CD $_{(0.05)}$	14.28	13.42		4.30	4.31		6.48	6.20	
Year (Y):			3.96			1.23			1.82
Treatment (T):			9.29			2.89			4.27
Y×T:			NS			NS			NS

These findings align with the observations of Saini (2011) and Sun et al. (2020), who reported an increase in available soil phosphorus with the application of an NPK fertilizer combination. Similarly, Clark et al. (1989) found that soil phosphorus content was maximized when 'Bluecrop' blueberry plants were treated with a 13:13:13 fertilizer blend. The increase in soil phosphorus with nitrogen fertilization can be attributed to enhanced microbial activity and nutrient interactions. Nitrogen fertilization stimulates soil microorganisms, promoting the mineralization of organic phosphorus compounds and thereby increasing phosphorus availability for plant uptake. Additionally, nitrogen application often improves root growth and nutrient uptake efficiency, facilitating better access to available phosphorus in the soil (Chen et al. 2014).

4.1.1.6 Available Potassium

Data pertaining due to different treatments on soil available potassium during 2022 and 2023 and pooled analysis are presented in Table 4.2. It is clear from the data that different treatments significantly affected the available potassium at experimental soil.

A perusal of data presented in Table 4.2 revealed that during 2022 and 2023, significantly highest soil available potassium (466.72 kg ha^{-1} and 478.91 kg ha^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_6, T_9 and T_{10}. Whereas, significantly lowest available potassium (458.38 kg ha^{-1} and 469.99 kg ha^{-1}) was recorded under T_3 (Soil application of 25% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage).

Pooled analysis of the data also revealed same trend with significantly highest soil available potassium (472.82 kg ha^{-1}) being recorded under T_{11} which was statistically at par with treatments T_9 and $T_{10.}$ Whereas, significantly lowest available potassium (464.18 kg ha^{-1}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on available soil potassium contents were found.

Increased application of potassium to the soil results in a higher concentration of potassium ions in the soil solution. These ions are retained on the surfaces of clay particles, which enhances the potassium reserves in the rhizosphere. This observation is supported by studies including Wrona et al. (1995), Bhat (2001), Ernani et al. (2002), Komosa and Szewczuk (2002) and Neilsen and Neilsen (2006) for apples, as well as Aroosa (2014) for grape orchards. Additionally, Chandel (1985); Xie and Cummings (1995) and Sun et al.

(2020) reported that the application of nitrogenous fertilizers leads to an increase in soil potassium (K) levels. The results obtained are supported by findings of Bhickta et al. (2018) who reported that the availability of potassium in the soil is significantly influenced by various nitrogen sources and levels, with potassium content increasing as different nitrogen applications are used.

4.1.1.7 Exchangeable Calcium

The data with respect to soil exchangeable calcium for 2022 and 2023 are cited in Table 4.3. The perusal of data showed that various treatments exerted a significant effect on exchangeable calcium during both the years of study.

It is evident from the data presented in Table 4.3 that during 2022 and 2023, significantly highest exchangeable calcium (7.43 cmol (p^+) kg^{-1} and 7.52 cmol (p^+) kg^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_9 and T_{10}. Whereas, significantly lowest exchangeable calcium (6.46 cmol (p^+) kg^{-1} and 6.51 cmol (p^+) kg^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest exchangeable calcium (7.48 cmol (p^+) kg^{-1}) being recorded under T_{11} which was statistically at par with treatment $T_{9.}$ Whereas, significantly lowest exchangeable calcium (6.49 cmol (p^+) kg^{-1}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on exchangeable calcium contents were found.

4.1.1.8 Exchangeable Magnesium

The data with respect to soil exchangeable magnesium for 2022 and 2023 are cited in Table 4.3. The perusal of data showed that various treatments exerted a significant effect on soil exchangeable magnesium during both the years of study.

It is evident from the data presented in Table 4.3 that during 2022 and 2023, significantly highest exchangeable magnesium (3.65 cmol (p^+) kg^{-1} and 3.73 cmol (p^+) kg^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_1, T_6, T_7, T_8, T_9 and T_{10}. Whereas, significantly lowest exchangeable magnesium (3.26 cmol (p$^+$) kg^{-1} and 3.34 cmol (p$^+$) kg^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Table 4.3: Effect of graded levels of N and nano-N on exchangeable calcium, magnesium and available sulphur in soil

Treatment Code	Exchangeable Ca [cmol (p+) kg^{-1}]			Exchangeable Mg [cmol (p+) kg^{-1}]			Available S (kg ha^{-1})		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	7.26	7.42	7.34	3.58	3.65	3.62	31.16	32.55	31.85
T_2	6.46	6.51	6.49	3.26	3.34	3.30	28.25	28.66	28.45
T_3	6.52	6.63	6.58	3.29	3.37	3.33	29.44	30.42	29.93
T_4	6.49	6.55	6.52	3.32	3.39	3.35	28.45	29.20	28.83
T_5	6.56	6.65	6.60	3.34	3.41	3.38	29.66	30.74	30.20
T_6	7.30	7.36	7.33	3.55	3.65	3.60	30.42	31.47	30.95
T_7	7.31	7.38	7.35	3.59	3.67	3.63	31.50	32.85	32.17
T_8	7.33	7.40	7.36	3.60	3.70	3.65	30.92	33.81	32.37
T_9	7.37	7.45	7.41	3.63	3.72	3.68	32.36	34.92	33.64
T_{10}	7.35	7.43	7.39	3.61	3.69	3.65	31.68	33.71	32.70
T_{11}	7.43	7.52	7.48	3.65	3.73	3.69	33.51	35.86	34.69
Mean	7.03	7.11		3.49	3.57		30.66	32.19	
CD $_{(0.05)}$	0.10	0.11		0.19	0.19		NS	NS	
Year (Y):			0.03			0.05			NS
Treatment (T):			0.07			0.13			NS
Y×T:			NS			NS			NS

Pooled analysis of the data also revealed same trend with significantly highest exchangeable magnesium (3.69 cmol (p$^+$) kg^{-1}) being recorded under T_{11} which was statistically at par with treatment T_1, T_6, T_7, T_8, T_9 and $T_{10.}$ Whereas, significantly lowest exchangeable magnesium (3.30 cmol (p$^+$) kg^{-1}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on exchangeable calcium contents were found.

The observed increase in calcium (Ca) contents relative to the initial status following the application of NPK fertilizers may be attributed to the addition of calcium through the use of Single Super Phosphate. These findings are consistent with those reported by Dias and Flore (2002). Significant increase in exchangeable calcium and magnesium in the treatments of 50% and 100% soil applied urea as compared to the treatments of 25% application rates may be attributed to the higher nitrogen and phosphorus availability. Significant increases in exchangeable soil calcium and magnesium concentrations were observed in soils treated with NPK + lime and NPK + silicate (Amoakwah et al. 2024). These results align with findings by Kumar (1984), Glenn et al. (1987) and Dhindsa (2018) who reported increased calcium content in soil following the addition of nitrogen fertilizers in apple cultivation.

4.1.1.9 Available Sulphur

The data with respect to soil available sulphur for 2022 and 2023 are cited in Table 4.3. The perusal of data showed that various treatments exerted a non- significant effect on soil available sulphur during both the years of study.

It is evident from the data presented in Table 4.3 that during 2022 and 2023, highest soil available sulphur (33.51 kg ha^{-1} and 35.86 kg ha^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest available sulphur (28.25 kg ha^{-1} and 28.66 kg ha^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with highest soil available sulphur (34.69 kg ha^{-1}) being recorded under T_{11}. Whereas, lowest available sulphur (28.45 kg ha^{-1}) was recorded under T_2. The data on effects of treatment (T), year (Y) and interaction (Y×T) were found to be non- significant.

4.1.1.10 DTPA- Extractable Fe

The data with respect to soil DTPA- extractable Fe for 2022 and 2023 are cited in Table 4.4. The perusal of data showed that various treatments exerted a significant effect on soil DTPA- extractable Fe during both the years of study.

It is evident from the data presented in Table 4.4 that during 2022 and 2023, significantly highest soil DTPA- extractable Fe (28.26 mg $kg^{-1}$and 29.38 mg kg^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_8, T_9 and T_{10}. Whereas, significantly lowest DTPA- extractable Fe (20.68 mg kg^{-1} and 21.72 mg kg^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest soil DTPA- extractable Fe (28.82 mg kg^{-1}) being recorded under T_{11} which was statistically at par with treatments T_8 and T_9. Whereas, significantly lowest DTPA- extractable Fe (21.20 mg kg^{-1}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on DTPA- extractable Fe contents were found.

Table 4.4: Effect of graded levels of N and nano-N on DTPA extractable iron and copper in soil

Treatment Code.	**DTPA extractable Fe (mg kg^{-1})**			**DTPA extractable Cu (mg kg^{-1})**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	25.22	25.88	25.55	2.23	2.19	2.21
T_2	20.68	21.72	21.20	1.92	2.07	1.99
T_3	22.15	23.10	22.63	1.96	2.11	2.03
T_4	21.08	22.37	21.73	1.94	2.10	2.02
T_5	22.36	23.24	22.80	1.96	2.13	2.05
T_6	25.49	26.49	25.99	2.15	2.25	2.20
T_7	26.20	27.33	26.77	2.19	2.25	2.22
T_8	27.55	28.76	28.16	2.25	2.28	2.27
T_9	27.94	29.09	28.51	2.26	2.29	2.28
T_{10}	26.56	28.00	27.28	2.22	2.27	2.24
T_{11}	28.26	29.38	28.82	2.28	2.31	2.30
Mean	24.86	25.94		2.12	2.20	
CD $_{(0.05)}$	1.73	1.85		NS	NS	
Year (Y):			0.51			0.07
Treatment (T):			1.20			0.18
Y×T:			NS			NS

4.1.1.11 DTPA- Extractable Cu

The data with respect to soil DTPA- extractable Cu for 2022 and 2023 are cited in Table 4.4. The perusal of data showed that various treatments exerted a non- significant effect on soil DTPA- extractable Cu during both the years of study.

It is evident from the data presented in Table 4.4 that during 2022 and 2023, highest soil DTPA- extractable Cu (2.28 mg kg^{-1} and 2.31 mg kg^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest DTPA- extractable Cu (1.92 mg kg^{-1} and 2.07 mg kg^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest soil DTPA- extractable Cu (2.30 mg kg^{-1}) being recorded under T_{11}. Whereas, significantly lowest DTPA- extractable Cu (1.99 mg kg^{-1}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on DTPA- extractable Cu contents were found.

4.1.1.12 DTPA- Extractable Zn

The data with respect to soil DTPA- extractable Zn for 2022 and 2023 are cited in Table 4.5. The perusal of data showed that various treatments exerted a non- significant effect on soil DTPA- extractable Zn during both the years of study.

It is evident from the data presented in Table 4.5 that during 2022 and 2023, highest soil DTPA- extractable Zn (2.60 mg kg^{-1} and 2.61 mg kg^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest DTPA- extractable Zn (2.40 mg kg^{-1} and 2.45 mg kg^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with highest soil DTPA- extractable Zn (2.61 mg kg^{-1}) being recorded under T_{11}. Whereas, lowest DTPA- extractable Zn (2.43 mg kg^{-1}) was recorded under T_2. The data on effects of treatment (T), year (Y) and their interaction (Y×T) were found to be non- significant.

4.1.1.13 DTPA- Extractable Mn

The data with respect to soil DTPA- extractable Mn for 2022 and 2023 are cited in Table 4.5. The perusal of data showed that various treatments exerted a significant effect on soil DTPA- extractable Mn during both the years of study.

It is evident from the data presented in Table 4.5 that during 2022 and 2023, significantly highest soil DTPA- extractable Mn (24.64 mg kg^{-1} and 24.87 mg kg^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_1, T_6, T_7, T_8, T_9 and T_{10}. Whereas, significantly lowest DTPA- extractable Mn (21.19 mg kg^{-1} and 21.40 mg kg^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Table 4.5: Effect of graded levels of N and nano-N on DTPA extractable zinc and manganese in soil

Treatment Code	DTPA extractable Zn (mg kg^{-1})			DTPA extractable Mn (mg kg^{-1})		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	2.51	2.55	2.53	23.14	23.35	23.25
T_2	2.40	2.45	2.43	21.19	21.40	21.30
T_3	2.44	2.50	2.47	21.75	21.94	21.84
T_4	2.42	2.48	2.45	21.44	21.64	21.54
T_5	2.46	2.51	2.49	21.93	22.13	22.03
T_6	2.50	2.54	2.52	23.36	23.59	23.48
T_7	2.53	2.55	2.54	23.50	23.69	23.60
T_8	2.56	2.59	2.57	24.10	24.34	24.22
T_9	2.58	2.59	2.58	24.43	24.63	24.53
T_{10}	2.55	2.57	2.56	23.85	24.05	23.95
T_{11}	2.60	2.61	2.61	24.64	24.87	24.76
Mean	2.50	2.53		23.03	23.23	
CD $_{(0.05)}$	NS	NS		2.04	2.02	
Year (Y):			NS			NS
Treatment (T):			NS			1.36
Y×T:			NS			NS

Pooled analysis of the data also revealed same trend with significantly highest soil DTPA- extractable Mn (24.76 mg kg^{-1}) being recorded under T_{11} which was statistically at par with treatments T_6, T_7, T_8, T_9 and $T_{10.}$ Whereas, significantly lowest DTPA- extractable Mn (21.30 mg kg^{-1}) was recorded under T_2. The data on interaction effect between year (Y), year × treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) on DTPA- extractable Mn contents were found.

Higher Nitrogen application rates in the treatments of 50% and 100% soil applied urea as compared to the treatments of 25% application rates resulted in significant increase in available micronutrients (Cu, Fe, and Mn). The results of this study are also consistent with the findings of Nijjar (1985), Kulandaivel et al. (2004) and Keram et al. (2012). Similarly, Sharma et al. (2016) reported that applying 50%, 100%, and 150% of the recommended N dose elevated the available Fe, Mn, Cu, B and Zn contents in the soil.

4.1.2 Effect of nano- nitrogen on leaf nutrient content of plant

4.1.2.1 Leaf Nitrogen

The data with respect to leaf nitrogen for 2022 and 2023 are cited in Table 4.6. The perusal of data showed that various treatments exerted a significant effect on leaf nitrogen during both the years of study.

It is evident from the data presented in Table 4.6 that during 2022 and 2023, significantly highest leaf nitrogen (3.12 % and 3.17 %) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_{10}. Whereas, significantly lowest leaf nitrogen (2.31 % and 2.36 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf nitrogen (3.15 %) being recorded under T_{11} which was statistically at par with treatments $T_{10.}$ Whereas, significantly lowest leaf nitrogen (2.34 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf nitrogen contents were found.

Gagne et al. (2019) reported that foliar nitrogen application in the form of nanoparticles is a practical and sustainable approach, capable of reducing nitrogen losses to the environment. Nanoparticles are able to move through all types of plant tissues, utilizing both stomatal and cuticular pathways, with minimal nitrogen loss through washing, as observed by Larue et al. (2014). In the present experiment, apple trees fertilized with 50% soil applied urea experienced an optimum nitrogen supply from soil coupled with foliar nano-nitrogen sprays which consequently enhanced accumulation of N in leaves. An increase in nitrogen supply to the plant leads to greater nitrogen uptake in the leaves, attributed to the efficient translocation of elevated nitrogen concentrations from the roots to other plant parts (Walsch et al. 1989; Singh 1992 and Amiri et al. 2008). The results obtained are supported by the findings of Vishekaii et al. (2021) who noticed a substantial rise in leaf N (1.67 and 2.04%) with foliar application of nano-chelated nitrogen fertilizer in olive orchards. Foliar nitrogen fertilizer containing nanoparticles injection at 0.50 g N/l enhanced leaf N concentrations in pomegranate fruit by 2.13% and 2.04%, respectively, over two years (Davarpanah et al. 2017). Additionally, Neilsen et al. (1984) reported that nitrogen treatments significantly increased leaf N concentrations in apple trees.

4.1.2.2 Leaf Phosphorus

The data with respect to leaf phosphorus for 2022 and 2023 are cited in Table 4.6. The perusal of data showed that various treatments exerted a non- significant effect on leaf phosphorus during both the years of study.

It is evident from the data presented in Table 4.6 that during 2022 and 2023, highest leaf phosphorus (0.27 % and 0.28 %) was recorded under T_{11} (Soil application of 50% RDN +nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest leaf phosphorus (0.21 % and 0.23 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf phosphorus (0.28 %) being recorded under T_{11}. Whereas, significantly lowest leaf phosphorus (0.22 %) was recorded under T_2. The data on year (Y) and interaction (Y×T) were found to be non- significant. However, significant effects of treatment (T) on leaf phosphorus contents were found.

Table 4.6: Effect of graded levels of N and nano-N on leaf nitrogen, phosphorus and potassium of apple

Treatment Code	**Leaf N (%)**			**Leaf P (%)**			**Leaf K (%)**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	2.72	2.79	2.75	0.25	0.26	0.26	1.60	1.64	1.62
T_2	2.31	2.36	2.34	0.21	0.23	0.22	1.55	1.58	1.57
T_3	2.33	2.38	2.35	0.23	0.24	0.24	1.58	1.63	1.61
T_4	2.47	2.52	2.50	0.22	0.23	0.23	1.67	1.71	1.69
T_5	2.50	2.59	2.55	0.23	0.24	0.24	1.70	1.75	1.73
T_6	2.76	2.83	2.80	0.25	0.26	0.26	1.58	1.62	1.60
T_7	2.79	2.85	2.82	0.25	0.26	0.26	1.59	1.64	1.61
T_8	2.94	3.01	2.98	0.26	0.27	0.27	1.61	1.65	1.63
T_9	2.95	3.03	2.99	0.27	0.28	0.27	1.68	1.72	1.70
T_{10}	3.08	3.14	3.11	0.26	0.27	0.26	1.69	1.73	1.71
T_{11}	3.12	3.17	3.15	0.27	0.28	0.28	1.71	1.75	1.73
Mean	2.72	2.78		0.24	0.25		1.63	1.67	
CD $_{(0.05)}$	0.13	0.13		NS	NS		0.10	0.10	
Year (Y):			0.04			NS			0.03
Treatment (T):			0.09			0.04			0.07
Y×T:			NS			NS			NS

The increase in leaf phosphorus (P) content may be attributed to elevated levels of phosphorus in the soil. This rise in phosphorus content can also be attributed to increased phosphorus mobilization activities, which improve the availability of otherwise sparingly soluble nutrient sources, as well as the action of ectoenzymes, leading to enhanced phosphate absorption (Dixon et al. 1985). The results are in consonance with findings of Abdel-Hak et al. (2018) who reported significant increases in leaf phosphorus (0.21 and 0.25%) with nano nitrogen fertilization in grape. Abd EL-Rahman and Abd-Elkarim (2022) also observed that by applying 80% RD of nitrogen as nano via foliar spray raised leaf phosphorus contents. Similar results have been reported by Al-Tayeb et al. (2022) in olive.

4.1.2.3 Leaf Potassium

The data with respect to leaf potassium for 2022 and 2023 are cited in Table 4.6. The perusal of data showed that various treatments exerted a significant effect on leaf potassium during both the years of study.

It is evident from the data presented in Table 4.6 that during 2022 and 2023, significantly highest leaf potassium (1.71 % and 1.75 %) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_4, T_5, T_8, T_9 and T_{10}. Whereas, significantly lowest leaf potassium (1.55 % and 1.58 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf potassium (1.73 %) being recorded under T_{11} which was statistically at par with treatments T_4, T_5, T_8, T_9 and $T_{10.}$ Whereas, significantly lowest leaf potassium (1.57 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf potassium contents were found.

Increased potassium levels in the soil were associated with higher potassium concentrations in the plant. This effect is likely due to the concentration gradient created between the potassium ions in the soil solution and those within the root, resulting from higher soil potassium applications, which ultimately enhances potassium absorption by the plant (Smith 1962). The results are supported by the findings of Shams (2019) who found that foliar application of nano urea at 150 mg l^{-1} resulted in the maximum potassium (2.22 and 2.40 g kg^{-1}) content in kohlrabi leaves/heads. Similar results have been reported by Abdel-Salam (2018) and Sharaf-Eldin et al. (2022) in lettuce Al- Jabri et al. (2020) in okra Hegab et al. (2018) in Salvia.

4.1.2.4 Leaf Calcium

The data with respect to leaf calcium for 2022 and 2023 are cited in Table 4.7. The perusal of data showed that various treatments exerted a non- significant effect on leaf calcium during both the years of study.

It is evident from the data presented in Table 4.7 that during 2022 and 2023, highest leaf calcium (2.72 % and 2.77 %) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest leaf calcium (2.49 % and 2.56 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf calcium (2.75 %) being recorded under T_{11}. Whereas, significantly lowest leaf calcium (2.52 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) on leaf calcium contents were found.

Table 4.7: Effect of graded levels of N and nano-N on leaf calcium, magnesium and sulphur of apple

Treatment Code	**Leaf Ca (%)**			**Leaf Mg (%)**			**Leaf S (%)**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
$\mathbf{T_1}$	2.52	2.56	2.54	0.44	0.47	0.45	0.64	0.68	0.66
$\mathbf{T_2}$	2.49	2.56	2.52	0.37	0.42	0.40	0.58	0.62	0.60
$\mathbf{T_3}$	2.57	2.63	2.60	0.42	0.45	0.43	0.63	0.66	0.65
$\mathbf{T_4}$	2.64	2.71	2.67	0.40	0.43	0.42	0.62	0.66	0.64
$\mathbf{T_5}$	2.60	2.67	2.63	0.43	0.47	0.45	0.66	0.70	0.68
$\mathbf{T_6}$	2.54	2.59	2.56	0.39	0.42	0.40	0.60	0.63	0.61
$\mathbf{T_7}$	2.52	2.59	2.56	0.41	0.44	0.43	0.63	0.68	0.66
$\mathbf{T_8}$	2.58	2.64	2.61	0.46	0.50	0.48	0.68	0.73	0.71
$\mathbf{T_9}$	2.67	2.71	2.69	0.50	0.52	0.51	0.70	0.74	0.72
$\mathbf{T_{10}}$	2.61	2.67	2.64	0.48	0.52	0.50	0.68	0.72	0.70
$\mathbf{T_{11}}$	2.72	2.77	2.75	0.51	0.55	0.53	0.71	0.74	0.73
Mean	2.58	2.64		0.43	0.47		0.64	0.68	
CD $_{(0.05)}$	NS	NS		0.19	0.19		NS	NS	
Year (Y):			0.06			0.03			0.03
Treatment (T):			0.13			0.06			0.06
Y×T:			NS			NS			NS

4.1.2.5 Leaf Magnesium

The data with respect to leaf magnesium for 2022 and 2023 are cited in Table 4.7. The perusal of data showed that various treatments exerted a non- significant effect on leaf magnesium during both the years of study.

It is evident from the data presented in Table 4.7 that during 2022 and 2023, highest leaf magnesium (0.51 % and 0.55 %) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest leaf magnesium (0.37 % and 0.42 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf magnesium (0.53 %) being recorded under T_{11}. Whereas, significantly lowest leaf magnesium (0.40 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf magnesium contents were found.

4.1.2.6 Leaf Sulphur

The data with respect to leaf sulphur for 2022 and 2023 are cited in Table 4.7. The perusal of data showed that various treatments exerted a non- significant effect on leaf sulphur during both the years of study.

It is evident from the data presented in Table 4.7 that during 2022 and 2023, highest leaf sulphur (0.71 % and 0.74 %) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest leaf sulphur (0.58 % and 0.62 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf sulphur (0.73 %) being recorded under T_{11}. Whereas, significantly lowest leaf sulphur (0.60 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf magnesium contents were found.

4.1.2.7 Leaf Iron

The data with respect to leaf iron for 2022 and 2023 are cited in Table 4.8. The perusal of data showed that various treatments exerted a non- significant effect on leaf iron during both the years of study.

It is evident from the data presented in Table 4.8 that during 2022 and 2023, highest leaf iron (228.14 ppm and 231.01 ppm) was recorded under T_9 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest leaf iron (219.25 ppm and 223.85 ppm) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with highest leaf iron (229.57 ppm) being recorded under T_9. Whereas, lowest leaf iron (221.55 ppm) was recorded under T_2. The data on interaction effect between treatment (T) and interaction (Y×T) were found to be non- significant. However, significant effects of year (Y) on leaf iron contents were found.

Table 4.8: Effect of graded levels of N and nano-N on leaf iron and copper of apple

Treatment Code	Leaf Fe (ppm)			Leaf Cu (ppm)		
	2022	2023	Pooled	2022	2023	Pooled
T_1	224.11	228.54	226.32	14.51	14.66	14.59
T_2	219.25	223.85	221.55	14.20	14.29	14.24
T_3	223.06	226.86	224.96	14.48	14.60	14.54
T_4	222.08	226.25	224.17	14.40	14.49	14.44
T_5	224.44	228.27	226.36	14.55	14.64	14.60
T_6	220.94	224.74	222.84	14.33	14.42	14.37
T_7	225.01	228.49	226.75	14.50	14.59	14.54
T_8	226.45	229.30	227.88	14.70	14.81	14.76
T_9	228.14	231.01	229.57	14.97	15.07	15.02
T_{10}	223.74	227.81	225.77	14.84	14.94	14.89
T_{11}	228.10	230.88	229.49	14.99	15.11	15.05
Mean	224.12	227.81		14.58	14.69	
CD $_{(0.05)}$	NS	NS		NS	NS	
Year (Y):			3.31			NS
Treatment (T):			NS			0.36
Y×T:			NS			NS

4.1.2.8 Leaf Copper

The data with respect to leaf copper for 2022 and 2023 are cited in Table 4.8. The perusal of data showed that various treatments exerted a non- significant effect on leaf copper during both the years of study.

It is evident from the data presented in Table 4.8 that during 2022 and 2023, highest leaf copper (14.99 ppm and 15.11 ppm) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest leaf copper (14.20 ppm and 14.29 ppm) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf copper (15.05 ppm) being recorded under T_{11}. Whereas, significantly lowest leaf copper (14.24 ppm) was recorded under T_2. The data on year (Y) and interaction (Y×T) were found to be non- significant. However, significant effects of treatment (T) on leaf copper contents were found.

4.1.2.9 Leaf Zinc

The data with respect to leaf zinc for 2022 and 2023 are cited in Table 4.9. The perusal of data showed that various treatments exerted a non- significant effect on leaf zinc during both the years of study.

It is evident from the data presented in Table 4.9 that during 2022 and 2023, highest leaf zinc (32.83 ppm and 33.78 ppm) content was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage). Whereas, lowest leaf zinc (25.28 ppm and 26.07 ppm) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf zinc (33.30 ppm) being recorded under T_{11}. Whereas, significantly lowest leaf zinc (25.67 ppm) was recorded under T_2. The data on year (Y) and interaction (Y×T) were found to be non- significant. However, significant effects of treatment (T) on leaf zinc contents were found.

4.1.2.10 Leaf Manganese

The data with respect to leaf manganese for 2022 and 2023 are cited in Table 4.9. The perusal of data showed that various treatments exerted a significant effect on leaf manganese during both the years of study.

It is evident from the data presented in Table 4.9 that during 2022 and 2023, significantly highest leaf manganese (78.62 ppm and 80.21 ppm) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_8, T_9 and T_{10}. Whereas, significantly lowest leaf manganese (66.13 ppm and 68.01 ppm) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf manganese (79.42 ppm) being recorded under T_{11} which was statistically at par with treatments T_9 and $T_{10.}$ Whereas, significantly lowest leaf manganese (67.07 ppm) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf manganese contents were found.

Table 4.9: Effect of graded levels of N and nano-N on leaf zinc and manganese of apple

Treatment Code	Leaf Zn (ppm)			Leaf Mn (ppm)		
	2022	2023	Pooled	2022	2023	Pooled
T_1	29.80	30.85	30.33	74.47	76.58	75.52
T_2	25.28	26.07	25.67	66.13	68.01	67.07
T_3	27.38	28.31	27.85	68.04	69.90	68.97
T_4	25.86	27.16	26.51	68.12	69.92	69.02
T_5	27.17	29.00	28.08	71.82	72.58	72.20
T_6	28.50	29.77	29.14	72.88	74.09	73.48
T_7	28.84	30.13	29.48	74.89	76.26	75.58
T_8	29.44	30.72	30.08	75.24	76.50	75.87
T_9	32.38	33.74	33.06	76.19	77.50	76.84
T_{10}	30.68	32.66	31.67	78.55	78.83	78.69
T_{11}	32.83	33.78	33.30	78.62	80.21	79.42
Mean	28.92	30.19		73.17	74.58	
CD $_{(0.05)}$	NS	NS		3.71	3.95	
Year (Y):			NS			1.10
Treatment (T):			3.93			2.57
Y×T:			NS			NS

The elevated levels of micronutrients observed may be due to both higher soil concentrations of these nutrients and the synergistic effects of nitrogen (N) on their uptake. These findings are consistent with those of Abdel-Hak et al. (2018), who reported significantly higher leaf concentrations of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), iron (Fe), zinc (Zn) and manganese (Mn) in 'Flame Seedless' grapes with the application of 80% N combined with 0.6% carbon nanotubes. Similar results were reported by Uçgun and Altındal (2021) in sweet cherry trees, where increased nitrogen levels had a non-significant effect on leaf calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu) and zinc (Zn). However, manganese (Mn) exhibited an increasing trend with higher nitrogen doses.

4.1.3 Effect of nano- nitrogen on plant growth parameters

4.1.3.1 Increase in tree height

The data with respect to increase in tree height for 2022 and 2023 are cited in Table 4.10. The perusal of data showed that various treatments exerted a significant effect on increase in tree height during both the years of study.

It is evident from the data presented in Table 4.10 that during 2022 and 2023, significantly highest increase in tree height (6.96 % and 7.14 %) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9. Whereas, significantly least increase in tree height (6.33 % and 6.45 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest increase in tree height (7.05 %) being recorded under T_8 which was statistically at par with treatments T_9. Whereas, significantly least increase in tree height (6.39 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in tree height were found.

4.1.3.2 Increase in tree spread

The data with respect to increase in tree spread for 2022 and 2023 are cited in Table 4.10. The perusal of data showed that various treatments exerted a significant effect on increase in tree spread during both the years of study.

It is evident from the data presented in Table 4.10 that during 2022 and 2023, significantly highest increase in tree spread (8.16 % and 8.22 %) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9. Whereas, significantly least increase in tree spread (7.49 % and 7.54 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest increase in tree spread (8.19 %) being recorded under T_8 which was statistically at par with treatments T_9. Whereas, significantly least increase in tree spread (7.52 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in tree spread were found.

Table 4.10: Effect of graded levels of N and nano-N on increase in tree height, spread and girth of apple

Treatment Code	Inc. in tree height (%)			Inc. in tree spread (%)			Inc. in trunk girth (%)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	6.64	6.73	6.69	7.77	7.96	7.86	2.65	2.70	2.67
T_2	6.33	6.45	6.39	7.49	7.54	7.52	2.41	2.46	2.43
T_3	6.39	6.42	6.40	7.56	7.60	7.58	2.48	2.53	2.50
T_4	6.46	6.54	6.50	7.60	7.69	7.65	2.47	2.53	2.50
T_5	6.49	6.59	6.54	7.66	7.76	7.71	2.55	2.54	2.55
T_6	6.67	6.75	6.71	7.83	7.91	7.87	2.61	2.63	2.62
T_7	6.72	6.78	6.75	7.89	8.00	7.94	2.68	2.72	2.70
T_8	6.96	7.14	7.05	8.16	8.22	8.19	2.82	2.88	2.85
T_9	6.89	6.97	6.93	8.09	8.19	8.14	2.78	2.84	2.81
T_{10}	6.82	6.90	6.86	8.00	8.11	8.05	2.74	2.79	2.77
T_{11}	6.77	6.84	6.81	7.96	8.05	8.00	2.67	2.73	2.70
Mean	6.64	6.73		7.81	7.91		2.62	2.66	
CD $_{(0.05)}$	0.20	0.22		0.14	0.11		0.12	0.11	
Year (Y):			0.06			0.04			0.03
Treatment (T):			0.15			0.09			0.08
Y×T:			NS			NS			NS

4.1.3.3 Increase in trunk girth

The data with respect to increase in trunk girth for 2022 and 2023 are cited in Table 4.10. The perusal of data showed that various treatments exerted a significant effect on increase in trunk girth during both the years of study.

It is evident from the data presented in Table 4.10 that during 2022 and 2023, significantly highest increase in trunk girth (2.82 % and 2.88 %) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9 and T_{10}. Whereas, significantly least increase in trunk girth (2.41 % and 2.46 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest increase in trunk girth (2.85 %) being recorded under T_8 which was statistically at par with treatments T_9 and T_{10}. Whereas, significantly least increase in trunk girth (2.43 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in trunk girth were found.

In the treatments where higher nitrogen dosages were applied through soil and foliar application of nano-urea, increase in tree height was observed which can be explained by nitrogen's role in promoting tissue growth and facilitating the synthesis of proteins and amino acids- essential components required for cell development and tissue expansion. The observed increase in vegetative growth is also attributable to the enhanced rate and efficiency of nutrient uptake from foliar application of nano urea, which act synergistically with soil-applied fertilizers. These findings are consistent with those reported by Klein et al. (2006); Imam and Al-Brifkany (2010).

Bi et al. (2003) also reported that foliar application of nano-nitrogen stimulates the synthesis of auxins, promoting cell division and elongation, which leads to increased vegetative growth. Bhatti et al. (2023) observed maximum incremental plant height and plant spread with treatments of 80-100% RDN+0.6% nano-urea in case of guava. The increase in tree girth may be attributed to the enlarged size and higher number of cells induced by nitrogen application. These findings are consistent with those reported by Fallahi et al. (2002): Kumar and Chandel (2004).

4.1.3.4 Increase in tree volume

The data with respect to increase in tree volume for 2022 and 2023 are cited in Table 4.11. The perusal of data showed that various treatments exerted a significant effect on increase in tree volume during both the years of study.

It is evident from the data presented in Table 4.11 that during 2022 and 2023, significantly highest increase in tree volume (4.44 m^3 and 5.22 m^3) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9, T_{10} and T_1. Whereas, significantly least increase in tree volume (3.78 m^3 and 4.50 m^3) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest increase in tree volume (4.83 m^3) being recorded under T_8 which was statistically at par with treatments T_9 and T_{10}. Whereas, significantly least increase in tree volume (4.14 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in tree volume were found.

Table 4.11: Effect of graded levels of N and nano-N on tree volume, annual shoot growth and leaf area of apple

Treatment Code	Inc. in tree volume (m^3)			Annual shoot growth (cm)			Leaf area (cm^2)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	4.19	4.98	4.58	27.37	30.38	28.88	29.66	30.24	29.95
T_2	3.78	4.50	4.14	22.76	26.01	24.39	26.49	27.12	26.81
T_3	3.85	4.55	4.20	23.08	26.27	24.67	26.57	27.28	26.92
T_4	3.91	4.61	4.26	23.24	26.30	24.77	27.34	27.13	27.24
T_5	3.97	4.69	4.33	24.25	27.46	25.86	27.74	28.42	28.08
T_6	4.13	4.80	4.47	27.06	30.13	28.59	28.74	29.48	29.11
T_7	4.19	4.90	4.55	27.93	30.96	29.45	29.63	30.49	30.06
T_8	4.44	5.22	4.83	30.14	33.36	31.75	31.94	32.87	32.40
T_9	4.37	5.12	4.74	29.62	32.84	31.23	31.28	32.23	31.76
T_{10}	4.33	5.09	4.71	28.75	31.89	30.32	30.65	31.71	31.18
T_{11}	4.28	5.02	4.65	28.33	31.42	29.88	30.94	31.94	31.44
Mean	4.12	4.86		26.59	29.72		29.18	29.90	
CD $_{(0.05)}$	0.16	0.18		4.47	4.40		1.20	1.22	
Year (Y):			0.05			1.27			0.35
Treatment (T):			0.12			2.97			0.82
Y×T:			NS			NS			NS

4.1.3.5 Annual shoot growth

The data with respect to annual shoot growth for 2022 and 2023 are cited in Table 4.11. The perusal of data showed that various treatments exerted a significant effect on annual shoot growth during both the years of study.

It is evident from the data presented in Table 4.11 that during 2022 and 2023, significantly highest annual shoot growth (30.14 cm and 33.36 cm) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_1, T_6, T_7, T_9, T_{10} and T_{11}. Whereas, significantly least increase in annual shoot growth (22.79 cm and 26.01 cm) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest annual shoot growth (31.75 cm) being recorded under T_8 which was statistically at par with treatments T_1, T_7, T_9, T_{10} and T_{11}. Whereas, significantly least increase in annual shoot growth (24.39 cm) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on annual shoot growth were found.

4.1.3.6 Leaf area

The data with respect to leaf area for 2022 and 2023 are cited in Table 4.11. The perusal of data showed that various treatments exerted a significant effect on leaf area during both the years of study.

It is evident from the data presented in Table 4.11 that during 2022 and 2023, significantly highest leaf area (31.94 cm^2 and 32.87 cm^2) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9 and T_{11}. Whereas, significantly least increase in leaf area (26.49 cm^2 and 27.12 cm^2) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf area (32.40 cm^2) being recorded under T_8 which was statistically at par with treatments T_9. Whereas, significantly least increase in leaf area (26.81 cm^2) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in leaf area were found.

The superior vegetative growth observed with combined soil (urea) and foliar applications of nano urea was likely due to the dual benefits of nitrogen absorption and translocation via xylem and phloem. Increase in tree volume and annual shoot growth might be attributed to enhanced nutrient uptake and utilization and nitrogen's role in promoting cell elongation and division. Comparable results were observed by Awasthi and Karkara (1979), Ernani et al. (2000), Rackso et al. (2005), Widmer et al. (2006), Asma et al. (2007) and Ehsan (2007). Increments in Leaf area might have resulted from nitrogen’s direct effect on leaf expansion, which boosts net photosynthesis and promotes leaf growth (Marshner 1995).

4.1.4 Effect of nano- nitrogen on fruit quality attributes

4.1.4.1 Fruit length

The data with respect to fruit length for 2022 and 2023 are cited in Table 4.12. The perusal of data showed that various treatments exerted a significant effect on fruit length during both the years of study.

It is evident from the data presented in Table 4.12 that during 2022 and 2023, significantly highest fruit length (65.33 mm and 70.22 mm) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9 and T_{10}. Whereas, significantly least increase fruit length (51.25mm and 56.70 mm) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest fruit length (67.77 mm) being recorded under T_8 which was statistically at par with treatments T_9 and T_{10}. Whereas, significantly least increase in fruit length (53.97 mm) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in fruit length were found.

4.1.4.2 Fruit diameter

The data with respect to fruit diameter for 2022 and 2023 are cited in Table 4.12. The perusal of data showed that various treatments exerted a significant effect on fruit diameter during both the years of study.

It is evident from the data presented in Table 4.12 that during 2022 and 2023, significantly highest fruit diameter (70.30 mm and 76.23 mm) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9 and T_{10}. Whereas, significantly least increase fruit diameter (56.54 mm and 60.74 mm) was recorded under T_3 (Soil application of 25% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage).

Pooled analysis of the data also revealed same trend with significantly highest fruit diameter (73.27 mm) being recorded under T_8 which was statistically at par with treatments T_9. Whereas, significantly least increase in fruit diameter (58.64 mm) was recorded under T_3. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in fruit diameter were found.

Table 4.12: Effect of graded levels of N and nano-N on fruit length, diameter, and weight of apple

Treatment Code	Fruit length (mm)			Fruit diameter (mm)			Fruit weight (g)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	60.60	65.17	62.89	65.22	71.22	68.22	137.68	142.54	140.11
T_2	51.25	56.70	53.97	57.68	61.82	59.75	125.12	131.25	128.19
T_3	52.66	57.70	55.18	56.54	60.74	58.64	126.10	132.04	129.07
T_4	54.00	59.35	56.68	59.67	65.10	62.38	126.82	136.54	131.68
T_5	55.25	60.51	57.88	60.45	65.78	63.11	128.35	139.49	133.92
T_6	59.69	63.25	61.47	64.80	69.36	67.08	136.32	139.80	138.06
T_7	60.20	64.39	62.30	65.87	69.74	67.81	136.71	142.43	139.57
T_8	65.33	70.22	67.77	70.30	76.23	73.27	144.32	150.64	147.48
T_9	63.28	69.35	66.32	68.31	74.29	71.30	143.69	149.11	146.40
T_{10}	62.66	68.93	65.80	68.29	74.22	71.26	141.53	147.83	144.68
T_{11}	60.61	65.93	63.27	67.23	72.61	69.92	139.34	147.53	143.44
Mean	58.68	63.77		64.03	69.19		135.08	141.74	
CD $_{(0.05)}$	3.25	3.09		3.09	2.79		6.71	6.69	
Year (Y):			0.91			0.85			1.93
Treatment (T):			2.14			1.99			4.58
Y×T:			NS			NS			NS

4.1.4.3 Fruit weight

The data with respect to fruit weight for 2022 and 2023 are cited in Table 4.12. The perusal of data showed that various treatments exerted a significant effect on fruit weight during both the years of study.

It is evident from the data presented in Table 4.12 that during 2022 and 2023, significantly highest fruit weight (144.32 g and 150.64 g) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9, T_{10} and T_{11}. Whereas, significantly least increase fruit weight (125.12 g and 131.25 g) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest fruit weight (147.48 g) being recorded under T_8 which was statistically at par with treatments T_9, T_{10} and T_{11}. Whereas, significantly least increase in fruit weight (128.19 g) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in fruit weight were found.

The observed maximum fruit length and diameter might be attributed to the increase in cell size and number following nitrogen application. These findings are consistent with the research conducted by Wargo et al. (2003), Rackso et al. (2005), Amiri et al. (2008) and Iqbal et al. (2012). The observed increase in fruit weight following nitrogen application might be attributed to a higher number of cells per fruit. Young fruitlets require elevated nitrogen concentrations in the tissues to support protein synthesis, which is essential for active metabolism and rapid cell division. This need is met when nitrogen levels in the tree are optimal. These findings are consistent with the research of Drake et al. (2002) and Imam and Al-Brifkany (2010). Nano fertilizers slow the release of nutrients and extend the duration of their effectiveness, thereby making nutrients available to plants for a longer period. This prolonged availability can lead to increased fruit size and weight. Specifically, the application of nano-nitrogen during critical growth stages enhances nitrogen penetration, leading to improved absorption of water and other nutrients by the treated fruits, which in turn increases pulp weight (Al-Mobark 2014). During the cell division stage, higher amounts of carbohydrates and nitrogen are essential for rapid cell division in fruitlet tissues (Xia et al. 2009). Davarpanah et al. (2017) reported increased fruit weight in pomegranate with foliar applications of urea and nano-nitrogen.

4.1.4.4 Fruit volume

The data with respect to fruit volume for 2022 and 2023 are cited in Table 4.13. The perusal of data showed that various treatments exerted a significant effect on fruit volume during both the years of study.

It is evident from the data presented in Table 4.13 that during 2022 and 2023, significantly highest fruit volume (159.58 cc and 179.99 cc) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_1, T_9, T_{10} and T_{11}. Whereas, significantly least increase in fruit volume (139.67 cc and 159.87 cc) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest fruit volume (169.79 cc) being recorded under T_8 which was statistically at par with treatments T_9, T_{10} and T_{11}. Whereas, significantly least increase in fruit volume (149.77 cc) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in fruit volume were found.

Table 4.13: Effect of graded levels of N and nano-N on fruit volume, fruit firmness and fruit color of apple

Treatment Code	**Fruit volume (cc)**			**Fruit firmness (kg cm^{-2})**			**Fruit color**	
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**
T_1	153.63	173.41	163.52	8.38	8.73	8.56	Red Group 46 B	Red Group 46 B
T_2	139.67	159.87	149.77	8.07	8.37	8.22	Red Group 46 B	Red Group 46 B
T_3	140.97	160.21	150.59	8.27	8.51	8.39	Red Group 46 B	Red Group 46 B
T_4	143.12	162.00	152.56	8.16	8.49	8.33	Red Group 46 B	Red Group 46 B
T_5	144.62	165.09	154.85	8.11	8.38	8.25	Red Group 46 B	Red Group 46 B
T_6	151.18	172.44	161.81	8.53	8.77	8.65	Red Group 46 B	Red Group 46 B
T_7	152.24	173.07	162.66	8.51	8.69	8.60	Red Group 46 B	Red Group 46 B
T_8	159.58	179.99	169.79	8.88	9.28	9.08	Red Group 46 B	Red Group 46 B
T_9	159.29	178.93	169.11	8.71	9.09	8.90	Red Group 46 B	Red Group 46 B
T_{10}	157.31	178.52	167.91	8.65	9.04	8.85	Red Group 46 B	Red Group 46 B
T_{11}	156.33	176.99	166.66	8.51	8.81	8.66	Red Group 46 B	Red Group 46 B
Mean	150.72	170.95		8.43	8.74			
CD $_{(0.05)}$	6.99	7.90		0.14	0.15			
Year (Y):			2.14			0.04		
Treatment (T):			5.02			0.10		
Y×T:			NS			NS		

4.1.4.5 Fruit firmness

The data with respect to fruit firmness for 2022 and 2023 are cited in Table 4.13. The perusal of data showed that various treatments exerted a significant effect on fruit firmness during both the years of study.

It is evident from the data presented in Table 4.13 that during 2022 and 2023, significantly highest fruit firmness (8.88 kg cm^{-2} and 9.28 kg cm^{-2}) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage). Whereas, significantly least increase in fruit firmness (8.07 kg cm^{-2} and 8.37 kg cm^{-2}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest fruit firmness (9.08 kg cm^{-2}) being recorded under T_8. Whereas, significantly least increase in fruit firmness (8.23 kg cm^{-2}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in fruit firmness were found.

4.1.4.6 Fruit color

The data cited in Table 4.13, Plate 2a and Plate 2b revealed that various treatments did not show any notable effect on fruit color during both the years of study.

During first year of study in 2022, Red Group fruit color grade 46 (B) was observed under all the treatments. Whereas, during 2nd year of the study similar results were reported among all treatments.

The increase in fruit volume in the treatments of higher soil applied urea and foliar applied nano urea doses can be attributed to the optimum nitrogen supply, which led to fruits with the greatest length and diameter, and consequently, the largest fruit volume. These results are consistent with the findings of David and Cahoon (1987) for apples and Dar (2009) for pears. The increase in fruit firmness may be linked to the enhanced levels of calcium in the leaves primarily due to foliar application of nano-urea. Calcium is crucial for the synthesis of pectic substances that improve fruit firmness. These findings align with those of Tuckey (1983) and Nijjer (1985) who reported that the beneficial effects of calcium applications on fruit firmness could be attributed to the physiological role of calcium, which plays a binding role in the complex polysaccharides and proteins forming the cell wall. The resulted in increased fruit firmness, which can be attributed to enhanced calcium (Ca) concentration.

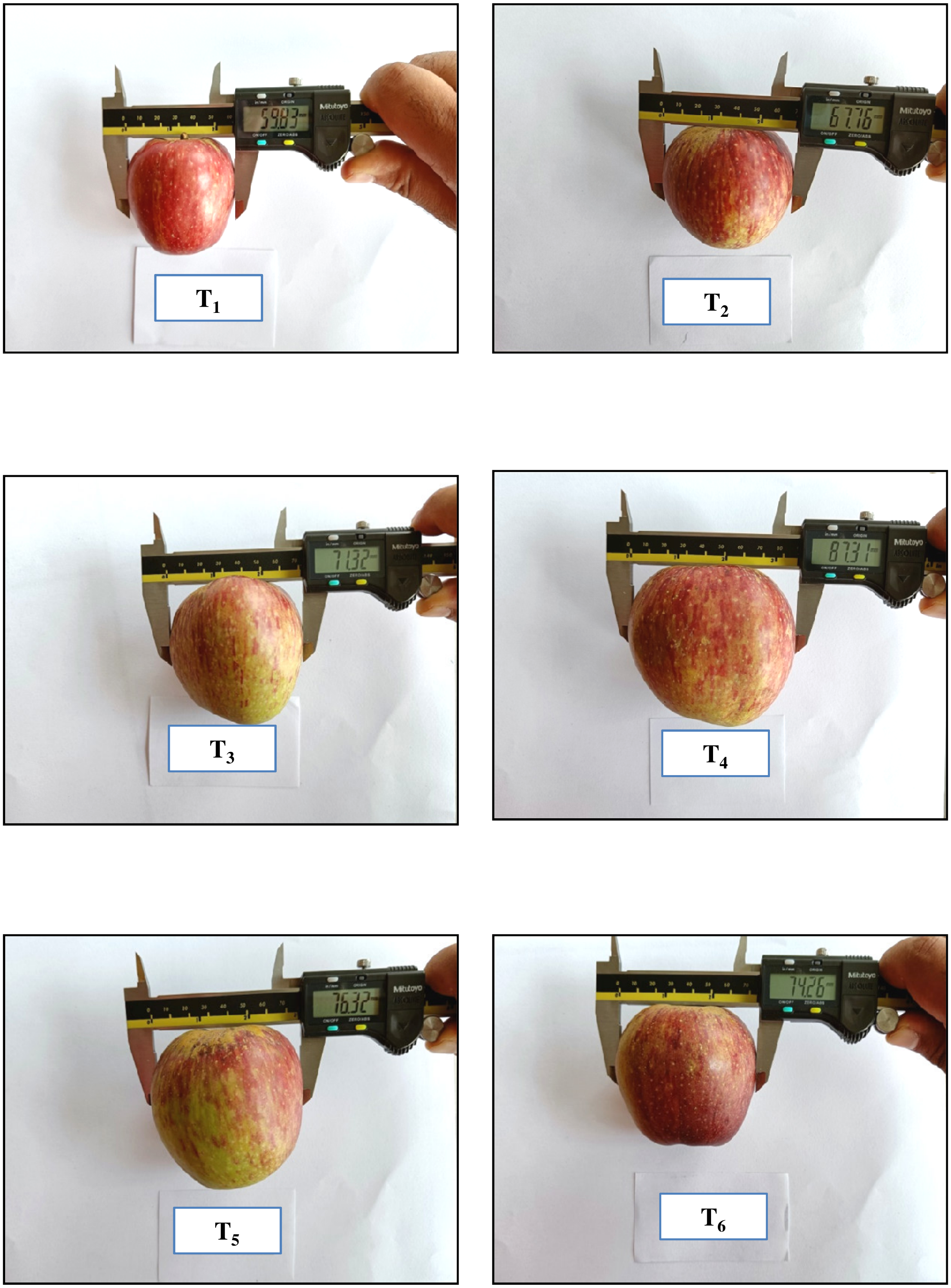
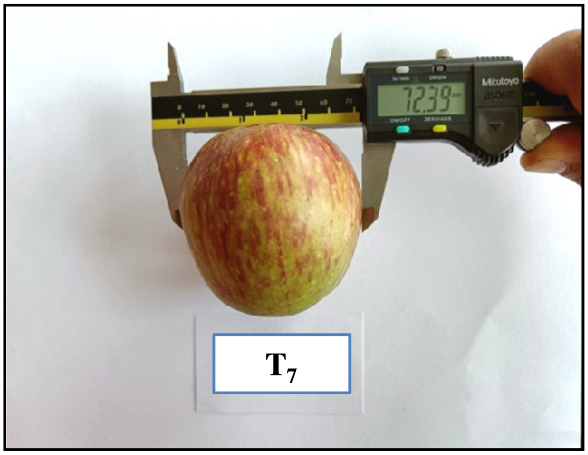
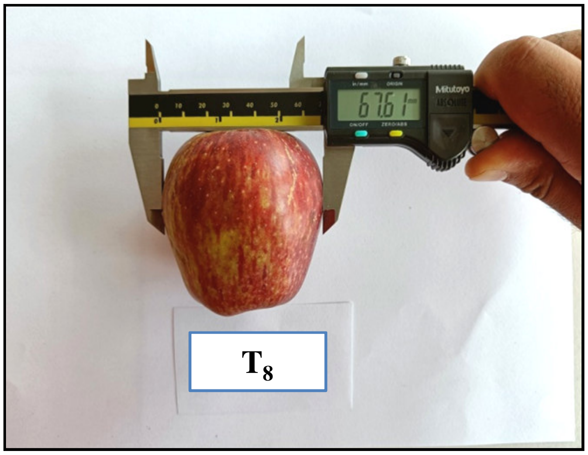


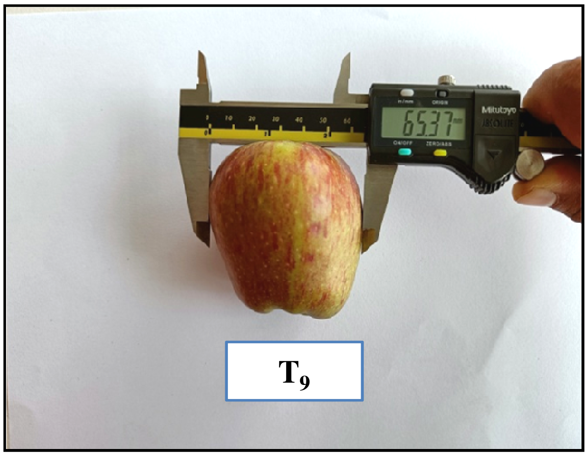
Plate 2a: Comparison of fruit diameter and fruit color of different treatments



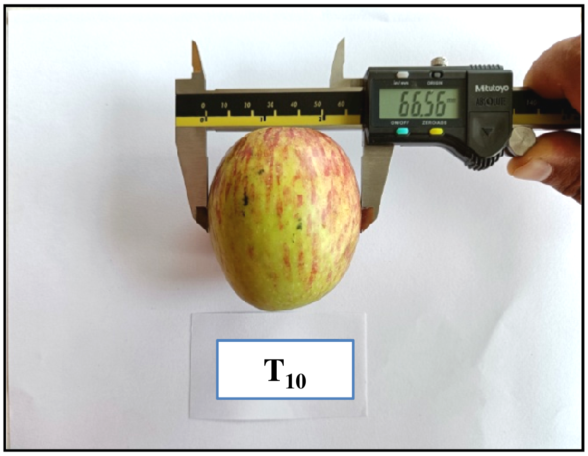
T_7



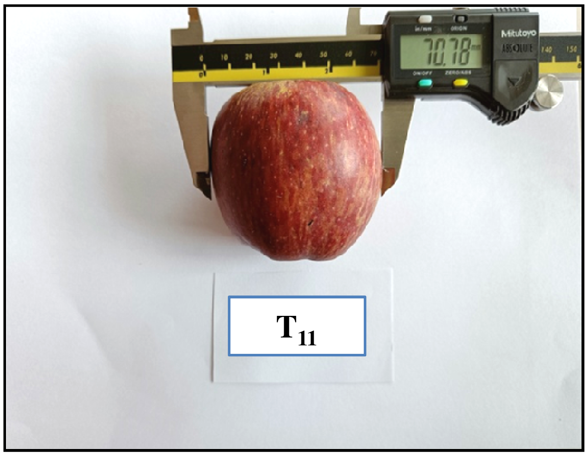
T_8



T_9



T_{10}



T_{11}

Plate 2b: Comparison of fruit diameter and fruit color of different treatments

4.1.6.7 Total soluble solids (TSS)

The data with respect to fruit TSS for 2022 and 2023 are cited in Table 4.14. The perusal of data showed that various treatments exerted a significant effect on fruit TSS during both the years of study.

It is evident from the data presented in Table 4.14 that during 2022 and 2023, significantly highest TSS (11.06 °B and 11.14 °B) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9. Whereas, significantly lowest TSS (10.27 °B and 10.38 °B) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest TSS (11.10 °B) being recorded under T_8. Whereas, significantly lowest TSS (10.33 °B) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in fruit TSS were found.

The observed increase in total soluble solids (TSS) following nitrogen application may be due to nitrogen's crucial roles in chloroplast structure, CO_2 assimilation and the activation of enzymes involved in photosynthesis. These findings are consistent with research on various fruit crops, including mango (Sarker and Rahim 2013) and persimmon (Choi et al. 2013).

4.1.6.8 Titratable acidity

The data with respect to titratable acidity for 2022 and 2023 are cited in Table 4.14. The perusal of data showed that various treatments exerted a significant effect on titratable acidity during both the years of study.

It is evident from the data presented in Table 4.14 that during 2022 and 2023, significantly lowest titratable acidity (0.23 % and 0.21 %) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage. Whereas, significantly highest titratable acidity (0.36 % and 0.33 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_3, T_4 and T_5.

Pooled analysis of the data also revealed same trend with significantly highest titratable acidity (0.34 %) being recorded under T_2, which was statistically at par with T_3, T_4 and T_5. Whereas, significantly lowest titratable acidity (0.22 %) was recorded under T_8. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in titratable acidity were found.

Table 4.14: Effect of graded levels of N and nano-N on total soluble solids, titratable acidity and TSS: acid ratio of apple

Treatment Code	TSS (°B)			Titratable acidity (%)			TSS: acid ratio		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	10.69	10.78	10.74	0.28	0.25	0.26	39.08	43.90	41.49
T_2	10.27	10.38	10.33	0.36	0.33	0.34	28.90	31.93	30.42
T_3	10.59	10.69	10.64	0.30	0.27	0.29	36.83	44.02	40.43
T_4	10.53	10.64	10.58	0.31	0.28	0.30	33.80	37.83	35.82
T_5	10.32	10.43	10.38	0.34	0.32	0.33	31.15	33.55	32.35
T_6	10.71	10.82	10.76	0.26	0.24	0.25	42.53	46.75	44.64
T_7	10.65	10.76	10.71	0.28	0.26	0.27	39.51	43.31	41.41
T_8	11.06	11.14	11.10	0.23	0.21	0.22	47.92	55.99	51.96
T_9	11.01	11.10	11.06	0.24	0.22	0.23	46.33	52.14	49.24
T_{10}	10.91	11.05	10.98	0.24	0.22	0.23	45.45	50.33	47.89
T_{11}	10.80	10.94	10.87	0.26	0.23	0.24	42.53	49.44	45.98
Mean	10.68	10.79		0.28	0.25		39.45	44.47	
CD $_{(0.05)}$	0.14	0.14		0.07	0.07		10.92	14.18	
Year (Y):			0.04			0.02			3.62
Treatment (T):			0.10			0.05			8.49
Y×T:			NS			NS			NS

4.1.6.9 TSS: acid ratio

The data with respect to fruit TSS: acid ratio for 2022 and 2023 are cited in Table 4.14. The perusal of data showed that various treatments exerted a significant effect on fruit TSS: acid ratio during both the years of study.

It is evident from the data presented in Table 4.14 that during 2022 and 2023, significantly highest TSS: acid ratio (47.92 and 55.99) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_1, T_6, T_7, T_9, T_{10} and T_{11}. Whereas, significantly lowest TSS: acid ratio (28.90 and 31.93) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest TSS: acid ratio (51.96) being recorded under T_8, which was statistically at par with T_6, T_9, T_{10} and T_{11}. Whereas, significantly lowest TSS: acid ratio (30.42) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on TSS: acid ratio were found.

Increased nitrogen levels resulted in higher total soluble solids in the respective treatments. This effect may be due to optimal nitrogen improving the availability of assimilates as excessively high doses can lead to excessive vegetative growth, which consumes most of the metabolites and leaves insufficient amounts for fruit storage. These findings are consistent with those reported by El-Gazzar (2000), Nava et al. (2007) and Imam and Al-Brifkany (2010). Fruit acidity decreased with higher levels of nitrogen fertilizer application. This outcome aligns with the findings of Lazarove (1985), Hikasa et al. (1986), El-Morshedy (1997) and Naiema (2003), who observed decreased fruit acidity with higher nitrogen doses in apples. The highest TSS/acid ratios were achieved with nitrogen treatment, which produced the maximum total soluble solids (TSS) and the minimum fruit acidity. These findings are consistent with the results of Sharma et al. (2014).

4.1.6.10 Total Sugars

The data with respect to total sugars in fruits for 2022 and 2023 are cited in Table 4.15. The perusal of data showed that various treatments exerted a significant effect on total sugars in fruits during both the years of study.

It is evident from the data presented in Table 4.15 that during 2022 and 2023, significantly highest total sugars in fruits (10.71 % and 10.96 %) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage). Whereas, significantly lowest total sugars in fruits (9.98 % and 10.09 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage.

Pooled analysis of the data also revealed same trend with significantly highest total sugars in fruits (10.84 %) being recorded under T_8. Whereas, significantly lowest total sugars in fruits (10.04 %) was recorded under T_2. The data on effects of treatment (T) and year (Y) and their interaction (Y×T) were found to be significant on total sugars.

Table 4.15: Effect of graded levels of N and nano-N on total, reducing and non-reducing sugars content of apple

Treatment Code	**Total sugars (%)**			**Reducing sugars (%)**			**Non-reducing sugars (%)**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	10.44	10.71	10.57	6.73	6.79	6.76	3.51	3.72	3.62
T_2	9.98	10.09	10.04	6.36	6.41	6.38	3.43	3.49	3.46
T_3	10.19	10.33	10.26	6.52	6.58	6.55	3.47	3.56	3.52
T_4	10.12	10.25	10.19	6.47	6.52	6.50	3.46	3.54	3.50
T_5	10.06	10.18	10.12	6.42	6.47	6.45	3.45	3.52	3.49
T_6	10.41	10.64	10.52	6.68	6.73	6.71	3.54	3.71	3.62
T_7	10.35	10.56	10.46	6.63	6.68	6.65	3.53	3.69	3.61
T_8	10.71	10.96	10.84	6.87	6.92	6.90	3.65	3.82	3.74
T_9	10.62	10.86	10.74	6.82	6.86	6.84	3.61	3.80	3.70
T_{10}	10.57	10.79	10.68	6.79	6.83	6.81	3.59	3.75	3.67
T_{11}	10.48	10.71	10.60	6.73	6.78	6.76	3.56	3.74	3.65
Mean	10.35	10.55		6.63	6.68		3.52	3.66	
CD $_{(0.05)}$	0.08	0.05		0.04	0.05		0.04	0.02	
Year (Y):			0.02			0.01			0.01
Treatment (T):			0.05			0.03			0.02
Y×T:			0.07			NS			0.03

4.1.6.11 Reducing sugars

The data with respect to reducing sugars in fruits for 2022 and 2023 are cited in Table 4.15. The perusal of data showed that various treatments exerted a significant effect on reducing sugars in fruits during both the years of study.

It is evident from the data presented in Table 4.15 that during 2022 and 2023, significantly highest reducing sugars in fruits (6.87 % and 6.92 %) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage). Whereas, significantly lowest reducing sugars in fruits (6.36 % and 6.41 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest reducing sugars in fruits (6.90 %) being recorded under T_8. Whereas, significantly lowest reducing sugars in fruits (6.38 %) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on reducing sugars in fruits were found.

4.1.6.12 Non- reducing sugars

The data with respect to non- reducing sugars in fruits for 2022 and 2023 are cited in Table 4.15. The perusal of data showed that various treatments exerted a significant effect on non- reducing sugars in fruits during both the years of study.

It is evident from the data presented in Table 4.15 that during 2022 and 2023, significantly highest non- reducing sugars in fruits (3.65 % and 3.82 %) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with T_9. Whereas, significantly lowest non- reducing sugars in fruits (3.43 % and 3.49 %) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest non-reducing sugars in fruits (3.74 %) being recorded under T_8. Whereas, significantly lowest non- reducing sugars in fruits (3.46 %) was recorded under T_2. The data on effects of treatment (T) and year (Y) and their interaction (Y×T) were found to be significant on non-reducing sugars.

With higher soil applied and foliar rates of nitrogen application, the increase in sugar content can be attributed to enhanced photosynthetic production and elevated activity of the invertase enzyme, which facilitates the conversion of sucrose to reducing sugars (glucose and fructose), as well as the translocation of sucrose and the regulation of sugar flow from the leaves to the fruits (Shabana et al. 2006). A positive correlation between nitrogen (N) application and total fruit sugars has been reported in various fruit species (Singh et al. 2005; Abd El-Rhman and Shadia 2012).

The enhancement in growth characteristics was attributed primarily to nitrogen, which improved leaf physiology by increasing chlorophyll concentrations (Bi et al. 2003; Elhindi et al. 2016).

4.1.6.13 Anthocyanin content

The data with respect to anthocyanin content for 2022 and 2023 are cited in Table 4.16. The perusal of data showed that various treatments exerted a significant effect on anthocyanin content during both the years of study.

It is evident from the data presented in Table 4.16 that during 2022 and 2023, significantly highest anthocyanin content (12.74 mg/100 g and 15.79 mg/100 g) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with T_9 and T_{10}. Whereas, significantly lowest anthocyanin content (11.44 mg/100 g and 14.24 mg/100 g) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest anthocyanin content (14.27 mg/100 g) being recorded under T_8. Whereas, significantly lowest anthocyanin content (12.84 mg/100 g) was recorded under T_2. The data on effects of treatment (T) and year (Y) and their interaction (Y×T) were found to be significant on anthocyanin content.

Increased anthocyanin content was observed with nitrogen application, likely due to nitrogen's role in enhancing the activity of phenylalanine ammonia-lyase, an enzyme crucial for anthocyanin accumulation. These findings align with the results reported by Meheriuk et al. (1996), Dauggard and Grauslund (2000), Papp (2000) and Nava et al. (2007). The application of nano-nitrogen might have enhanced anthocyanin content, likely due to increased nitrogen supply to the fruits. Similarly, Delgado et al. (2006) reported elevated anthocyanin accumulation with moderate nitrogen levels in grapes. Nitrogen influences the expression of genes encoding enzymes involved in flavonoid and anthocyanin biosynthesis, thus playing a role in anthocyanin formation (Saure 1990).

4.1.5 Effect of nano- nitrogen on tree physiological and yield traits

4.1.5.1 Leaf chlorophyll content

The data with respect to leaf chlorophyll content for 2022 and 2023 are cited in Table 4.16. The perusal of data showed that various treatments exerted a significant effect on leaf chlorophyll content during both the years of study.

It is evident from the data presented in Table 4.16 that during 2022 and 2023, significantly highest leaf chlorophyll content (3.25 mg g^{-1} and 3.33 mg g^{-1}) was recorded under T_{11} (Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage), which was statistically at par with treatment T_9 and T_{10}. Whereas, significantly lowest leaf chlorophyll content (2.50 mg g^{-1} and 2.56 mg g^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest leaf chlorophyll content (3.29 mg g^{-1}) being recorded under T_{11} which was statistically at par with treatments T_{10}. Whereas, significantly lowest leaf chlorophyll content (2.53 mg g^{-1}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant, however, significant effects of treatment (T) and year (Y) on leaf chlorophyll content were found.

Table 4.16: Effect of graded levels of N and nano-N on leaf chlorophyll, anthocyanin content and yield of apple

Treatment Code	**Leaf chlorophyll content (mg g^{-1})**			**Anthocyanin content (mg/ 100 g)**			**Yield (kg tree^{-1})**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	2.72	2.85	2.79	12.23	15.17	13.70	31.50	34.34	32.92
T_2	2.50	2.56	2.53	11.44	14.24	12.84	23.37	26.39	24.88
T_3	2.52	2.58	2.55	11.49	14.67	13.08	23.45	27.58	25.52
T_4	2.54	2.61	2.57	11.62	14.36	12.99	24.67	28.26	26.47
T_5	2.56	2.63	2.60	11.51	14.25	12.88	24.48	28.73	26.61
T_6	2.77	2.85	2.81	12.22	15.58	13.90	28.59	32.10	30.35
T_7	2.81	2.89	2.85	12.14	15.38	13.76	29.14	33.16	31.15
T_8	3.03	3.09	3.06	12.74	15.79	14.27	35.34	38.02	36.68
T_9	3.05	3.12	3.09	12.64	15.70	14.17	34.12	37.39	35.76
T_{10}	3.13	3.21	3.17	12.56	15.67	14.11	34.69	36.44	35.56
T_{11}	3.25	3.33	3.29	12.42	15.19	13.81	33.52	35.98	34.75
Mean	2.80	2.88		12.09	15.09		29.35	32.58	
CD $_{(0.05)}$	0.21	0.25		0.26	0.25		1.34	1.30	
Year (Y):			0.07			0.07			0.38
Treatment (T):			0.16			0.18			0.90
Y×T:			NS			0.24			NS

The maximum leaf chlorophyll content observed with nano-nitrogen treatments can be attributed to elevated nitrogen levels, which enhance the efficiency of the photosynthetic process. Moreover, foliar application of nano formulations enhances nutrient availability through improved penetration via leaf stomata during gas exchange. Nitrogen fertilizer activates enzymes involved in chlorophyll synthesis, thereby increasing chlorophyll content in the leaves. These findings are consistent with Abdel-Hak et al. (2018), who reported a significant increase in total leaf chlorophyll and carbohydrate content in the grape cultivar ‘Flame Seedless’ with the application of nano-carbon and nitrogen fertilization. Similar observations were reported by Roshdy and Refaai (2016) in date palms and Abdelaziz et al. (2019) in mangoes.

4.1.5.2 Yield

The data with respect to fruit yield for 2022 and 2023 are cited in Table 4.16. The perusal of data showed that various treatments exerted a significant effect on fruit yield during both the years of study.

It is evident from the data presented in Table 4.16 that during 2022 and 2023, significantly highest fruit yield (35.34 kg tree^{-1} and 38.02 kg tree^{-1}) was recorded under T_8 (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage), which was statistically at par with treatment T_9. Whereas, significantly lowest fruit yield (23.37 kg tree^{-1} and 26.39 kg tree^{-1}) was recorded under T_2 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest fruit yield (36.68 kg tree^{-1}) being recorded under T_8, which was statistically at par with treatment T_9. Whereas, significantly lowest fruit yield (24.88 kg tree^{-1}) was recorded under T_2. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on fruit yield were found.

These results are consistent with the findings of Parizad et al. (2017) and can be attributed to nitrogen’s role as an essential nutrient that enhances photosynthetic efficiency. Nitrogen is a key component of amino acids, which are integral to the protein system, thereby contributing to the production of substantial biomass (Akbarinia et al. 2013).

Significantly higher yield achieved with soil application of 50% recommended dose of nitrogen+ nano nitrogen @ 250 ppm split at Pink bud and Fruit Set stage of the apple crop under study is attributed to superior fruit length, diameter and weight observed which might be due to better nitrogen availability in soil and its uptake. In addition, foliar application of

Nano-urea might have favourably affected cell division and elongation, leaf nutrient and chlorophyll contents and carbohydrate metabolism. Similar results have been reported by Barker and Pilbeam (2007); Li et al. (2024). The physiological and metabolic functions of nitrogen in flowering and fruit set are attributed to its role in carbohydrate supply, which is essential for flower bud growth, flower initiation and development, ovule lifespan, effective pollination, and fertility which have a direct effect on fruit yield (Etehadnejad and Aboutalebi 2014). Increases in the number of fruits per tree and yield with nitrogen fertilization have been documented in various crops, such as apple (Amiri et al. 2008).

4.2 Experiment-2: Effect of foliar applications of potassium (K) and calcium (Ca) on growth, yield, and quality of apple

4.2.1 Effect of foliar applications of K and Ca on leaf nutrient content of plant

4.2.1.1 Leaf Nitrogen

The data with respect to leaf nitrogen for 2022 and 2023 are cited in Table 4.17. The perusal of data showed that various treatments exerted a significant effect on leaf nitrogen during both the years of study.

It is evident from the data presented in Table 4.17 that during 2022 and 2023, significantly highest leaf nitrogen (2.48 % and 2.54 %) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting), which was statistically at par with treatment T_5, T_6, T_8 and T_9. Whereas, significantly lowest leaf nitrogen (2.27 % and 2.35 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf nitrogen (2.51 %) being recorded under T_{11} which was statistically at par with treatments T_6, T_8 and T_9. Whereas, significantly lowest leaf nitrogen (2.31 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on leaf nitrogen contents were found.

Mosa et al. (2015) reported that potassium and calcium applications increased leaf nitrogen (N) concentrations in the 'Anna' apple variety. Compared to other nutrients, potassium has a more pronounced effect on nitrogen content, as an adequate potassium supply enhances the synthesis of amino acids and proteins, as well as nitrogen metabolism (Coskun et al. 2016; Xu et al. 2020).

4.2.1.2 Leaf Phosphorus

The data with respect to leaf phosphorus for 2022 and 2023 are cited in Table 4.17. The perusal of data showed that various treatments exerted a non- significant effect on leaf phosphorus during both the years of study.

It is evident from the data presented in Table 4.17 that during 2022 and 2023, highest leaf phosphorus (0.29 % and 0.30 %) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting). Whereas, lowest leaf phosphorus (0.24 % and 0.24 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with highest leaf phosphorus (0.29 %) being recorded under T_{11}. Whereas, lowest leaf phosphorus (0.24 %) was recorded under T_1. The data on year (Y), treatment (T) and their interaction (Y×T) were found to be non- significant.

Table 4.17: Effect of foliar application of K and Ca on leaf N, P and K of apple

Treatment Code	**Leaf N (%)**			**Leaf P (%)**			**Leaf K (%)**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	2.27	2.35	2.31	0.24	0.24	0.24	1.65	1.70	1.68
T_2	2.44	2.51	2.48	0.25	0.26	0.26	1.71	1.76	1.74
T_3	2.30	2.37	2.34	0.24	0.25	0.25	1.73	1.79	1.76
T_4	2.33	2.40	2.36	0.24	0.25	0.24	1.67	1.72	1.70
T_5	2.39	2.46	2.42	0.26	0.27	0.26	1.85	1.90	1.88
T_6	2.45	2.50	2.48	0.27	0.28	0.28	1.76	1.81	1.78
T_7	2.32	2.39	2.36	0.25	0.26	0.25	1.78	1.84	1.81
T_8	2.41	2.48	2.45	0.29	0.30	0.29	1.86	1.91	1.89
T_9	2.46	2.52	2.49	0.28	0.29	0.29	1.80	1.86	1.83
T_{10}	2.34	2.41	2.38	0.26	0.27	0.26	1.81	1.87	1.84
T_{11}	2.48	2.54	2.51	0.29	0.30	0.29	1.88	1.93	1.91
Mean	2.38	2.44		0.25	0.26		1.77	1.82	
CD $_{(0.05)}$	0.10	0.10		NS	NS		0.13	0.13	
Year (Y):			0.03			NS			0.04
Treatment (T):			0.07			NS			0.09
Y×T:			NS			NS			NS

4.2.1.3 Leaf Potassium

The data with respect to leaf potassium for 2022 and 2023 are cited in Table 4.17. The perusal of data showed that various treatments exerted a significant effect on leaf potassium during both the years of study.

It is evident from the data presented in Table 4.17 that during 2022 and 2023, significantly highest leaf potassium (1.88 % and 1.93 %) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)), which was statistically at par with treatment T_5, T_6, T_7, T_8, T_9 and T_{10}. Whereas, significantly lowest leaf potassium (1.65 % and 1.70 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf potassium (1.91 %) being recorded under T_{11} which was statistically at par with treatments T_5, T_8, T_9 and $T_{10.}$ Whereas, significantly lowest leaf potassium (1.68 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on leaf potassium contents were found.

Ebeed and Abd El-Migeed (2005) found that spraying 'Fagri Kalan' mango trees with potassium citrate improved nitrogen and potassium levels in the leaves. Additionally, Abd El-Razek et al. (2013) reported that spraying mango trees with Sward (25% potassium) enhanced tree growth, as measured by leaf area, and increased the nitrogen (N), phosphorus (P) and potassium (K) content in the leaf mineral composition. The results corroborate earlier findings that higher levels of potassium application increase the potassium content in leaves, as observed in 'Bombai' litchi (Pathak et al. 2013). These findings are consistent with those of Southwick et al. (1996) and Shen et al. (2016). The observed increase in leaf potassium content is attributed to the higher application rates of foliar potassium nitrate sprays, which are rapidly absorbed and utilized by the plants. This observation is in agreement with Mostafa et al. (2005); Mostafa and Saleh (2006), who also found that potassium applications, such as KNO_3 or KH_2PO_4, elevated nitrogen and potassium levels in the leaves. Furthermore, these results align with the findings of Kaith and Awasthi (1998), Papp (2000), Hudina and Stampar (2002), Anjum et al. (2008), Neilsen and Neilsen (2011) and Aroosa (2014).

4.2.1.4 Leaf Calcium

The data with respect to leaf calcium for 2022 and 2023 are cited in Table 4.18. The perusal of data showed that various treatments exerted significant effect on leaf calcium during both the years of study.

It is evident from the data presented in Table 4.18 that during 2022 and 2023, significantly highest leaf calcium (2.86 % and 2.92 %) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)), which was statistically at par with T_4, T_6, T_7, T_8, T_9 and T_{10} treatments under study. Whereas, significantly lowest leaf calcium (2.62 % and 2.68 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf calcium (2.89 %) being recorded under T_{11}, which was statistically at par with T_6, T_7, T_8, T_9 and T_{10} treatments under study. Whereas, significantly lowest leaf calcium (2.65 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of year (Y) and treatment (T) on leaf calcium contents were found.

The results obtained can be attributed to the enhanced absorption of nutrients by healthy plants, as well as the indirect availability of moisture through foliar sprays, which facilitated improved nutrient uptake. Additionally, the absorption of calcium and potassium is synergistic; thus, increased potassium uptake is often accompanied by a corresponding increase in calcium absorption in plants. These findings are consistent with the observations reported by Childers (1983). It has also been reported that application of calcium (Ca) to apple trees (Dilmaghani et al. 2005; Korkmaz 2005; Kucukyumuk and Erdal 2022) and to pear trees (Shen et al. 2016) resulted in increased leaf calcium content.

4.2.1.5 Leaf Magnesium

The data with respect to leaf magnesium for 2022 and 2023 are cited in Table 4.18. The perusal of data showed that various treatments exerted a non- significant effect on leaf magnesium during both the years of study.

It is evident from the data presented in Table 4.18 that during 2022 and 2023, highest leaf magnesium (0.55 % and 0.60 %) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)). Whereas, lowest leaf magnesium (0.44 % and 0.48 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf magnesium (0.57 %) being recorded under T_{11}. Whereas, significantly lowest leaf magnesium (0.46 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf magnesium contents were found.

Table 4.18: Effect of foliar application of K and Ca on leaf Ca, Mg and S of apple

Treatment Code	**Leaf Ca (%)**			**Leaf Mg (%)**			**Leaf S (%)**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	2.62	2.68	2.65	0.44	0.48	0.46	0.44	0.53	0.49
T_2	2.70	2.76	2.73	0.47	0.51	0.49	0.48	0.57	0.53
T_3	2.68	2.75	2.72	0.45	0.50	0.48	0.51	0.59	0.55
T_4	2.74	2.80	2.77	0.45	0.48	0.47	0.46	0.55	0.51
T_5	2.71	2.77	2.74	0.50	0.54	0.52	0.54	0.63	0.59
T_6	2.80	2.86	2.83	0.51	0.55	0.53	0.52	0.60	0.56
T_7	2.79	2.86	2.83	0.48	0.53	0.51	0.56	0.65	0.61
T_8	2.83	2.89	2.86	0.54	0.59	0.57	0.58	0.67	0.63
T_9	2.84	2.90	2.87	0.54	0.60	0.57	0.53	0.61	0.57
T_{10}	2.82	2.88	2.85	0.49	0.54	0.52	0.57	0.66	0.62
T_{11}	2.86	2.92	2.89	0.55	0.60	0.57	0.60	0.68	0.64
Mean	2.76	2.82		0.49	0.53		0.52	0.61	
CD $_{(0.05)}$	0.13	0.14		NS	NS		0.06	0.07	
Year (Y):			0.04			0.03			0.02
Treatment (T):			0.09			0.07			0.05
Y×T:			NS			NS			NS

4.2.1.6 Leaf Sulphur

The data with respect to leaf sulphur for 2022 and 2023 are cited in Table 4.18. The perusal of data showed that various treatments exerted a significant effect on leaf sulphur during both the years of study.

It is evident from the data presented in Table 4.18 that during 2022 and 2023, significantly highest leaf sulphur (0.60 % and 0.68 %) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage + K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting), which was statistically at par with T_5, T_7, T_8 and T_{10} treatments under study. Whereas, significantly lowest leaf sulphur (0.44 % and 0.53 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf sulphur (0.64 %) being recorded under T_{11}, which was statistically at par with T_5, T_7, T_8 and T_{10} treatments under study. Whereas, significantly lowest leaf sulphur (0.49 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf sulphur contents were found.

4.2.1.7 Leaf Iron

The data with respect to leaf iron for 2022 and 2023 are cited in Table 4.19. The perusal of data showed that various treatments exerted a non- significant effect on leaf iron during both the years of study.

It is evident from the data presented in Table 4.18 that during 2022 and 2023, highest leaf iron (237.23 % and 252.90 %) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage + K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting). Whereas, lowest leaf iron (220.80 % and 233.21 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf iron (245.07 %) being recorded under T_{11}. Whereas, significantly lowest leaf iron (227.00 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf iron contents were found.

It has been reported that iron uptake exhibits antagonism with potassium, meaning that higher potassium levels in the plant can reduce iron uptake (Çakmak 2005). In a study on black locust, the application of different potassium doses did not have a statistically significant effect on iron content (Çömez 2009).

4.2.1.8 Leaf Copper

The data with respect to leaf copper for 2022 and 2023 are cited in Table 4.19. The perusal of data showed that various treatments exerted a significant effect on leaf copper during both the years of study.

It is evident from the data presented in Table 4.19 that during 2022 and 2023, significantly highest leaf copper (15.83 ppm and 15.96 ppm) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage + K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)), which was statistically at par with treatment T_8 and T_{10}. Whereas, significantly lowest leaf copper (14.36 ppm and 14.45 ppm) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf copper (15.89 ppm) being recorded under T_{11} which was statistically at par with treatments T_8 and T_{10}. Whereas, significantly lowest leaf copper (14.40 ppm) was recorded under T_1. The data on year (Y) and interaction (Y×T) were found to be non- significant. However, significant effects of treatment (T) on leaf copper contents were found.

Table 4.19: Effect of foliar application of K and Ca on leaf Fe and Cu of apple

Treatment Code	**Leaf Fe (ppm)**			**Leaf Cu (ppm)**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	220.80	233.21	227.00	14.36	14.45	14.40
T_2	227.56	238.97	233.26	14.68	14.76	14.72
T_3	222.88	235.53	229.21	15.17	15.26	15.22
T_4	224.87	237.28	231.08	14.78	14.87	14.82
T_5	230.98	242.45	236.72	15.22	15.31	15.27
T_6	232.55	243.81	238.18	14.95	15.05	15.00
T_7	226.64	239.01	232.82	15.36	15.44	15.40
T_8	234.81	246.11	240.46	15.56	15.65	15.60
T_9	235.71	247.39	241.55	15.15	15.22	15.18
T_{10}	231.41	243.49	237.45	15.63	15.75	15.69
T_{11}	237.23	252.90	245.07	15.83	15.96	15.89
Mean	229.58	241.83		15.15	15.24	
CD $_{(0.05)}$	NS	NS		0.50	0.48	
Year (Y):			3.59			NS
Treatment (T):			8.43			0.33
Y×T:			NS			NS

4.2.1.9 Leaf Zinc

The data with respect to leaf zinc for 2022 and 2023 are cited in Table 4.20. The perusal of data showed that various treatments exerted a significant effect on leaf zinc during both the years of study.

It is evident from the data presented in Table 4.20 that during 2022 and 2023, significantly highest leaf zinc (38.68 ppm and 40.49 ppm) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage + K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)), which was statistically at par with treatment T_{10}. Whereas, significantly lowest leaf zinc (21.54 ppm and 22.68 ppm) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf zinc (39.59 ppm) being recorded under T_{11} which was statistically at par with treatments T_7, T_8 and T_{10}. Whereas, significantly lowest leaf zinc (22.11 ppm) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of year (Y) and treatment (T) on leaf zinc contents were found.

Table 4.20: Effect of foliar application of K and Ca on leaf Zn and Mn of apple

Treatment Code	Leaf Zn (ppm)			Leaf Mn (ppm)		
	2022	2023	Pooled	2022	2023	Pooled
T_1	21.54	22.68	22.11	67.57	70.57	69.07
T_2	24.65	25.71	25.18	75.51	78.53	77.02
T_3	30.55	31.56	31.06	72.88	76.45	74.66
T_4	27.54	28.21	27.88	70.51	73.23	71.87
T_5	32.52	34.55	33.54	82.91	85.88	84.40
T_6	29.74	31.62	30.68	78.14	80.94	79.54
T_7	33.45	35.60	34.53	77.59	80.67	79.13
T_8	34.47	36.78	35.63	84.67	87.74	86.20
T_9	31.36	33.68	32.52	81.21	84.32	82.77
T_{10}	36.41	38.60	37.51	80.57	83.68	82.13
T_{11}	38.68	40.49	39.59	85.51	88.36	86.94
Mean	30.99	32.68		77.91	80.94	
CD $_{(0.05)}$	3.46	3.21		3.79	3.64	
Year (Y):			0.96			1.06
Treatment (T):			2.24			2.49
Y×T:			NS			NS

4.2.1.10 Leaf Manganese

The data with respect to leaf manganese for 2022 and 2023 are cited in Table 4.20. The perusal of data showed that various treatments exerted a significant effect on leaf manganese during both the years of study.

It is evident from the data presented in Table 4.20 that during 2022 and 2023, significantly highest leaf manganese (85.51 ppm and 88.36 ppm) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)), which was statistically at par with treatment T_5 and T_8. Whereas, significantly lowest leaf manganese (67.57 ppm and 70.57 ppm) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf manganese (86.94 ppm) being recorded under T_{11} which was statistically at par with treatment T_8. Whereas, significantly lowest leaf manganese (69.07 ppm) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on leaf manganese contents were found.

Similar findings were reported by Mosa et al. (2015), who concluded that the foliar application of potassium sulphate, boric acid and humic acid, whether applied singly or in combination, positively influenced the leaf mineral content of 'Anna' apple trees. Specifically, this treatment led to a notable increase in leaf Fe and Zn contents. This enhancement in Fe and Zn levels was consistently observed over two growing seasons and represented a significant improvement compared to the control treatment. These results are consistent with the findings of Davarpanah et al. (2018), Norozi et al. (2019) and Hagagg et al. (2020). The results also align with the findings of Korkmaz and Aşkın (2015), who reported that the application of 2% calcium nitrate significantly increased the copper concentration in leaf tissues.

4.2.2 Effect of foliar applications of K and Ca on plant growth parameters

4.2.2.1 Increase in tree height

The data with respect to increase in tree height for 2022 and 2023 are cited in Table 4.21. The perusal of data showed that various treatments exerted a significant effect on increase in tree height during both the years of study.

It is evident from the data presented in Table 4.21 that during 2022 and 2023, significantly highest increase in tree height (7.44 % and 7.65%) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_{11}. Whereas, significantly lowest increase in tree height (6.06 % and 6.25 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest increase in tree height (7.55 %) being recorded under T_8 which was statistically at par with treatments $T_{11.}$ Whereas, significantly lowest increase in tree height (6.16 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in tree height were found.

Table 4.21: Effect of foliar application of K and Ca on increase in tree height, tree spread and trunk girth of apple

Treatment Code	Inc. in tree height (%)			Inc. in tree spread (%)			Inc. in trunk girth (%)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	6.06	6.25	6.16	7.15	7.30	7.23	2.54	2.60	2.57
T_2	6.55	6.75	6.65	7.76	7.91	7.83	2.62	2.67	2.64
T_3	6.26	6.44	6.35	7.35	7.50	7.42	2.57	2.64	2.61
T_4	6.48	6.67	6.57	7.64	7.76	7.70	2.59	2.65	2.62
T_5	6.63	6.84	6.74	7.85	8.00	7.92	2.66	2.73	2.69
T_6	7.05	7.24	7.15	8.22	8.37	8.29	2.81	2.88	2.85
T_7	6.75	6.92	6.84	7.94	8.09	8.02	2.70	2.77	2.74
T_8	7.44	7.65	7.55	8.63	8.78	8.70	2.98	3.04	3.01
T_9	7.12	7.33	7.23	8.34	8.48	8.41	2.87	2.94	2.91
T_{10}	6.94	7.17	7.06	8.18	8.32	8.25	2.75	2.82	2.78
T_{11}	7.36	7.60	7.48	8.53	8.69	8.61	2.92	2.98	2.95
Mean	6.78	6.98		7.96	8.10		2.72	2.79	
CD $_{(0.05)}$	0.26	0.20		0.18	0.20		0.11	0.11	
Year (Y):			0.07			0.05			0.03
Treatment (T):			0.16			0.15			0.07
Y×T:			NS			NS			NS

4.2.2.2 Increase in tree spread

The data with respect to increase in tree spread for 2022 and 2023 are cited in Table 4.21. The perusal of data showed that various treatments exerted a significant effect on increase in tree spread during both the years of study.

It is evident from the data presented in Table 4.21 that during 2022 and 2023, significantly highest increase in tree spread (8.63 % and 8.78 %) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_{11}. Whereas, significantly lowest increase in tree spread (7.15 % and 7.30 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest increase in tree spread (8.70 %) being recorded under T_8 which was statistically at par with treatments $T_{11.}$ Whereas, significantly lowest increase in tree spread (7.23 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in tree spread were found.

4.2.2.3 Increase in trunk girth

The data with respect to increase in trunk girth for 2022 and 2023 are cited in Table 4.21. The perusal of data showed that various treatments exerted a significant effect on increase in trunk girth during both the years of study.

It is evident from the data presented in Table 4.21 that during 2022 and 2023, significantly highest increase in trunk girth (2.98 % and 3.04 %) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_9 and T_{11}. Whereas, significantly lowest increase in trunk girth (2.54 % and 2.60 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest increase in trunk girth (3.01 %) being recorded under T_8 which was statistically at par with treatment T_{11}. Whereas, significantly lowest increase in trunk girth (2.57 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in trunk girth were found.

4.2.2.4 Increase in tree Volume

The data with respect to increase in tree volume for 2022 and 2023 are cited in Table 4.22. The perusal of data showed that various treatments exerted a significant effect on increase in tree volume during both the years of study.

It is evident from the data presented in Table 4.22 that during 2022 and 2023, significantly highest increase in tree volume (4.36 m^3 and 4.97 m^3) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_6, T_9 and T_{11}. Whereas, significantly least increase in tree volume (3.78 m^3 and 4.37 m^3) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest increase in tree volume (4.67 m^3) being recorded under T_8 which was statistically at par with treatments T_9 and T_{11}. Whereas, significantly least increase in tree volume (4.07 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in tree volume were found.

Combined application of Potassium sulphate, Potassium nitrate and Calcium chloride resulted in higher tree growth (height, spread and girth) which might be attributed to beneficial effects of potassium, nitrogen and calcium on tree growth which is often linked to their role in enhancing photosynthesis and involvement in hormone metabolism. Calcium contributes to the synthesis of auxin, a crucial hormone that regulates various growth processes (Kazemi 2013). Additionally, potassium enhanced tree growth by acting as an enzyme activator involved in the synthesis of peptide bonds during protein synthesis and its crucial role in the translocation of carbohydrates. The increase in tree growth observed positively influenced tree volume. The results obtained are consistent with the findings of Jadczuk et al. (1998), Robinson and Stiles (2000) and Simnani (2012).

4.2.2.5 Annual shoot growth

The data with respect to annual shoot growth for 2022 and 2023 are cited in Table 4.22. The perusal of data showed that various treatments exerted a significant effect on annual shoot growth during both the years of study.

It is evident from the data presented in Table 4.22 that during 2022 and 2023, significantly highest annual shoot growth (37.72 cm and 40.78 cm) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)), which was statistically at par with treatment

T_6, T_7, T_8, T_9 and T_{10}. Whereas, significantly least increase in annual shoot growth (26.64 cm and 29.45 cm) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest annual shoot growth (39.25 cm) being recorded under T_{11} which was statistically at par with treatments T_6, T_8, T_9 and T_{11}. Whereas, significantly least increase in annual shoot growth (28.04 cm) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in annual shoot growth were found.

Table 4.22: Effect of foliar application of K and Ca on tree volume, annual shoot growth and leaf area of apple

Treatment Code	Inc. in tree volume (m^3)			Annual shoot growth (cm)			Leaf area (cm^2)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	3.78	4.37	4.07	26.64	29.45	28.04	22.16	23.33	22.75
T_2	3.97	4.55	4.26	29.75	32.61	31.18	24.82	26.00	25.41
T_3	3.86	4.45	4.16	28.49	31.69	30.09	23.90	24.88	24.39
T_4	3.92	4.51	4.21	29.09	32.19	30.64	24.31	25.36	24.83
T_5	4.08	4.66	4.37	30.69	33.52	32.11	25.49	26.62	26.06
T_6	4.24	4.83	4.53	35.67	38.81	37.24	29.89	30.69	30.29
T_7	4.15	4.74	4.44	33.82	37.32	35.57	27.52	28.61	28.07
T_8	4.36	4.97	4.67	37.45	40.64	39.05	31.28	32.16	31.72
T_9	4.28	4.89	4.59	36.23	39.32	37.78	30.65	31.92	31.29
T_{10}	4.20	4.79	4.50	34.44	37.56	36.00	28.92	29.95	29.44
T_{11}	4.32	4.94	4.63	37.72	40.78	39.25	31.49	32.47	31.98
Mean	4.10	4.69		32.72	35.80		27.31	28.36	
CD (0.05)	0.15	0.16		3.53	3.62		1.71	1.84	
Year (Y):			0.05			1.02			0.50
Treatment (T):			0.11			2.40			1.19
Y×T:			NS			NS			NS

4.2.2.6 Leaf area

The data with respect to leaf area for 2022 and 2023 are cited in Table 4.22. The perusal of data showed that various treatments exerted a significant effect on leaf area during both the years of study.

It is evident from the data presented in Table 4.22 that during 2022 and 2023, significantly highest leaf area (31.49 cm^2 and 32.47 cm^2) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)), which was statistically at par with treatment T_8 and T_9. Whereas, significantly least increase in leaf area (22.16 cm^2 and 23.33 cm^2) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf area (31.98 cm^2) being recorded under T_{11} which was statistically at par with treatments T_8 and T_9. Whereas, significantly least increase in leaf area (22.75 cm^2) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in leaf area were found.

Foliar application of nutrients is an effective method for nutrient delivery, as it ensures immediate absorption and utilization, thereby promoting overall plant growth and development. This approach is corroborated by El-Sherif et al. (2000), who found that foliar application of potassium and zinc in guava trees during full bloom significantly enhanced shoot length, fruit set, fruit retention, and yield, both in terms of fruit weight and number. Specifically, applications of 1% or 2% potassium sulphate were effective. Mosa et al. (2015) also found that the foliar application of a combination of potassium sulphate, calcium chloride, boric acid and humic acid resulted in increased shoot diameter, shoot length, and leaf area in the Anna variety of apple. The observed increase in leaf areas can be attributed to potassium's role in regulating the plant's water relations, which in turn supports the development of a larger and more efficient leaf area. Foliar application of nano calcium carbonate significantly improved growth parameters, including leaf area in basil plants (Ghahremani et al. 2014). Youssef et al. (2017) also found that foliar application of calcium chloride at 20 mM significantly enhanced leaf area. These results are in line with the findings of Kaith and Awasthi (1998), Singh et al. (2005), Robinson (2006), Simnani (2012), Taha et al. (2014) and Hagagg et al. (2020).

4.2.3 Effect of foliar applications of K and Ca on fruit quality attributes

4.2.3.1 Fruit length

The data with respect to fruit length for 2022 and 2023 are cited in Table 4.23. The perusal of data showed that various treatments exerted a significant effect on fruit length during both the years of study.

It is evident from the data presented in Table 4.23 that during 2022 and 2023, significantly highest fruit length (68.12 mm and 72.91 mm) was recorded under T_{11} (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)), which was statistically at par with treatment T_8 and T_9. Whereas, significantly least increase fruit length (53.21 mm and 58.27 mm) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest fruit length (70.52 mm) being recorded under T_{11} which was statistically at par with treatments T_9. Whereas, significantly least increase in fruit length (55.74 mm) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in fruit length were found.

Mohit and Thakur (2017) reported that the application of various nitrogen fertilizers, including urea and calcium nitrate, significantly enhanced the yield and quality of apricot fruit. They observed that the maximum fruit width, length, and weight were achieved with the highest concentration of calcium nitrate. Foliar spraying of various fruit trees with potassium fertilizers, such as potassium nitrate (KNO_3) in olives (Hegazi et al. 2011) and potassium sulfate in figs (Soliman et al. 2018), has been shown to increase fruit length, weight, and yield. Increased vegetative growth and fruit quality are associated with potassium and nitrogen due to their roles in cell growth, sugar transport, and turgor pressure (Solhjoo et al. 2017).

4.2.3.2 Fruit diameter

The data with respect to fruit diameter for 2022 and 2023 are cited in Table 4.23. The perusal of data showed that various treatments exerted a significant effect on fruit diameter during both the years of study.

It is evident from the data presented in Table 4.23 and Plate 3 that during 2022 and 2023, significantly highest fruit diameter (73.24 mm and 79.66 mm) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_9 and

T_{11}. Whereas, significantly least increase fruit diameter (58.85 mm and 64.44 mm) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest fruit diameter (76.45 mm) being recorded under T_8 which was statistically at par with treatment T_{11}. Whereas, significantly least increase in fruit diameter (61.65 mm) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in fruit diameter were found.

Table 4.23: Effect of foliar application of K and Ca on fruit length, diameter and weight of apple

Treatment Code	Fruit length (mm)			Fruit diameter (mm)			Fruit weight (g)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	53.21	58.27	55.74	58.85	64.44	61.65	133.59	145.75	139.67
T_2	58.72	63.28	61.00	63.90	68.75	66.32	137.81	148.02	142.91
T_3	55.41	60.30	57.86	60.90	66.64	63.77	135.29	147.23	141.26
T_4	57.49	62.36	59.92	62.13	68.05	65.09	136.59	147.99	142.29
T_5	60.15	65.38	62.77	65.47	71.49	68.48	139.49	151.17	145.33
T_6	64.74	69.71	67.23	69.27	75.37	72.32	143.10	153.72	148.41
T_7	62.95	68.32	65.64	67.32	73.26	70.29	141.83	153.49	147.66
T_8	67.85	69.99	68.92	73.24	79.66	76.45	147.03	159.01	153.02
T_9	65.13	70.18	67.66	70.29	76.86	73.58	144.47	155.31	149.89
T_{10}	63.14	68.12	65.63	68.75	75.44	72.09	142.56	153.50	148.03
T_{11}	68.12	72.91	70.52	72.29	77.99	75.14	146.53	158.48	152.50
Mean	61.53	66.25		66.58	72.54		140.75	152.15	
CD $_{(0.05)}$	4.30	4.10		3.53	3.16		6.63	6.72	
Year (Y):			1.20			0.96			1.91
Treatment (T):			2.83			2.25			4.48
Y×T:			NS			NS			NS

4.2.3.3 Fruit weight

The data with respect to fruit weight for 2022 and 2023 are cited in Table 4.23. The perusal of data showed that various treatments exerted a significant effect on fruit weight during both the years of study.

It is evident from the data presented in Table 4.23 that during 2022 and 2023, significantly highest fruit weight (147.03 g and 159.01 g) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and

60 days before harvesting)), which was statistically at par with treatments T_6, T_7, T_9, T_{10} and T_{11}. Whereas, significantly least increase fruit weight (133.59 g and 145.75 g) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest fruit weight (153.02 g) being recorded under T_8 which was statistically at par with treatments T_9 and T_{11}. Whereas, significantly least increase in fruit weight (139.67 mm) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in fruit weight were found.

Potassium is a crucial nutrient for fruit development, particularly in enhancing fruit size, weight and overall quality. In the present studies, significantly higher fruit size and weight were achieved with combined foliar application of Potassium sulphate, Potassium nitrate and Calcium chloride which might be due to the rapid absorption of potassium and calcium by the leaves and their role in translocating photosynthates to the sink. Potassium's impact extends to various physiological functions such as phosphorylation, the transport of photo-assimilates via the phloem, enzyme activation, turgor maintenance, transpiration, photosynthesis, and stress tolerance (Usherwood 1985; Pettigrew 2008). Rashid et al. (2008) documented an increase in both fruit length and diameter with potassium application on 'Red Delicious' apples. Mukadam and Haldankar (2013) reported that foliar application of KNO_3 (3%) at 20 days after fruit set significantly improved fruit length and diameter in Karonda. Similarly, Khayyat et al. (2012) observed a remarkable effect of KNO_3 (250 mg L^{-1}) on increasing fruit length and diameter in pomegranate trees compared to the control. The increase in fruit diameter with potassium application is associated with enhanced water uptake into the cells through osmotic processes, leading to increased cell size (Ruiz 2006). Solhjoo et al. (2017) reported that applying a calcium chloride ($CaCl_2$) solution to 'Red Delicious' apple trees resulted in an increase in fruit weight. Gill et al. (2012) also reported that foliar application of potassium improved fruit weight in 'Patharnakh' pear. Additionally, Singh et al. (2007) demonstrated that two pre-harvest foliar sprays of Poly feed (19:19:19) applied at 15 and 45-day intervals after fruit set effectively increased the fruit weight of litchi plants. Similar observations were reported by Kilany and Kilany (1991), Naiema (2003), Doroshenko et al. (2005) and Anjum et al. (2008). These findings are also consistent with studies conducted by Singh et al. (1994), Sanas et al. (2015), Ramesh et al. (2016) and Kumar et al. (2017) further supporting the beneficial effects of potassium on fruit development.

4.2.3.4 Fruit volume

The data with respect to fruit volume for 2022 and 2023 are cited in Table 4.24. The perusal of data showed that various treatments exerted a significant effect on fruit volume during both the years of study.

It is evident from the data presented in Table 4.24 that during 2022 and 2023, significantly highest fruit volume (161.08 cc and 182.96 cc) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_6, T_9, T_{10} and T_{11}. Whereas, significantly least increase in fruit volume (146.53 cc and 167.69 cc) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest fruit volume (172.02 cc) being recorded under T_8 which was statistically at par with treatments T_9 and T_{11}. Whereas, significantly least increase in fruit volume (157.11 cc) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in fruit volume were found.

4.2.3.5 Fruit firmness

The data with respect to fruit firmness for 2022 and 2023 are cited in Table 4.24. The perusal of data showed that various treatments exerted a significant effect on fruit firmness during both the years of study.

It is evident from the data presented in Table 4.24 that during 2022 and 2023, significantly highest fruit firmness (9.03 kg cm^{-2} and 9.45 kg cm^{-2}) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatments T_{10} and T_{11}. Whereas, significantly least increase in fruit firmness (7.91 kg cm^{-2} and 8.33 kg cm^{-2}) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest fruit firmness (9.24 kg cm^{-2}) being recorded under T_8 which was statistically at par with treatments T_{10}. Whereas, significantly least increase in fruit firmness (8.12 kg cm^{-2}) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on increase in fruit firmness were found.

Calcium (Ca) plays a crucial role in the cell membrane by inducing rigidification at the membrane surface of apple fruit tissue. The maintenance of higher firmness in treated fruits is likely due to the thickening of the middle lamella of fruit cells, which is a result of increased deposition of calcium pectate (Ortiz et al. 2011). Tzoutzoukou and Bouranis (1997) reported that foliar application of apricot trees with a 0.5% $CaCl_2$ solution at 13, 17, and 21 days before harvest maintained tissue firmness that was greater than that of the control at harvest. In the study by Sürücü and Küçükyumuk (2023), the combined foliar application of 1% calcium (Ca) and 1% potassium (K) was more effective in increasing fruit firmness than the separate application of these nutrients.

Solhjoo et al. (2017) found that despite the larger fruit size observed in trees treated with $CaCl_2$ (either alone or in combination with potassium sources), the fruits exhibited markedly greater firmness due to increased calcium content. This result confirms that the addition of calcium enhances cell wall resistance and fruit firmness (Fallahi et al. 1997). Additionally, our results align with the findings of Casero et al. (2002), who reported that foliar application of calcium on 'Golden' apple trees was particularly effective during the latter part of the growing season, when the uptake of calcium ions by roots declined rapidly. Similarly, Benavides et al. (2002) observed that calcium application on 'Golden Smoothee' apples increased fruit firmness. Additionally, Świątkiewicz and Błaszczyk (2009) reported that fruits treated with $Ca(NO_3)_2$ exhibited higher flesh firmness compared to those from the control group.

4.2.3.6 Fruit color

The data cited in Table 4.24, Plate 3a and Plate 3b revealed that various treatments showed noteable effect on fruit color during both the years of study.

During first year of study in 2022, Red Group fruit color grade 46 (B) was observed under T_1, T_2, T_3, T_4, T_6, T_7 and T_9 treatments. Whereas, Red Group fruit color grade 46 (A) was noticed under T_5, T_8, T_{10} and T_{11} treatments.

Similarly, during 2nd year of the study in 2023, the fruits harvested under T_1, T_2, T_3, T_4, T_6, T_7 and T_9 treatments exhibited Red Group color grade 46 (B). Whereas, trees harvested under T_5, T_8, T_{10} and T_{11} treatments exabits Red Group fruit color grade 46 (A).

Table 4.24: Effect of foliar application of K and Ca on fruit volume, fruit firmness and fruit color of apple

Treatment Code	**Fruit volume (cc)**			**Fruit firmness (kg cm^{-2})**			**Fruit Color**	
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**
T_1	146.53	167.69	157.11	7.91	8.33	8.12	Red Group 46 B	Red Group 46 B
T_2	151.17	172.50	161.84	8.03	8.45	8.24	Red Group 46 B	Red Group 46 B
T_3	148.72	170.15	159.44	8.28	8.68	8.48	Red Group 46 B	Red Group 46 B
T_4	150.21	172.16	161.19	8.32	8.71	8.52	Red Group 46 B	Red Group 46 B
T_5	153.13	174.16	163.65	8.23	8.64	8.43	Red Group 46 A	Red Group 46 A
T_6	158.59	178.43	168.51	8.58	8.80	8.69	Red Group 46 B	Red Group 46 B
T_7	155.61	176.34	165.98	8.84	9.25	9.05	Red Group 46 B	Red Group 46 B
T_8	161.08	182.96	172.02	9.03	9.45	9.24	Red Group 46 A	Red Group 46 A
T_9	159.49	180.79	170.14	8.62	9.05	8.84	Red Group 46 B	Red Group 46 B
T_{10}	156.44	178.25	167.35	8.94	9.35	9.14	Red Group 46 A	Red Group 46 A
T_{11}	160.80	182.55	171.67	8.92	9.33	9.12	Red Group 46 A	Red Group 46 A
Mean	154.70	175.99		8.51	8.91			
CD $_{(0.05)}$	4.65	4.97		0.14	0.16			
Year (Y):			1.38			0.04		
Treatment (T):			3.23			0.10		
Y×T:			NS			NS		

The foliar application of calcium (Ca) in combination with various potassium (K) sources has the potential to enhance fruit color, firmness, and other quality attributes simultaneously. Su et al. (2022) reported that potassium sulphate spray promoted fruit color via regulation of pigment profile in litch fruit pericarp and lower acidity in fruit epicarp, both of which jointly contribute to the highest visual color preference. Solhjoo et al. (2017) demonstrated that a combined foliar application of calcium chloride ($CaCl_2$) and potassium from different sources was more effective in improving fruit quality traits- particularly color, firmness, K and Ca uptake, and the K/Ca ratio- than the separate application of either compound. Similar results were reported by Raese and Drake (2000) who found that the fruit skin color of the 'Red Delicious' apple cultivar was improved with the application of calcium (Ca) leaf fertilization.

4.2.3.7 Total soluble solids (TSS)

The data with respect to fruit TSS for 2022 and 2023 are cited in Table 4.25. The perusal of data showed that various treatments exerted a significant effect on fruit TSS during both the years of study.

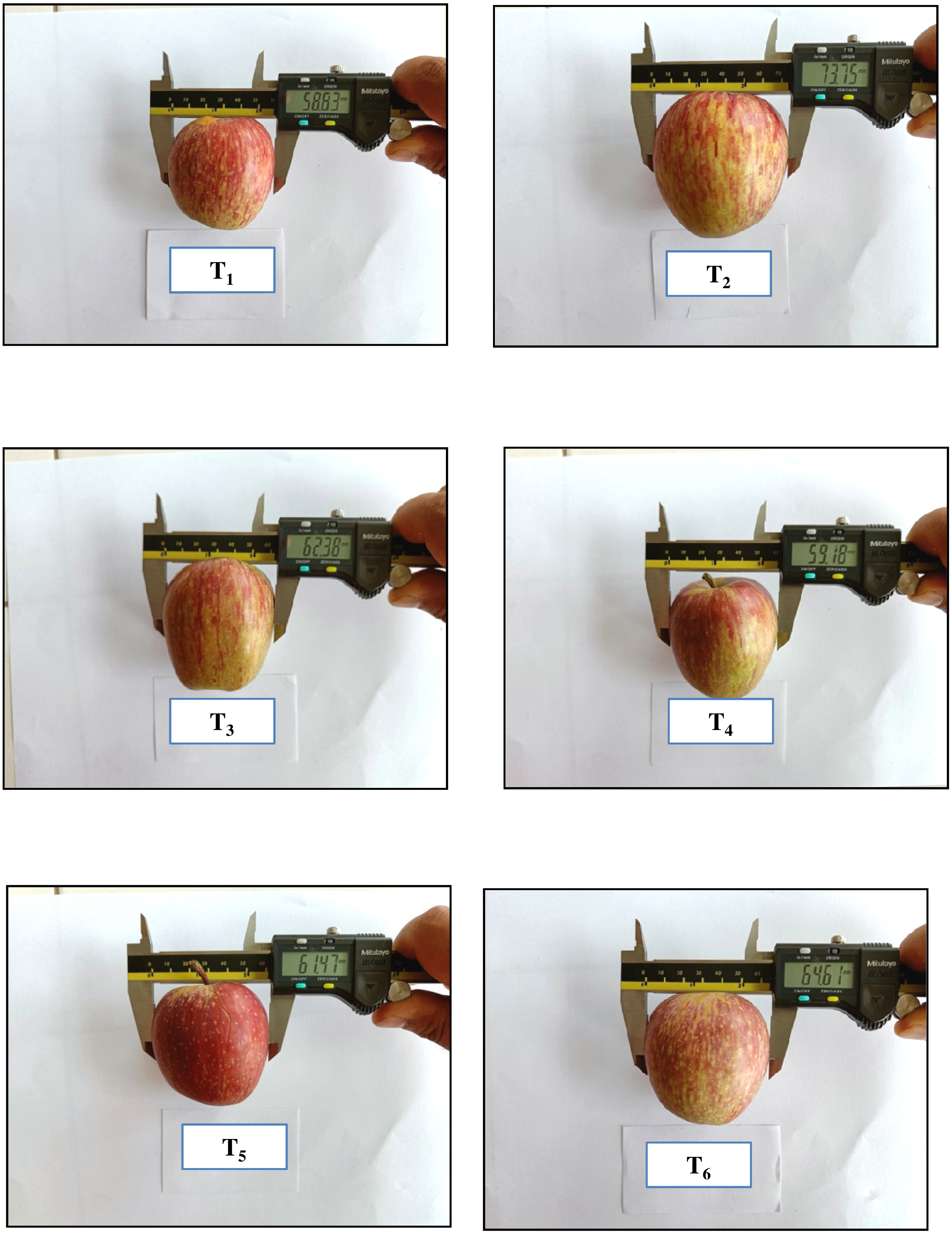
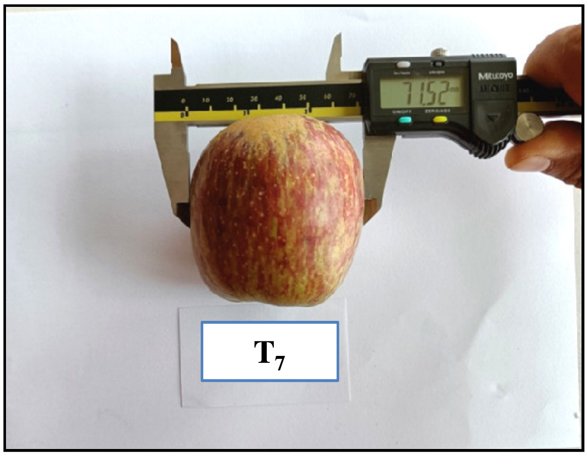
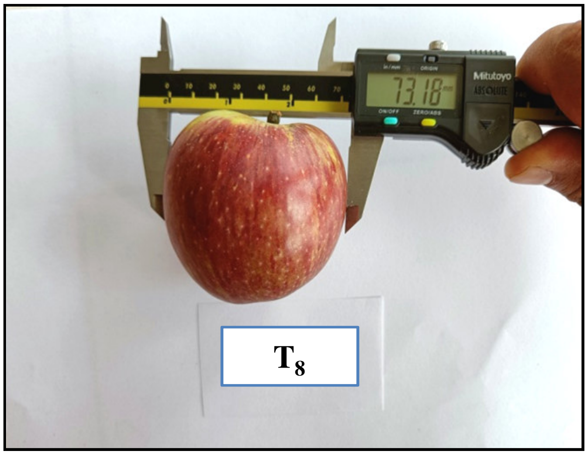
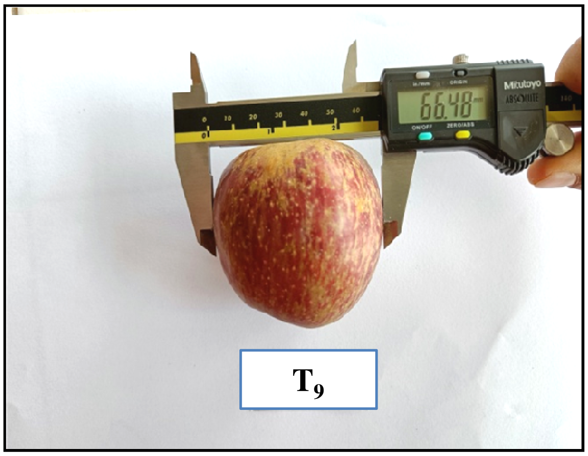
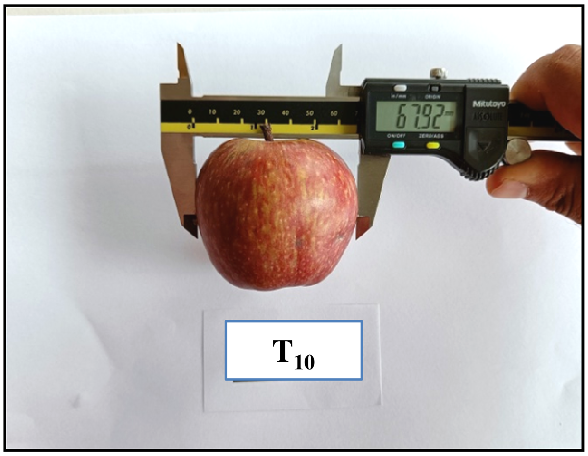


Plate 3a: Comparison of fruit diameter and fruit color of different treatments









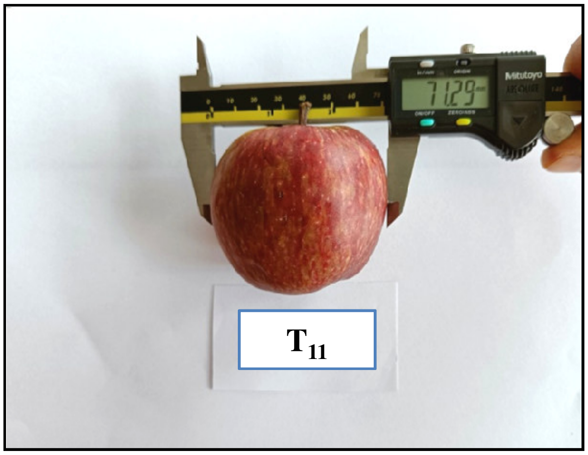


Plate 3b: Comparison of fruit diameter and fruit color of different treatments

It is evident from the data presented in Table 4.25 that during 2022 and 2023, significantly highest TSS (11.25 °B and 11.37 °B) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_9 and T_{11}. Whereas, significantly lowest TSS (10.32 °B and 10.43 °B) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest TSS (11.31 °B) being recorded under T_8, which was statistically at par with T_{11}. Whereas, significantly lowest TSS (10.38 °B) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on increase in fruit TSS were found.

Higher potassium supply increased the total soluble solids content and decreased the total acidity of berries (Martín et al. 2004). The findings of Mosa et al. (2015) indicate that the application of calcium chloride increases fruit acidity, which helps to delay the ripening process. These results are consistent with those reported by Wójcik and Lewandowski (2003).

4.2.3.8 Titratable acidity

The data with respect to titratable acidity for 2022 and 2023 are cited in Table 4.25. The perusal of data showed that various treatments exerted a significant effect on titratable acidity during both the years of study.

It is evident from the data presented in Table 4.25 that during 2022 and 2023, significantly lowest titratable acidity (0.24 % and 0.22 %) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)). Whereas, significantly highest titratable acidity (0.37 % and 0.35 %) was recorded under T_1 (Water spray- Control), which was statistically at par with treatment T_2, T_3, T_4, T_5, T_7 and T_{10}.

Pooled analysis of the data also revealed same trend with significantly highest titratable acidity (0.36 %) being recorded under T_1, which was statistically at par with T_2, T_3, T_4, T_5 and T_7. Whereas, significantly lowest titratable acidity (0.23 %) was recorded under

T_8. The data on year (Y) and the interaction (Y×T) were found to be non- significant. However, significant effects of treatment (T) on increase in titratable acidity were found.

Prasad et al. (2015) reported that the foliar application of calcium chloride ($CaCl_2$) and potassium nitrate (KNO_3) at a 2% concentration significantly increased the titratable acidity (TA) of mango fruit. Titratable acidity is directly associated with the concentration of organic acids in the fruit, which play a crucial role in maintaining fruit quality (Moradinezhad and Jahani 2019).

Table 4.25: Effect of foliar application of K and Ca on TSS, titratable acidity and TSS: acid ratio of apple

Treatment Code	**TSS (°B)**			**Titratable acidity (%)**			**TSS: acid ratio**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	10.32	10.43	10.38	0.37	0.35	0.36	28.37	30.35	29.36
T_2	10.64	10.75	10.69	0.34	0.32	0.33	31.72	34.10	32.91
T_3	10.53	10.64	10.58	0.35	0.33	0.34	30.29	32.50	31.39
T_4	10.48	10.59	10.54	0.36	0.34	0.35	29.37	31.49	30.43
T_5	10.75	10.86	10.80	0.33	0.30	0.31	33.70	37.69	35.69
T_6	11.10	11.21	11.16	0.28	0.26	0.27	40.55	44.21	42.38
T_7	10.80	10.89	10.85	0.32	0.30	0.31	34.73	37.52	36.12
T_8	11.25	11.37	11.31	0.24	0.22	0.23	46.73	51.53	49.13
T_9	11.17	11.26	11.21	0.26	0.24	0.25	44.32	47.67	46.00
T_{10}	10.92	11.04	10.98	0.30	0.28	0.29	37.04	40.19	38.62
T_{11}	11.22	11.31	11.26	0.25	0.23	0.24	44.86	49.23	47.04
Mean	10.83	10.94		0.30	0.28		36.51	39.67	
CD (0.05)	0.13	0.14		0.07	0.07		9.20	10.56	
Year (Y):			0.04			NS			2.83
Treatment (T):			0.09			0.05			6.64
Y×T:			NS			NS			NS

4.2.3.9 TSS: acid ratio

The data with respect to fruit TSS: acid ratio for 2022 and 2023 are cited in Table 4.25. The perusal of data showed that various treatments exerted a significant effect on fruit TSS: acid ratio during both the years of study.

It is evident from the data presented in Table 4.25 that during 2022 and 2023, significantly highest TSS: acid ratio (46.73 and 51.53) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_6, T_9 and T_{11}.

Whereas, significantly lowest TSS: acid ratio (28.37 and 30.35) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest TSS: acid ratio (49.13) being recorded under T_8, which was statistically at par with T_9 and T_{11}. Whereas, significantly lowest TSS: acid ratio (29.36) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on TSS: acid ratio were found.

Mosa et al. (2015) reported that the foliar application of a combination of potassium sulphate, calcium chloride, boric acid and humic acid had the most significant positive effect on improving yield percentage, fruit set, reducing sugar content, total soluble solids (TSS), TSS/acid ratio, anthocyanin concentration, fruit diameter, fruit length, average fruit weight and fruit firmness. Additionally, this treatment reduced fruit drop and acidity percentages in both seasons compared to the control and other treatments.

4.2.3.10 Total Sugars

The data with respect to total sugars in fruits for 2022 and 2023 are cited in Table 4.26. The perusal of data showed that various treatments exerted a significant effect on total sugars in fruits during both the years of study.

It is evident from the data presented in Table 4.26 that during 2022 and 2023, significantly highest total sugars in fruits (10.62 % and 10.99 %) were recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with T_6, T_9 and T_{11}. Whereas, significantly lowest total sugars in fruits (9.72 % and 10.02 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest total sugars in fruits (10.81 %) being recorded under T_8 which was statistically at par with T_9 and T_{11}. Whereas, significantly lowest total sugars in fruits (9.87 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on total sugars in fruits were found.

Lu et al. (2013) reported that the foliar application of calcium chloride ($CaCl_2$) at a concentration of 10 g L^{-1} during the fruit set stage significantly increased the total sugar concentration in 'Fuji' apples.

Table 4.26: Effect of foliar application of K and Ca on total, reducing and non- reducing sugar content of apple

Treatment Code	**Total sugars (%)**			**Reducing sugars (%)**			**Non-reducing sugars (%)**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	9.72	10.02	9.87	6.33	6.44	6.39	3.23	3.40	3.31
T_2	10.04	10.36	10.20	6.56	6.65	6.61	3.30	3.51	3.41
T_3	9.90	10.23	10.06	6.33	6.40	6.37	3.54	3.63	3.58
T_4	9.85	10.15	10.00	6.33	6.42	6.38	3.29	3.54	3.41
T_5	10.19	10.49	10.34	6.56	6.74	6.65	3.45	3.56	3.50
T_6	10.44	10.76	10.60	6.82	6.93	6.88	3.43	3.63	3.53
T_7	10.23	10.55	10.39	6.61	6.72	6.67	3.43	3.63	3.53
T_8	10.62	10.99	10.81	7.02	7.21	7.12	3.41	3.58	3.50
T_9	10.50	10.82	10.66	6.85	7.02	6.93	3.47	3.62	3.55
T_{10}	10.36	10.67	10.52	6.71	6.93	6.82	3.46	3.56	3.51
T_{11}	10.57	10.85	10.71	6.97	7.16	7.07	3.42	3.56	3.49
Mean	10.21	10.53		6.64	6.78		3.40	3.56	
CD $_{(0.05)}$	0.21	0.26		0.14	0.14		NS	NS	
Year (Y):			0.07			0.04			0.05
Treatment (T):			0.16			0.09			0.12
Y×T:			NS			NS			NS

4.2.3.11 Reducing sugar

The data with respect to reducing sugars in fruits for 2022 and 2023 are cited in Table 4.26. The perusal of data showed that various treatments exerted a significant effect on reducing sugars in fruits during both the years of study.

It is evident from the data presented in Table 4.26 that during 2022 and 2023, significantly highest reducing sugars in fruits (7.02 % and 7.21 %) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with T_{11} treatment. Whereas, significantly lowest reducing sugars in fruits (6.33 % and 6.40 %) was recorded under T_3 (Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage).

Pooled analysis of the data also revealed same trend with significantly highest reducing sugars in fruits (7.12 %) being recorded under T_8 which was statistically at par with T_{11} treatment. Whereas, significantly lowest reducing sugars in fruits (6.37 %) was recorded under T_3. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on reducing sugars in fruits were found.

4.2.3.12 Non- reducing sugars

The data with respect to non- reducing sugars in fruits for 2022 and 2023 are cited in Table 4.26. The perusal of data showed that various treatments exerted a non- significant effect on non- reducing sugars in fruits during both the years of study.

It is evident from the data presented in Table 4.26 that during 2022 and 2023, highest non- reducing sugars in fruits (3.54 % and 3.63 %) was recorded under T_3 (K_2SO_4 @ 0.5% (45 days before harvesting)). Whereas, lowest non- reducing sugars in fruits (3.23 % and 3.40 %) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest non-reducing sugars in fruits (3.58 %) being recorded under T_3. Whereas, significantly lowest non- reducing sugars in fruits (3.31 %) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on non- reducing sugars were found.

4.2.3.13 Anthocyanin content

The data with respect to anthocyanin content for 2022 and 2023 are cited in Table 4.27. The perusal of data showed that various treatments exerted a significant effect on anthocyanin content during both the years of study.

It is evident from the data presented in Table 4.27 that during 2022 and 2023, significantly highest anthocyanin content (12.64 mg/100 g and 15.79 mg/100 g) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)). Whereas, significantly lowest anthocyanin content (11.26 mg/100 g and 13.48 mg/100 g) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest anthocyanin content (14.22 mg/100 g) being recorded under T_8. Whereas, significantly lowest anthocyanin content (12.37 mg/100 g) was recorded under T_1. The data on year (Y), treatment (T) and their interaction (Y×T) were found to be significant.

Potassium foliar application (1.5 and 3 g L^{-1} Potassium Metalosate) has been reported to influence anthocyanin concentration in pomegranate (Tehranifar and Mahmoodi Taber 2009). Potassium appears to be a key element in the anthocyanin biosynthesis pathway and may act as a cofactor in the activation of specific enzymes, such as UDP-galactose:flavonoid-3-O-glycosyltransferase (Nava et al. 2007).

Table 4.27: Effect of foliar application of K and Ca on leaf chlorophyll, anthocyanin content and yield of apple

Treatment Code	Leaf chlorophyll content (mg g^{-1})			Anthocyanin content (mg/ 100 g)			Yield (kg tree^{-1})		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	2.11	2.23	2.17	11.26	13.48	12.37	29.46	32.36	30.91
T_2	2.54	2.67	2.61	11.51	13.53	12.52	32.58	35.93	34.26
T_3	2.27	2.40	2.33	11.54	13.68	12.61	30.31	32.28	31.29
T_4	2.45	2.56	2.51	11.35	13.53	12.44	31.20	34.23	32.71
T_5	2.64	2.76	2.70	11.62	14.63	13.13	29.90	32.49	31.19
T_6	3.04	3.17	3.11	12.02	14.26	13.14	30.84	34.04	32.44
T_7	2.84	2.95	2.89	11.71	14.46	13.09	32.33	35.09	33.71
T_8	3.27	3.36	3.31	12.64	15.79	14.22	34.29	37.16	35.73
T_9	3.17	3.26	3.22	12.46	15.56	14.01	32.18	35.40	33.79
T_{10}	2.90	2.99	2.95	11.93	15.17	13.55	33.25	36.36	34.81
T_{11}	3.21	3.33	3.27	12.30	15.59	13.95	33.71	36.79	35.25
Mean	2.76	2.88		11.84	14.51		31.82	34.74	33.28
CD $_{(0.05)}$	0.21	0.20		0.20	0.42		1.22	1.59	
Year (Y):			0.06			0.09			0.41
Treatment (T):			0.14			0.23			0.97
Y×T:			NS			0.32			NS

4.2.4 Effect of foliar applications of K and Ca on tree physiological and yield traits

4.2.4.1 Leaf chlorophyll content

The data with respect to leaf chlorophyll content for 2022 and 2023 are cited in Table 4.27. The perusal of data showed that various treatments exerted a significant effect on leaf chlorophyll content during both the years of study.

It is evident from the data presented in Table 4.27 that during 2022 and 2023, significantly highest leaf chlorophyll content (3.27 mg g^{-1} and 3.36 mg g^{-1}) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_9 and T_{11}. Whereas, significantly lowest leaf chlorophyll content (2.11 mg g^{-1} and 2.23 mg g^{-1}) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest leaf chlorophyll content (3.31 mg g^{-1}) being recorded under T_8 which was statistically at par with treatments T_9 and $T_{11.}$ Whereas, significantly lowest leaf chlorophyll content (2.17 mg g^{-1}) was recorded under T_1. The data on interaction effect between year and treatment (Y×T) were found to be non- significant. However, significant effects of treatment (T) and year (Y) on leaf chlorophyll content were found.

Medan (2020) reported that the foliar application of potassium and calcium chelates to 'Royal' apricot trees resulted in a significant increase in leaf area and chlorophyll content. This enhancement in chlorophyll levels subsequently influenced the synthesis of secondary metabolites, including phenolic compounds.

4.2.4.2 Yield

The data with respect to fruit yield for 2022 and 2023 are cited in Table 4.27. The perusal of data showed that various treatments exerted a significant effect on fruit yield during both the years of study.

It is evident from the data presented in Table 4.27 that during 2022 and 2023, significantly highest fruit yield (34.29 kg $tree^{-1}$ and 37.16 kg $tree^{-1}$) was recorded under T_8 (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)), which was statistically at par with treatment T_{10} and T_{11}. Whereas, significantly lowest fruit yield (29.46 kg $tree^{-1}$ and 32.36 kg $tree^{-1}$) was recorded under T_1 (Water spray- Control).

Pooled analysis of the data also revealed same trend with significantly highest fruit yield (35.73 kg $tree^{-1}$) being recorded under T_8, which was statistically at par with treatment T_{10} and T_{11}. Whereas, significantly lowest fruit yield (30.91 kg $tree^{-1}$) was recorded under T_1.

The data on interaction effect between year and treatment (Y×T) were found to be non-significant. However, significant effects of treatment (T) and year (Y) on fruit yield were found.

Ghahremani et al. (2014) also demonstrated that foliar application of calcium nano chelate on sweet basil plants resulted in improved yield compared to control plants. This suggests that calcium nano chelates can effectively enhance plant growth and productivity. Hosseini et al. (2021) reported that KNO_3 application increased the yield of barberry, while Mosa et al. (2015) found that it improved the yield of apple fruit. This indicates that KNO_3 is beneficial for enhancing the productivity of various fruit crops. The results were in line with the findings of Razzaquea and Hanafib (2001); Mimoun and Marchand (2013); Sürücü and Küçükyumuk (2023).

Chapter-5

SUMMARY AND CONCLUSION

The present study entitled "**Impact of foliar application of nano- nitrogen, potassium and calcium on growth, yield and quality of apple (*Malus* × *domestica Borkh.*)**" was carried out during the years 2022 and 2023 at Experimental Farm of Krishi Vigyan Kendra, Shimla at Rohru, Himachal Pradesh, India.

Based on the pooled data, the important findings obtained in the present investigation have been summarized below:

Experiment- I: Effect of nano- nitrogen (nN) applications on growth, yield, and quality of apple

- The experimental site was sandy loam in texture, acidic in nature, having safer limits of electrical conductivity and high in organic carbon content. Application of various treatments had a non-significant effect on soil pH and EC, however, soil OC showed significant variations.
- Significantly, highest available soil N (358.41 kg ha^{-1}), P (89.29 kg ha^{-1}), K (472.82 kg ha^{-1}), exchangeable Ca (7.48 cmol (p^{+}) kg^{-1}), Mg (3.69 cmol (p^{+}) kg^{-1}), DTPA extractable Fe (28.82 mg kg^{-1}), DTPA extractable Cu (2.30 mg kg^{-1}) and DTPA extractable Mn (24.76 mg kg^{-1}) was noticed under treatment T_{11}. However, available S and DTPA extractable Zn does not reach the level of statistical significance.
- Trees subjected to treatment T_{11} exhibited significantly highest leaf N (3.15 %), P (0.28 %), K (1.73 %), Ca (2.75 %), Mg (0.53 %), S (0.73 %), Cu (15.05 ppm), Zn (33.30 ppm) and Mn (79.42 ppm). Whereas, Leaf Fe does not reach the level of statistical significance.
- Significantly, highest increase in tree height (7.05 %), tree spread (8.19 %), trunk girth (2.85 %), tree volume (4.83 m^{3}), annual shoot growth (31.75 cm) and leaf area (32.40 cm^{2}) was recorded under T_8 treatment.
- Significantly, highest fruit length (67.77 mm), fruit diameter (73.27 mm), fruit weight (147.48 g), fruit volume (169.79 cc) and fruit firmness (9.08 kg cm^{-2}) were recorded under T_8 treatment.

- The treatments applied exhibited a non- significant effect on fruit colour. Red Group colour grade 46 (B) was the predominant color among all the treatments.
- The trees subjected to T_8 treatment had significantly improved fruit TSS (11.10 °B), TSS: acid ratio (51.96), total sugars (10.84 %), reducing sugars (6.90 %), non-reducing sugars (3.74 %) and anthocyanin content (14.27 mg/ 100 g). Whereas, the maximum values of titratable acidity (0.34 %) were reported under T_2 treatment.
- Significantly, highest leaf chlorophyll content (3.29 mg g^{-1}) was recorded under T_{11} treatment. Whereas, least leaf chlorophyll (2.53 mg g^{-1}) content was reported under T_2 treatment.
- Soil and foliar application of nitrogen significantly affected the tree yield. The pooled data for two consecutive years showed that the highest yield (36.68 kg $tree^{-1}$) was recorded under T_8 treatment and the lowest yield (24.88 kg $tree^{-1}$) was recorded under T_2 treatment.

Experiment- II: Effect of foliar applications of potassium (K) and calcium (Ca) on growth, yield, and quality of apple

- Foliar feeding of trees with K and Ca had significantly affected the leaf nutrient content in plants. The pooled data for both the years showed that the trees subjected to treatment T_{11} exhibited significantly highest leaf N (2.51 %), K (1.91 %), Ca (2.89 %), Mg (0.57 %), S (0.64 %), Fe (245.07 ppm), Cu (15.89 ppm), Zn (39.59 ppm) and Mn (86.94 ppm) which were statistically at par with T_8 and T_{10}.
- Significantly, highest increase in tree height (7.55 %), tree spread (8.70 %), trunk girth (3.01 %) and tree volume (4.67%) were recorded under T_8 treatment. However, significantly highest increase in annual shoot growth (39.25 cm) and leaf area (31.98 cm^2) was reported under T_{11} treatment which was statistically at par with T_8.
- The conjoint foliar application of K and Ca reported a significant increase in physical fruit quality characteristics. Treatment T_8 reported significantly highest increase in fruit diameter (76.45 mm), fruit weight (153.02 mm), fruit volume (172.02 cc) and fruit firmness (9.24 kg cm^{-2}) which was statistically at par with T_{11}. However, the highest increment in fruit length (70.38 mm) was reported at T_{11} treatment which was statistically at par with T_8.
- Application of K and Ca on apple trees showed an improvement of fruit color. The trees subjected to T_8 treatment registered highest values of TSS (11.31°B), TSS: acid

ratio (49.13), total sugars (10.81 %) and reducing sugars (7.12 %). Whereas, T_1 treatment reported maximum titratable acidity (0.36 %), T_3 treatment reported highest non- reducing sugars (3.58 %). Significantly highest values for anthocyanin content (14.22 mg/ 100 g) was found under T_8 treatment which was statistically at par with T_{11}.

- Significantly, highest values for leaf chlorophyll content (3.31 mg g^{-1}) and yield (35.73 kg $tree^{-1}$) were noticed under T_8 treatment which were statistically at par with T_{11}.

CONCLUSION

It is concluded from the present study that the soil application of nitrogen and foliar nano- nitrogen significantly affected the soil, leaf nutrient content, plant growth parameters, fruit quality parameters, tree physiology and yield traits of apple orchard. Application of T_8 treatment consisting of 50% RDN (soil application) + nN @ 250 ppm split at pink bud and fruit set stage enhanced the overall performance in terms of soil and leaf nutrient contents, plant growth parameters, fruit quality parameters, tree physiology and yield traits in apple. Foliar application of potassium and calcium had a significant effect on leaf nutrient content, plant growth parameters, fruit quality parameters, tree physiology and yield traits of apple orchard. Among the different treatments applied, the conjoint application of KNO_3 @ 0.5 % at walnut stage + K_2SO_4 @ 0.5% (45 days before harvest) + $CaCl_2$ @ 0.5 % (45 and 60 days before harvesting), improved the plant growth parameters, fruit quality, tree physiology and yield traits in apple.

LITERATURE CITED

A.O.A.C. 1975. Official Methods of Analysis of the Association of Analytical Chemists (12th edition). Benjamin Franklin Station, Washington DC, USA. pp. 564-565.

A.O.A.C. 1980. Official Methods of Analysis of the Association of Analytical Chemists (13th edition). Benjamin Franklin Station, Washington DC, USA. pp. 376-384.

Abbas M, Abdel-Lattif H and Shahba M. 2021. Ameliorative effects of calcium sprays on yield and grain nutritional composition of maize (*Zea mays* L.) cultivars under drought stress. *Agriculture* **11**:285.

Abd El-baset MM. 2018. Effect of nano material lithovit on growth, flowering and chemical composition of *Echinacea purpurea* L. *Journal of Plant Production*, Mansoura University **9**(6):531-536.

Abd El-Migeed MMM, Saleh MMS and Mostafa EAM. 2007. The beneficial effect of minimizing mineral nitrogen fertilizers on Washington Naval orange trees by using organic and biofertilizers. *World Journal of Agricultural Sciences* **3**(1): 80-85.

Abd EL-Rahman MMA and Abd-Elkarim NAA. 2022. Effect of Nano-N fertilizer on growth, fruiting and the fruits nutritive value of zaghloul date palm. *SVU-International Journal of Agricultural Sciences* **4**(1):124-134.

Abd El-Razek E, ASE Abd-Allah and MMS Saleh. 2013. Foliar spray of some nutrient elements and antioxidants for improving yield and fruit quality of Hindi mango trees. *Middle-East J. Sci. Res.* **14**:1257-1262.

Abd El-Rhman IE and Shadia AA. 2012. Effect of foliar sprays of urea and zinc on yield and physico-chemical composition on jujube (*Ziziphus mauritiana*). *Middle East Journal of Agriculture Research* **1**(1):52-57.

Abdelaziz FH, Amma AKL, Mohamed AZ and Zakier MA. 2019, Response of Keitte mango trees to spray boron prepared by nanotechnology technique. *NY Science Journal* **12**:48-55.

Abdel-Hak RS, El-Shazly SA, El-Gazzar AA and Shaaban EA. 2018. Effects of nano carbon and nitrogen fertilization on growth, leaf mineral content, yield and fruit quality of flame seedless grape. *Journal of Agricultural Science* **26**:1429-1448.

Abdel-Salam MA. 2018. Response of lettuce (*Lactuca sativa* L.) to foliar spray using nano-urea combined with mycorrhiza. *Journal of Soil Science and Agricultural Engineering* **9**(10):467-472.

Abobatta WF and Ahmed FK. 2023. Effect of Urea and Nano-nitrogen spray treatments on some Citrus rootstock seedlings. *Horticulture Research Journal* **1**(1):68-84.

Adhikari B, Dhungana SK, Kim ID and Shin DH. 2020. Effect of foliar application of potassium fertilizers on soybean plants under salinity stress. *Journal of the Saudi Society of Agricultural Sciences* **19**:261-269.

Ahmad I, Bibi F, Bakhsh A, Ullah H, Danish S and Asif-ur-Rehman. 2018. Assessment of various levels of potassium citrate and sucrose along with boric acid on quality and yield of Sufaid Chaunsa. *International Journal of Biosciences* **13**(1):188-195.

Akbarinia A, Ghalavand A, Sefidkon F, Rezaee MB, Sharifi A. 2013. Study on the effect of different rates of chemical fertilizer, manure and mixture of them on seed yield and main, compositions of essential oil of Ajowan (*Trachyspermum copticum*). *Iranian Research and Development* **16**(4):32-41.

Al-Jabri ABAR, Jassim AHR and Jabar AK. 2020. The effect of nano nitrogen and bio-fertilizer types on NPK concentration in soil and okra plant. *Plant Archives* **20**(2):4031-4037.

Al-Juthery HWA, Ali EAHM, Al-Ubori RN, AlShami QMN and Al-Taey DKA. 2020. Role of foliar application of nano NPK, micro fertilizers and yeast extract on growth and yield of wheat. *International Journal of Agricultural and Statistical Sciences* **16**(1):1295-1300.

Al-Juthery HWA, Hardan HM, Al-Swedi FGA, Obaid MH and Al-Shami. 2019. Effect of foliar nutrition of nano fertilizers and amino acids on growth and yield of wheat. *International Conference of Agricultural Sciences* **388**:1-7.

Al-Mobark NR. 2014. *Effect of seaweed extract "Kelpak" and NPK fertilizer on leaves and fruits characteristics and yield components of Phoenix dactylifera* L. cv. Barhi (MSc Thesis).Agriculture College. Basra University. Iraq. 198 p.

Al-Mohammadi MMI and Al-Dolaimi RMH. 2024. The effect of adding nano NPK fertilizer EM1 biofertilizer and spraying with algae extract on some growth characteristics and yield of date palm variety khastawi. *IOP Conference Series: Earth and Environmental Science* **1371**:042006.

Al-Saif AM, Mosa WFA, Saleh AA, Ali MM, Sas-Paszt L, Abada HS and Abdel-Sattar M. 2022. Yield and fruit quality response of pomegranate (*Punica granatum*) to foliar spray of potassium, calcium and kaolin. *Horticulturae* **8**:946.

Al-Saif AM, Sas-Paszt L, Saad RM, Abada HS, Ayoub A and Mosa WFA. 2023. Biostimulants and nano-potassium on the yield and fruit quality of date palm. *Horticulturae* **9**:1137.

Al-Tayeb SG, El-Deeb MD, Marzouk ER and Elalakmy DA. 2022. Response of "Manzanillo" olive seedlings to unconventional nitrogen applications and growth stimuli. *Sinai Journal of Applied Sciences* **11**(2):229-244.

Aly MA, Harhash MM, Awad RM and El-Kelawy HR. 2015. Effect of foliar application with calcium, potassium and zinc treatments on yield and fruit quality of Washington Navel Orange trees. *Middle East Journal of Agriculture Research* **4**(3):564-568.

Aly MAM, Muhsin AT, Abdelsalam NR and Mosa WFA. 2022. Effect of some nano fertilizers on yield and fruit quality of apple. *Egyptian Academic Journal of Biological Sciences* **13**(2):59-64.

Amiri ME, Fallahi E and Golchin A. 2008. Influence of foliar and ground fertilization on yield, fruit quality, and soil, leaf and fruit mineral nutrients in apple. *Journal of Plant Nutrition* **31**(3):515-525.

Amoakwah E, Kim S-H, Jeon S, Shim J-H, Lee Y-H, Kwon S-I and Park S-J. 2024. Long-term fertilization and liming increase soil fertility but reduce carbon stratification and stocks of paddy rice soils. *Frontiers in Soil Science* **4**:1426894.

Anees MA, Ali A, Shakoor U, Ahmed F, Hasnain Z and Hussain A. 2016. Foliar applied potassium and zinc enhances growth and yield performance of maize under rainfed conditions. *International Journal of Agriculture and Biology* **18**:1025-1032.

Anjum R, Kirmani NA, Nageena N and Sameera S. 2008. Quality of apple Cv. Red Delicious as influenced by potassium. *Asian Journal of Soil Science* **3**(2):227-229.

Aroosa K. 2014. *Standardization of management techniques to enhance growth, yield and quality of grape (Vitis vinifera) cv. Sahebi*. Ph.D. Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar.

Asma BM, Colak S, Akca Y and Genc C. 2007. Effect of fertilizer rate on growth, yield and fruit characteristics of dried apricot cv. Hacihaliloglu. *Asian Journal of Plant Sciences* **6**(2):294-297.

Awasthi RP and Karkara BK 1979. Studieis on the standardization of NPK levels in Golden Delicious apple. *Indian Journal of Horticulture* **36**:413- 418.

Bamouh A, Bouras H and Nakro A. 2019. Effect of foliar potassium fertilization on yield and fruit quality of strawberry, raspberry and blueberry. *Acta Horticulturae* **1265**:255-262.

Bangroo S, Najar G and Rasool A. 2017. Effect of altitude and aspect on soil organic carbon and nitrogen stocks in the Himalayan Mawer forest range. *Catena* **158**:63-68.

Barker AV and Pilbeam DJ. 2007. Handbook of Plant Nutrition. CRC Press, Taylor and Francis Group. USA. 764 p.

Bedrech SA and Farroh KY. 2022. The impact of foliar spray of chitosan nano-particles and bulk form on Crimson Seedless grapevine quality and productivity. *Egyptian Journal of Horticulture* **49**(1):15-24.

Benavides A, Recasens I, Casero T, Soria Y and Puy J. 2002. Multivariate analysis of quality and mineral parameters on "Golden Smoothee" apples treated before harvest with calcium and stored in controlled atmosphere. *Food Science and Technology International* **8**:139-145.

Beniwal M, Mishra S and Bahadur V. 2024. Effect of foliar application of nano urea, boron and zinc sulphate on growth, fruit yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn. *Journal of Advances in Biology & Biotechnology* **27**(6):725-735.

Bhargava BS, Singh HP and Chadha KL. 1993. Role of potassium in development of fruit quality. **In**: *Advances in Horticulture*, Vol. 2 *Fruit Crops*: Part 2. K.L. Chadha and O.P. Pareek (Eds.). Malhotra Publishing House, New Delhi, pp. 947-60.

Bhat AH. 2019. Trends and growth in area, production and productivity of apples in India from 2001-02 to 2017-18. *Research Ambition: An International Multidisciplinary e-Journal* **4**:13-23.

Bhat MS. 2001. *Nutritional status of high density plantation of apple orchards of North Kashmir*. MSc Thesis, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar.

Bhatti D, Varu DK and Dudhat M. 2023. Effect of different doses of urea and nano-urea on growth and yield of guava (*Psidium guajava* L.) Cv. Lucknow-49. *The Pharma Innovation Journal* **12**(7):464-468.

Bhickta G, Chauhan N and Sharma NC. 2018. Effect of different nitrogen sources and their levels on leaf and soil nutrient status of apple (*Malus* × *domestica* Borkh.) cv. Starking Delicious. *International Journal of Chemical Studies* **6**(2):2022-2025.

Bi G, Scagel CF, Cheng L, Dong S and Fuchigami H. 2003. Spring growth of almond nursery trees depends upon nitrogen from both plant reserves and spring fertilizer application. *Journal of Horticultural Science and Biotechnology* **78**:853-858.

Bibi F, Ahmad I, Bakhsh A, Kiran S, Danish S, Ullah H and Rehman A. 2019. Effect of foliar application of boron with calcium and potassium on quality and yield of mango cv. Summer Bahisht (SB) Chaunsa. *Open Agriculture* **4**(1):98-106.

Çakmak I. 2005. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. *Journal of Plant Nutrition and Soil Science* **168**:521-530.

Casero T, Benavides A, Recasens I and Rufat J. 2002. Preharvest calcium sprays and fruit calcium absorption in 'Golden' apples. *Acta Horticulturae* **594**:467-473.

Chandana P, Latha KR, Chinnamuthu CR, Malarvizhi P and Lakhshmanan A. 2021. Impact of foliar application of nano nitrogen, zinc and copper on yield and nutrient uptake of rice. *International Journal of Plant and Soil Science* **33**:276-282.

Chandel CK. 1985. *Studies on the nutrition of apricot cv. New Castle*. M.Sc. Thesis. HPKV, Palampur, India.

Chapman HD. 1964. Suggested foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and plantation crops. *Indian Journal of Horticulture* **21**:97-119.

Chen BC, Lai HY, Liu CW and Sung Y. 2014. Effects of nitrogen fertilizers on the growth and nitrate content of lettuce (*Lactuca sativa* L.). *International Journal of Environmental Research and Public Health* **11**(4):4427-4440.

Chesnin L and Yien CH. 1950. Turbidimetric determination of available sulphates. *Soil Science Society of America Proceedings* **15**:149-51.

Chidananda G, Shivakumar BS, Salimath SB, Girish R and Chaitanya HS. 2020. Impact of foliar application of potassium on quality of pomegranate cv. Bhagwa. *International Journal of Current Microbiology and Applied Sciences* **9**(10):2885-2893.

Childers JK. 1983. In the shadow of Everest. *AORN Journal* **37**(1):59-73.

Choi ST, Park DS and Yoon YH. 2013. Responses of 'Fuyu' persimmon to K forms and fertigation rates on tree growth and fruit quality. *Acta Horticulturae* **996**:293-297.

Clark JR, Fernandez GE, Maples R and Bordelon B. 1989. Nitrogen fertilization of high bush blueberry. *Research Series Arkansas Agricultural Experiment Station* **398**:1-3.

Çömez Ö. 2009. *Effects of potassium applications at different levels on the growth and nutrient uptake of Black Acacia (Robinia pseudoacacia L.) and Black Pine (Pinus nigra Arnold) Saplings.* Master Thesis, Selçuk University Fen Bilimleri Enstitüsü.

Coskun D, Britto DT and Kronzucker HJ. 2016. The nitrogen-potassium intersection: membranes, metabolism and mechanism. *Plant Cell Environ* **10**:2029-2041.

Cousson A. 2009. Involvement of phospholipase C-independent calcium-mediated abscisic acid signalling during Arabidopsis response to drought. *Plant Biology* **53**(1):5362.

Dar MA. 2009. *Effect of altitude on nutritional status of pear orchard soils of Kashmir valley*. Ph.D. Thesis, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar.

Dauggard H and Grauslund J. 2000. Fruit colour and correlation with orchard factors and post harvest characteristics in apple cv. Mutsu. *Journal of Horticultural Science & Biotechnology* **74**:283-287.

Davarpanah S, Tehranifar A and Davarynejad G. 2017. Effects of foliar nano-nitrogen and urea fertilizers on the physical and chemical properties of pomegranate (*Punica granatum* cv. Ardestani) fruits. *HortScience* **52**(2):288-294.

Davarpanah S, Tehranifar A, Abadía J, Val J, Davarynejad G, Aran M and Khorassani R. 2018. Foliar calcium fertilization reduces fruit cracking in pomegranate (*Punica granatum* cv. Ardestani). *Scientia Horticulturae* **230**:86-91.

David CF and Cahoon GA. 1987. Foliar fertilization of Anab-e-Shahi grapes. *Journal of Research India* **9**(2):264-271.

Delgado R, Gonzalez M and Martin P. 2006. Interaction effects of nitrogen and potassium fertilization on anthocyanin composition and chromatic features of tempranillo grapes. *Journal International des Sceines de la Vigne et du Vin* **40**(3):141-150.

Dhindsa RK. 2018. *Comparative efficiency of different nitrogen sources on soil properties and productivity of apple* (Ph.D. Thesis). Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP), India. 121p.

Dias J and Flore JA. 2002. Annual addition of potassium to the soil increased apple yield in Brazil. *Communications in Soil Science and Plant Analysis* **33**:15-18

Dilmaghani MR, Malakouti MJ, Neilsen GH and Fallahi E. 2005. Interactive effects of potassium and calcium on K/Ca ratio and its consequences on apple fruit quality in calcareous soils of Iran. *Journal of Plant Nutrition* **27**:1149-62.

Ditta A, Arshad M and Ibrahim M. 2015. Nanoparticles in Sustainable Agricultural Crop Production: Applications and Perspectives. *Nanotechnology and Plant Sciences,* pp. 55-75.

Dixon RK, Gravelt HE and Cox GS. 1985. Cytokinins in the root pressure exudates of *Citrus jambhiri* colonized by vesicular arbuscular mycorrhizae. *Tree physiology* **4**:9-18.

DoH. 2024. Department of Horticulture, Himachal Pradesh, eudyan- departmental-statistical-data-at-glance. https://eudyan.hp.gov.in/cms/en/departmental-statistical-data-at-glance accessed on 24 July, 2024.

Doroshenko TN, Ostapenko VI, Ryazanova LG, Dubravina IV and Chumakov SS. 2005. Formation of quality of apple fruits under the effect of the foliar application of potassium. *Russian Agricultural Sciences* **5**:29-32.

Drake SR, Rease JT and Smith TJ. 2002. Time of nitrogen application and its influence on ‘Golden delicious’ apple yield and quality. *Journal of Plant Nutrition* **25**:143-157.

Ebeed S and MMM Abd El-Migeed. 2005. Effect of spraying sucrose and some nutrient elements on Fagri Kalan mango trees. *Journal of Applied Science and Research.* **1**:341-346.

Ehsan F. 2007. *Effect of S, N and foliar spray on vegetative growth and mineral content of young apple trees cv. Anna and Vistabella*. M.Sc. Thesis, University of Mosul.

Eichert T, Dreitz S, Goldbach HE and Burkhardt J. 1999. Stomatal uptake as an important factor for foliar fertilization. In: Technology and Application of foliar Fertilizers: Proceedings of the second international workshop on foliar fertilization. Bangkok: Soil and Fertilizer Society of Thailand, pp. 63-72.

Eisenacha C and Angeli A De. 2017. Ion Transport at the Vacuole during Stomatal Movements. *Plant Physiology* **174**:520-530.

Ekka SK, Mishra S, Bahadur V, Joseph AV and Topno SE. 2024. Yield and quality improvement in Kinnow mandarin using nano formulations. *Indian Journal of Horticulture* **81**(2):155-160.

El-Gazzar AAM. 2000. Effect of fertilization with nitrogen, potassium and magnesium application on Anna apples. *Annals of Agricultural Science Cairo* **3**:1145-1152.

Elakkuvan S, Sujin GS, Madhavan S and Sugavanam RS. 2021. Effect of foliar application of potassium nitrate and ethephon on yield characters of papaya (*Carica papaya* L.) cv. Red Lady. *Research Journal of Agricultural Sciences* **12**(4):1462-1466.

El-Boray MS, Mostafa MA, Iraqui MF and Mohamad AA. 2007. Some recent trends of apple trees fertilizers. *World Journal of Agricultural Sciences* **2**(4): 403-411.

El-Ghobashi YE and Ismail MR. 2022. Effect of mineral and nano-nitrogen fertilizers on yield and its components of soyabean and maize hybrids under intercropping system. *Journal of Plant Production* **13**(8):621-628.

Elhindi K, El-Hendawy S, Abdel-Salam E, Elgorban A and Ahmed M. 2016. Impacts of fertigation via surface and subsurface drip irrigation on the growth rate, yield and flower quality of Zinnia elegans. *Brigantia*. 75:96-107.

El-Morshedy FA. 1997. Fertigation studies on Anna apple trees. *Alexandria Journal of Agricultural Research* **42**(2):101-111.

El-Sayed SA, Algarni AA and Shaban KAH. 2020. Effect of NPK nano-fertilizers and compost on soil fertility and root rot severity of soybean plants caused by *Rhizoctonia solani*. *Plant Pathology Journal* **19**: 140-150.

El-Sherif AA, Saeed WT and Nouman VF. 2000. Effects of foliar application of potassium and zinc on behavior of Montakhab El-Kanater guava trees. *Bulletin Agriculture University Cario* **51**:73-84.

El-Wakeel HF. 2005. Preliminary studies on fertilization of mango trees under U.A.E conditions: II-response of Amrapali mango trees to nitrogen and potassium fertilization. *Annals of Agricultural Sciences Cairo* **50**:563-572.

Ernani PR, Amarante CVT, Dias J and Bessegato AA. 2002. Preharvest calcium sprays improve fruit quality of “Gala” apples in Southern Brazil. *Acta Horticulturae* **594**:481-86.

Ernani PR, Dias J and Borges M. 2000. Application of nitrogen to the soil at different stages does not affect fruit yield of apple cultivars. *Ciencia Rural* **30**:223-227.

Etehadnejad F and Aboutalebi A. 2014. Evaluating the effects of foliar application of nitrogen and zinc on yield increasing and quality improvement of apple cv. ‘Golab Kohanz’. *Indian Journal of Fundamental and Applied Life Sciences* **4**:125-129.

Fadhil AH and Balaket RTMA. 2024. Response of Seedlings of Three Cultivars of Mandarin to Spraying and Addition of Nano-Fertilizer. *IOP Conference Series: Earth and Environmental Science* **1371**:042026.

Fadzil NI, Masdor NA, Rosmi MNM, Wahid NS, Nor NSM, Karim MSA and Anuar MFM. 2024. Effects of MARDI nano-fertilizer application frequency on the growth of rock melon. *International Journal of Nanoelectronics and Materials (IJNeaM)* **17**:137–141. https://doi.org/10.58915/ijneam.v17iJune.847

Fallahi E, Khemira H, Righetti TL and Azarenko AN. 2002. Influence of foliar application of urea on tree growth, fruit quality, leaf minerals and distribution of urea-derived nitrogen in apples. *Acta Horticulturae* **594**:603-608.

Fallahi E, Righetti TL and Wernz JG. 1997. Effect of drip and vaccum infiltration of various inorganic chemical on post harvest quality of apple. *Community Soil Science Plant Annal* **18**:1017-1029.

Fan L and Silberbush M. 2002. Response of maize to foliar vs. soil application of nitrogen, phosphorus and potassium fertilizers. *Journal of Plant Nutrition* **25**:2333-2342.

FAOSTAT. 2024. Food and Agriculture Organization of the United Nations, FAOSTAT statistical database. https://www.fao.org/faostat/en/#data/QCL accessed on 10 February, 2024.

Gagne MA, Minocha R, Long S and Minocha SC. 2019. Effects of different foliar nitrogen fertilizers on cellular nitrogen metabolism and biomass of two shrub willow cultivars. *Canadian Journal of Forest Research* **49**:1548-1559.

Gaiotti F, Lucchetta M, Rodegher G, Lorenzoni D, Longo E, Boselli E, Cesco S, Belfiore N, Lovat L, Delgado-Lopez JM, Carnona FJ, Guagliardi A, Masciocchi N and Pi Y. 2021. Urea-doped calcium phosphate nanoparticles as sustainable nitrogen nanofertilizers for viticulture: implications on yield and quality of Pinot Gris grapevines. *Agronomy* **11**:1026-1044.

Garhwal PC, Yadav PK, Sharma BD, Singh RS and Ramniw AS. 2014. Effect of organic manure and nitrogen on growth, yield and quality of kinnow mandarin in sandy soils of hot arid region. *African Journal of Agricultural Research* **9**(34):2638-2647.

Ghahremani A, Akbari K, Yousefpour M and Ardalani H. 2014. Efects of nano-potassium and nano-calcium chelated fertilizers on qualitative and quantitative characteristics of *Ocimum basilicum*. *Int. J. Pharm. Res. Sch.* **3**:540-550.

Ghahremani A, Akbari K, Yousefpour M and Ardalani H. 2014. Efects of nano-potassium and nano-calcium chelated fertilizers on qualitative and quantitative characteristics of *Ocimum basilicum*. *Int. J. Pharm. Res. Sch.* **3**:540-550.

Gill PPS, Ganaie MY, Dhillon WS and Singh NP. 2012. Effect of foliar sprays of potassium on fruit size and quality of 'Patharnakh' pear. *Indian Journal of Horticulture* **69**:512-516.

Glenn DM, Miller SS and Habecker MA. 1987. Effect of soil management and calcium nitrate fertilization on the availability of soil nitrate and cations in an eastern apple orchard. *Journal of the American Society for Horticultural Science* **112**:436-440.

Hafsi C, Debez A and Abdelly C. 2014. Potassium deficiency in plants: effects and signaling cascades. *Acta Physiologiae Plantarum* **36**(5):1055-1070.

Hagagg LF, Mustafa NS, Genaidy EAE and El-Hady ES. 2018a. Effect of spraying nano-NPK on growth performance and nutrients status for (Kalamat cv.) olive seedling. *Bioscience Research* **15**(2):1297-1303.

Hagagg LF, Merwad MA, Shahin MMF and El-Hady ES. 2020. Ameliorative effect of foliar application of calcium on vegetative growth and mineral contents of olive trees Kalmata and Manzanillo cultivars irrigated with saline water. *Bulletin of the National Research Centre* **44**:128.

Hagagg LF, Mustafa NS, Shahin MFM and El-Hady ES. 2018b. Impact of nanotechnology application on decreasing used rate of mineral fertilizers and improving vegetative growth of Aggizi olive seedlings. *Bioscience Research* **15**(2):1304-1311.

Halfacre RG, Baradent JA and Pollens JHA. 1968. Effect of alar on morphology, chlorophyll contents and net CO_2 assimilation rate of young apple trees. *Proceedings of the American Society for Horticultural Science* **193**:40-52.

Hao X and and Papadopoulos AP. 2003. Effects of calcium and magnesium on growth, fruit yield and quality in a fall greenhouse tomato crop grown on rockwool. *Canadian Journal of Plant Science* **83**(4): 903-912.

Harborne JB. 1973. Phytochemical Methods. Chapman and Hall Limited. London. England p. 49-188.

Hegab RH, Abou Batta WF and El-Shazly MM. 2018. Effect of mineral, nano and bio nitrogen fertilization on nitrogen content and productivity of *Salvia officinalis* L. plant. *Journal of Soil Science and Agricultural Engineering* **9**(9):393-401.

Hegazi ES, Mohamed SM, El-Sonbaty MR, Abd El-Naby SKM and El-Sharony TF. 2011. Effect of potassium nitrate on vegetative growth, nutritional status, yield and fruit quality of Olive cv. "Picual". *Journal of Horticultural Science and Ornamental Plants* **3**:252-58.

Hepler PK and Winship LJ. 2010. Calcium at the cell wall-cytoplast interface. *Journal of Integrative Plant Biology* **52**(2):147160.

Hikasa Y, Murmatsu H and Minegishe T. 1986. Effect of nitrogen application rate on the growth, yield and fruit quality of dwarf apple trees. *Bull Hokkaido Prefectural Agricultural Experimental Station* **55**:23-31.

Hiscox JD and Israelstam GF. 1979. A method for the extraction of chlorophyll content from leaf tissue without maceration. *Canadian Journal of Botany* **57**:1332-1334.

Hosseini A, Moradinezhad F, Khayyat M and Aminifard MH. 2021. Influence of Foliar Application of Calcium Nitrate and Potassium Nitrate on Qualitative and Quantitative Traits of Seedless Barberry (*Berberis vulgaris* L.). *Erwerbs-Obstbau* **63**:151-161.

Hudina M and Stampar F. 2002. Effect of phosphorus and potassium foliar fertilization on fruit quality of pears. *Acta Horticulturae* **594**:487-93.

Hussein AS, Abeed AHA, Usman ARA and Abou-Zaid EAA. 2024. Conventional vs. nano-micronutrients as foliar fertilization for enhancing the quality and nutritional status of pomegranate fruits. *Journal of the Saudi Society of Agricultural Sciences* **23**:112-122.

Ibrahim HKM, El-Hefnawi NN, Arafa MMA and Shahin SI. 2021. Effect of foliar application with calcium, boron and zinc on the yield and quality of strawberry fruits and post-harvest diseases. *Journal of Environmental Studies and Researches* **11**(2):300-314.

Ibrahim NM, Ismail SA, Mohamed NA and Ashour HM. 2017. Effect of some calcium sources on growth, yield, quality and storability of Jerusalem Artichoke. *Middle East Journal of Agriculture Research* **6**(3):766-778.

Imam NMAA and Al-Brifkany MA. 2010. Effect of nitrogen fertilization and foliar application of boron on fruit set, vegetative growth and yield of ‘Anna’ apple cultivar (*Malus X domestica* Borkh.). *Mesopotamia Journal of Agriculture* **38**:1815-1816.

Iqbal M, Niamatullah M and Mohammad D. 2012. Effect of different doses of nitrogen on economical yield and physico-chemical characteristics of apple fruits. *The Animal and Plant Sciences* **22**(1):165-168.

Jackson ML. 1973. Soil Chemical Analysis. Prentice Hall, New Delhi. India. 120 p.

Jadczuk E, Lipecki M, Jakubczyk H, Lata B, Sadoowshi A and Whitehead P. 1998. Influence of K fertilization on growth, yield and leaf mineral concentration in ‘Katja’ apple trees Ecological aspects of nutrition and alternatives for herbicides in horticulture. *International seminar, Warszawa, Poland* 27-28.

Jifon JL and Lester GE. 2008. Effects of foliar potassium fertilization on muskmelon fruit quality and yield. *HortScience*: a publication of the American Society for Horticultural Science.

Johnson RS and Uriu K. 1989. Mineral nutrition. **In**: *Peaches, Plums, and Nectarines – Growing and Handling for Fresh Market.* J.H. LaRue and R.S. Johnson, (Eds.), Univ. of California DANR Pub. No. 3331, pp. 68-91.

Kadir SA. 2005. Fruit quality at harvest of "Jonathan" apple treated with foliarly-applied calcium chloride. *Journal of Plant Nutrition* **27**(11):1991-2006.

Kaith NS and Awasthi RP. 1998. Effect of K on growth, yield, fruit quality and leaf nutrient status of apple Starking Delicious. *Indian Journal of Horticulture* **55**(1):10-15.

Kazemi M. 2013. Foliar application of salicylic acid and calcium on yield, yield component and chemical properties of strawberry. *Bulletin of Environment, Pharmacology and Life Sciences* **2**(11):19-23.

Kenworthy AL. 1964. Fruit, nut and plantation crops, deciduous and evergreen: a guide for collecting foliar samples for nutrient element analysis. Meno. Report Horticulture Department. Michigan State University. Michigan. USA.

Keram KS, Sharma BL and Sawarkar SD. 2012. Impact of Zn application on yield, quality, nutrients uptake and soil fertility in a medium deep black soil (vertisol). *International Journal of Science and Environment* **1**(5): 563-571.

Khan OA, Sofi JA, Kirmani NA, Hassan GI, Bhat SA, Chesti MH and Ahmad SM. 2019. Effect of N, P and K nano fertilizers in Red Delicious (*Malus* × *domestica* Borkh.). *Journal of Pharmacognosy and Phytochemistry* **8**:978-981.

Khayyat M, Tafazoli E, Eshghi S and Rajaee S. 2012. Effect of nitrogen, boron, potassium and zinc sprays on yield and fruit quality of date palm. *American-Eurasian J Agric Environ Sci* **2**:289-296.

Kilany AE and Kilany OA. 1991. Effect of potassium and boron nutrients on growth, yield and fruit quality of Anna apple trees. *Bul Facult Agr Uni Cairo* **42**:415-428.

Klein I, Levin I, Bar-Yosef B, Assaf R and Berkovitz A. 2006. Drip nitrogen fertigation of Starking Delicious apple trees. *Plant and Soil* **119**:305-314.

Komosa A and Szewezuk A. 2002. Effects of soil potassium level and different potassium fertilizer forms on the nutritional status, growth and yield of apple trees in the first three years after planting. *J Fruit Ornamental Pl Res* **10**:41-54.

Korkmaz GC. 2005. *The Effects of Foliar Application of Calcium and Boron on Fruit Quality of Different Apple Varieties Grafted on M9 Rootstock.* PhD Thesis, Uludag University Institute of Science and Technology.

Korkmaz N and Aşkin MA. 2015. Effects of calcium and boron foliar application on pomegranate (*Punica granatum* L.) fruit quality, yield, and seasonal changes of leaf mineral nutrition. *Acta Horticulturae* **1089**:413-422.

Korkmaz N, Askin MA, Ercisli S and Okatan V. 2016. Foliar application of calcium nitrate, boric acid and gibberellic acid affects yield and quality of pomegranate (*Punica Granatum* L.). *Acta Scientiarum Polonorum Hortorum Cultus* **15**(3):105-112.

Küçükyumuk Z and Erdal İ. 2022. Effect of calcium on mineral nutrient concentrations and fruit quality in different apple tree varieties. *J. Elem.* **27**(1):75-85.

Kulandaivel S, Mishra BN, Gangiah B and Mishra PK. 2004. Effect of levels of zinc and iron and their chelation on yield and soil micronutrient status in hybrid rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **49**(2): 80-83.

Kumar A, Joseph AV and Bahadur V. 2024. Effect of foliar application of nano urea, boron and zinc sulphate on growth, yield and quality of guava (*Psidium guajava* L.) cv. Allahabad Surkha. *Journal of Advances in Biology & Biotechnology* **27**(6):285-292.

Kumar J. 1984. *Effect of various system of orchard soil management at different levels of nitrogen in Santa Rosa plum*. Ph.D. Thesis. HPKVV, Palampur, India. 178p.

Kumar J and Chandel JS. 2004. Effect of different levels of N, P and K on growth and yield of pear cv. Red Bartlett. *Progressive Horticulture* **32**:202-206.

Kumar KGN, Sudha VV, Dorajee AVD, Subbaramamma P and Sujatha RV. 2017. Effect of foliar sprays of nitrogen, potassium and zinc on flowering and yield attributes of guava cv. Taiwan Pink. *International Journal of Current Microbiology and Applied Sciences* **6**:3475-3480.

Kurtyka R, Małkowski E, Kita A, Karcz W. 2008. Effect of calcium and cadmium on growth and accumulation of cadmium, calcium, potassium and sodium in maize seedlings. *Polish Journal of Environmental Studies* **17**(1):5156.

Larue C, Castillo-Michel H, Sobanska S, Cécillon L, Bureau S, Barthès V, Ouerdane L, Carrière M and Sarret G. 2014. Foliar exposure of the crop Lactuca sativa to silver nanoparticles: Evidence for internalization and changes in Ag speciation. *Journal of Hazardous Materials* **264**:98-106.

Lazarove I. 1985. Chemical and mineral composition of Williams pear fruit in relation to mineral fertilization. *Rastenievdni Nauki* **22**(4):89-95.

Li X, Li S, Qiang X, Yu Z, Sun Z, Wang R, He J, Han L and Li Q. 2024.Effects of water and nitrogen regulation on apple tree growth, yield, quality and their water and nitrogen utilization efficiency. *Plants* **13**-2404.

Lindsay WH and Norvell WA. 1978. Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Science Society of America Journal* **42**:420-428.

Lu YQ, Liu HP, Wang Y, Zhang XZ and Han ZH. 2013. Synergistic roles of leaf boron and calcium during the growing season in affecting sugar and starch accumulation in ripening apple fruit. *Acta Physiol. Plant.* **35**(8):2483-2492.

Maji S, Yadav A and Meena KR. 2017. Effect of calcium and boron on growth, yield and quality of pomegranate (*Punica granatum* L.). *International Journal of Plant Sciences* **12** (2):108-113.

Marshner H. 1995. Mineral Nutrition of Higher Plants. Academic Press, London.

Martín P, Delgado R, González MR and Gallegos JI. 2004. Colour of "Tempranillo" grapes as affected by different nitrogen and potassium fertilization rates. *Acta Horticulturae* **652**:153-159.

Medan RA. 2020. Effect of foliar application of potassium and calcium on vegetative growth, yield and fruit quality of "royal" apricot trees. *Plant Cell Biotechnol Mol Biol* **21**:106-112.

Meheriuk M, McKenzie DL, Neilsen GH and Hall JW. 1996. Fruit pigmentation of 4 green apple cultivars responds to urea sprays but not to nitrogen fertilization. *Horticulture Science* **31**(6):992-993.

Merwin HD and Peach M. 1951. Exchange ability of soil potassium in the sand, silt and clay fractions as influenced by the nature and complementary exchangeable cations. *Proceedings of American Soil Science* **15**:125-128.

Mimoun B and Marchand M. 2013. Effects of potassium foliar fertilization on different fruit tree crops over five years of experiments. *Acta Horticulturae* **984**:211-217.

Mirji P, Mukunda GK and Srinivasappa KN. 2023. Effect of nano NPK fertilizers on growth, yield and fruit quality of sapota [*Manilkara achrus* (Mill.). Fosberg] Cv. Kalipatti. *The Mysore Journal of Agricultural Sciences* **57**(1):245-250.

Mishra B, Sahu GS, Mohanty LK, Swain BC and Hati S. 2020. Effect of nano fertilizers on growth, yield and economics of tomato variety Arka Rakshak. *Indian Journal of Pure and Applied Biosciences* **8**(6):200-204.

Mohit ML and Thakur J. 2017. Effect of different nitrogenous fertilizers on fruit quality and yield of apricot (*Prunus armeniaca* L.). *Journal of Pharmacognosy and Phytochemistry* **6**:217-220.

Moradinezhad F and Dorostkar M. 2021. Pre-harvest foliar application of calcium chloride and potassium nitrate influences growth and quality of apricot (*Prunus armeniaca* L.) Fruit cv. 'Shahroudi'. *Journal of Soil Science and Plant Nutrition* **21**:1642-1652.

Moradinezhad F and Jahani M. 2019. Effect of potassium permanganate, 1-Methylcyclopropene and modified atmosphere packaging on postharvest losses and quality of fresh apricot cv. Shahroudi. *J Hortic Postharvest Res* **2**:39-48.

Morwal BR and Das S. 2021. Foliar application of boron and calcium nitrate decreased fruit cracking and improved quality in pomegranate (*Punica granatum* L.). *Journal of Krishi Vigyan* **9**:72-75.

Mosa WFA El-Gleel, EL-Megeed NAB, and Paszt LS. 2015. The Effect of the Foliar Application of Potassium, Calcium, Boron and Humic Acid on Vegetative Growth, Fruit Set, Leaf Mineral, Yield and Fruit Quality of 'Anna' Apple Trees. *American Journal of Experimental Agriculture* **8**(4):224-234.

Mostafa EAM and Saleh MMS. 2006. Response of Balady mandarin trees to girdling and potassium sprays under sandy soil conditions. *Res J Agri Biological Sci* **2**:137-41.

Mostafa EAM, Abd-El-Migeed MMM and Saleh MMS. 2005. Effect of some macro nutrients sprays on mineral status, yield and fruit quality of Hamlin orange trees grown under Rafah conditions. *J Agric Sci Mansoura Univ* **25**:403-11.

Mousavi SR and Rezaei M. 2011. Nanotechnology in agriculture and food production. *Journal of Applied Environmental and Biological Sciences* **1**:414-419.

Mukadam SJ and Haldankar PM. 2013. Effect of paclobutrazol and post flowering foliar sprays of nutrients for accelerating harvesting of Karonda (*Carissa carandas* Linn.). *J Pl Studies* **2**:145.

Nabi HMA, Dawa KK, El-Gamily EI and Imryed YFE. 2017. Effect of magnetic water, foliar application with nanomaterial and nitrogen levels on productivity and quality of head lettuce. *International Journal of Advanced Research in Biological Sciences* **4**(5):171-181.

Naiema MS. 2003. Effect of different doses of nitrogen and potassium on leaf mineral content, fruit set, yield and fruit quality of apple grown in calcarious soils. *Alexandria Journal of Agricultural Research* **48**(1):85- 92.

Nava G, Dechen AR and Nachtigall GR. 2007. Nitrogen and potassium fertilization affect apple fruit quality in Southern Brazil. *Communication in Soil Science and Plant Analysis* **39**(1/2):96-107.

Neilsen GH and Neilsen D. 2011. Consequences of potassium, magnesium sulphate fertilization of high density Fuji apple orchards. *Canadian Journal of Soil Sciences* **91**(6):1013-1027.

Neilsen GH and Neilson D. 2006. The effect of K-fertilization on apple fruit Ca concentration and quality. *Acta Horticulturae* **721**:177-183.

Neilsen GH, Meheriuk M and Hogue EJ. 1984. The Effect of orchard floor and N fertilizer on nutrient uptake and fruit quality of "Golden Delicious" apple trees. *HortScience* **19**:547-50.

Nibin PM and Ushakumari. 2019. Organic nano NPK formulations for enhancing soil post-harvest nutrient status of bhindi. *Journal of Pharmocognosy and Phytochemistry* **2**:22-25.

Nijjar G S. 1985. Nutrition of Fruit Trees. Kalyani Publisher. New Delhi. India. 320 p.

Nikbakht M, Solouki M and Aran M. 2021. Effects of foliar application of nano-nitrogen and urea fertilizers on quantity and quality properties of bitter apple (*Citrullus colocynthis* L.). *Spring* **1**(23):155-168.

Norozi M, ValizadehKaji B, Karimi R and Sedghi MN. 2019. Effects of foliar application of potassium and zinc on pistachio (*Pistacia vera* L.) fruit yield. *International Journal of Horticultural Science and Technology* **6**(1):113-123.

Okba, SK, Mazrou Y, Elmenofy HM, Ezzat A and Salama AM. 2021. New insights of potassium sources impacts as foliar application on 'Canino' Apricot fruit yield, fruit anatomy, quality and storability. *Plants* **10**:1163.

Olsen SR, Cole CV, Watanable FS and Dean LA. 1954. Estimation of available phosphorus by extraction with sodium bicarbonate. United States Department of Agriculture, Circular Number 939. pp.19-23.

Ortiz A, Graell J and Lara I. 2011. Cell wall-modifying enzymes and firmness loss in ripening 'golden reinders' apples: a comparison between calcium dips and ULO storage. *Food Chem* **128**:1072-1079.

Panda J, Nandi A, Mishra SP, Pal AK, Pathak AK and Jena NK. 2020. Effects of nano fertilizer on yield, yield attributes and economics in tomato (*Solanum lycopersicum*). *International Journal of Current Microbiology and Applied Sciences* **9**:2583-2591.

Panse VG and Sukhatme PV. 2000. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi. India. 381 p.

Papp J. 2000. Effect of nitrogen dressings to Jonathan apple trees in a long term experiment. *International Journal of Horticultural Sciences* **6**(1):128-130.

Parizad M, Mehrdad Y, Reza A, Alireza T, Hosein M. 2017. Comparison of the effect of nano urea and nano Iron fertilizers with common chemical fertilizers on some growth traits and essential oil Production of *Borago officinalis* L. *Journal of dairy and Veterinary Sciences* **2**(2):555-585.

Pathak PK, Majumdar K and Mitra SK. 2013. Levels and time of potassium fertilization influence soil and leaf nutrient composition and its relation with yield of litchi. *Indian Journal of Horticulture* **69**:33-38.

Pettigrew WT. 2008. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. *Physiol Plant* **133**:670-681.

Piper CS. 1966. Soil and Plant Analysis. Hans Publishers. Bombay. India. pp. 40-51.

Prasad B, Dimri DC and Bora L. 2015. Effect of pre-harvest foliar spray of calcium and potassium on fruit quality of pear cv. Pathernakh. *Sci Res Essays* **10**:376-380.

Rackso J, Szabo Z and Nyeki J. 2005. Effect of nutrient supply on fruit quality of apple (*Malus x domestica* Borkh). *Journal of Central European Agriculture* **6**:35-41.

Raese JT and Drake SR. 2000. Effect of calcium spray materials, rate, time of spray application and rootstocks on fruit quality of 'red' and 'golden delicious' apples. *Journal of Plant Nutrition* **23**:1435-1447.

Rahman El-A bd and Naglaa El-Abd. 2022. Effect of Nano-N fertilizer on growth, fruiting and the fruits nutritive value of zaghloul date palm. SVU-*International Journal of Agricultural Sciences* **4**(1):124-134.

Rai V, Acharya S and Dey N. 2012. Implications of nanobiosensors in Agriculture. *Journal of Biomaterial and Nano biotechnology* **3**:315-324.

Rajesh, Choudhary M, Kumar R, Meena RK, Ram H, Kumar M, Kumar V, Makarana G, Kumar D and Basu U. 2023. Assessment of growth parameters in oats (*Avena sativa* L.) with application of nano urea fertilizer: A field-based study. *International Journal of Environment and Climate Change* **13**(3):65-72.

Ramesh D, Kumar ST, Venkatalaxmi K and Kumar KCH. 2016. Effect of foliar application of urea, KNO_3 and $ZnSO_4$ on yield and yield contributing characters of custard apple (*Annona Squamosa* L.) cv. Balanagar. *International Journal of Agriculture Sciences* **8**:3371-3373.

Ramezani S and Shekafandeh A. 2011. Influence of Zn and K Sprays on fruit and pulp growth in olive (*Olea europaea* L. cv. 'Amygdalifolia'). *Iran Agricultural Research* **30**:1-10.

Ramezanian A, Rahemi M and Vazifehshenas MR. 2009. Effects of foliar application of calcium chloride and urea on quantitative and qualitative characteristics of pomegranate fruits. *Scientia Horticulturae* **121**(2):171-175.

Ranganna S. 1995. Handbook of Analysis and Quality Control for Fruits and Vegetable products. Tata McGraw Hill Publishing Company Limited. New Delhi. India. pp.1-21.

Ranganna S. 1997. Handbook of Analysis and Quality Control for Fruits and Vegetable products. 2nd ed., Tata McGraw Hill Publication Company Limited. New Delhi. India. 112 p.

Ranjbar S, Rahemi M and Ramezanian A. 2018. Comparison of nano-calcium and calcium chloride spray on postharvest quality and cell wall enzymes activity in apple cv. Red Delicious. *Scientia Horticulturae* **240**:57-64.

Rashid A, Kirmani NA, Nazir N and Shafi S. 2008. Quality of apple cv. Red Delicious as influenced by potassium. *Asian Journal of Soil Science* **3**:227-29.

Razzaquea AHM and Hanafib MM. 2001. Effect of potassium on growth, yield and quality of pineapple in tropical peat. *Fruit* **56**:45-49.

Reganold JP, Glover JD, Andrews PK and Hinman HR. 2001. Sustainability of three apple production systems. *Nature* **410**: 926-930.

Rentel MC and Knight MR. 2004. Oxidative stress induced calcium signaling in Arabidopsis. *Plant Physiology* **135**(3):14711479.

Robinson TL and Stiles W. 2000. Effect of source and timing of potassium fertilizer on 'Empire' apple tree growth, yield and fruit quality. *HortScience* **35**(3):481.

Robinson TL. 2006. Interaction of fertilization, rootstocks and irrigation on growth, thinning efficiency, yield and fruit quality of ‘Empire’ apple. *Acta Horticulturae* **721**:41-45.

Roosta HR, Samadi A and Bikdeloo M. 2023. Different cultivation systems and foliar application of calcium nanoparticles affect the growth and physiological characteristics of pennyroyal (*Mentha pulegium* L.). *Scientifc Reports* **13**:20334.

Roshdy KA and Refaai MM. 2016. Effect of nanotechnology fertilization on growth and fruiting of Zaghloul date palms. *Journal of Plant Production* **7**:93-98.

Ruiz R. 2006. Effects of different potassium fertilizers on yield, fruit quality and nutritional status of "Fairlane" nectarine trees and on soil fertility. *Acta Hort* **721**:185-190.

Saied HHM. 2018. Response of Keitte mango trees to spraying nano NPKMg fertilizers. *Researcher* **10**:1-5.

Saini P. 2011. *Comparative studies on effects on nitrogenous fertilizers on growth, fruit set and yield in plum cv. Santa Rosa*. Ph.D. Thesis. Dr. YS Parmar University of Horticulture and Forestry, Solan, India.

Sajid M, Ul Haq S, Jan A, Noor F, Ali QS, Alam M, Zaman A, Shah FA, Mosa WFA and Abada HS. 2022. Effect of foliar application with potassium nitrate and copper sulfate on fruit yield and quality of pear (*Pyrus communis* L.) trees. *International Journal of Fruit Science* **22**(1):759-768.

Sanas MP, Haldankar PM, Haldavnekar PC and Dhekale JS. 2015. Effect of post-flowering foliar nutrient sprays on maturity, yield and quality of Karonda (*Carissa conjesta* L.) cv. ‘Konkan Bold’. *Ecology, Environment and Conservation Paper* **21**:1789-1794.

Sarker BC and Rahim MA. 2013. Yield and quality of mango (*Mangifera indica* L.) as influenced by foliar application of potassium nitrate and urea. *Bangladesh Journal of Agricultural Research* **38**(1):145–154.

Sarma V A K, Krishna P and Budihal S L. 1987. Soil Resource Mapping of Different States in India - A Laboratory Manual. National Bureau of Soil Survey and Land Use Planning, Nagpur. 49p.

Saure MC. 1990. External control of anthocyanin formation in apple. *Scientia Horticulturae* **42**:181-218.

Sayah ZN and Jameel DA. 2020. Effect of nano NPK balanced fertilizer (20-20-20) on some vegetative and fruiting growth of *Cucurbita pepo* L. *EurAsian Journal of BioSciences* **14**:6627-6633.

Shabana HA, Zaed A and Alsunbl A. 2006. Fruit date palm physiology: harvest and post-harvest. Publications of the Food and Agriculture Organization of the United Nations. Rome. Italy.

Shams AS. 2019. Foliar application of nano chitosan-urea and inoculation with mycorrihza on kohlrabi (*Brassica oleracea* var. *gongylodes* L.). *Journal of Plant Production* **10**(10):799-805.

Sharaf-Eldin MA, Elsawy MB, Eisa MY, El-Ramady H, Usman M and Zia-ur-Rehman M. 2022. Application of nano-nitrogen fertilizers to enhance nitrogen efficiency for lettuce growth under different irrigation regimes. *Pakistan Journal of Agricultural Sciences* **59**(3):367-379.

Sharma SK, Kapoor S and Rana SS. 2016. Effect of the application of nitrogen, zinc and boron on soil properties and available nutrients status after the harvest of wheat. *International Journal of Advances in Agricultural Science and Technology* **3**(7): 12-20.

Sharma YP. 1987. *Response of peach trees to nitrogen and weed management practices*. Ph.D. Thesis. Dr. YS Parmar University of Horticulture and Forestry, Solan.

Sharma VK, Tiwari R and Chouhan P. 2014. Effect of N, P and their interaction on physico-chemical parameters of Guava (*Psidium guajava*) cv. L-49 under Malwa Plateau conditions. *International Journal of Scientific and Research Publications* **4**(11):1-4.

Shen C, Ding Y, Lei X, Zhao P, Wang S, Xu Y and Dong C. 2016. Effects of foliar potassium fertilization on fruit growth rate, potassium accumulation, yield and quality of 'Kousui' Japanese Pear. *HortTechnology* **26**(3):270-277.

Shinde VN, Waghmare GM, Yadlod SS and Dhamak AL. 2019. Effect of foliar application potassium forms, micronutrients and its combination on quality attributes of sweet orange (*Citrus sinensis* L Osbeck). *International Journal of Chemical Studies* **7**(3):4840-4842.

Simnani SA. 2012. *Management of apple orchards by plant bio-regulators and nutrient sprays for improvement in growth, yield and quality of apple (Malus domestica Borkh.) cv. Red Delicious*. PhD Thesis, S.K. University of Agricultural Sciences and Technology of Kashmir, Srinagar.

Singh D. 1992. *Effect of pruning intensities under different levels of nitrogen on growth, yield and quality of peach (Prunus persica Batsch.). cv. July Elberta*. Ph.D. Thesis. Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, India.

Singh JN, Singh DK and Chakravarthy D. 1994. Effect of urea and NAA on fruit retention and physicochemical composition of mango (*Mangifera indica* L.) cv. Langra. *Orissa Journal of Horticulture* **22**:26-30.

Singh NP, Malhi CS and Sharma RC. 2005. Effect of foliar feeding of N, P and K on vegetative and fruiting characteristics of Mango cv. Dashehari. *International Conference on Mango and Date Palm; Culture and Export*. p. 27-31.

Singh VP, Kumar G and Singh AK. 2007. Effect of water soluble fertilizer 'Polyfeed" on physicochemical attributes of litchi fruits cv. Rose Scented. *Prog Agric* **7**:22-24.

Sinha A, Jawandha SK, Gill PPS and Singh H. 2019. Influence of pre-harvest sprays of calcium nitrate on storability and quality attributes of plum fruits. *Journal of Food Science and Technology* **56**:1427–1437.

Smith CB. 1962. Mineral analysis of plant tissue. *Plant physiology* **13**:81-108.

Sohair EED, Abdall AA, Amany AM, Hossain MF and Houda RA. 2018. Evaluation of nitrogen, phosphorus and potassium nano-fertilizers on yield, yield components and foliar properties of Egyptian cotton (*Gossypium barbadense* L.). *Journal of Plant Sciences and Crop Protection* **1**:208-219.

Solhjoo S, Gharaghani A and Fallahi E. 2017. Calcium and potassium foliar sprays affect fruit skin color, quality Attributes and mineral nutrient concentrations of 'Red Delicious' apples. *International Journal of Fruit Science* **17**(4):358-373.

Soliman SS, Alebidi AI, Al-Obeed, RS and Al-Saif AM. 2018. Effect of potassium fertilizer on fruit quality and mineral composition of fig (*Ficus carica* L. cv. Brown Turky). *Pakistan Journal of Botany* **50**(5):1753-1758.

Southwick SM, Olson W, Yeager J and Weis KG. 1996. Optimum timing of potassium nitrate spray application to "French" prune trees. *J Am Soc Hort Sci* **121**:326-33.

Su X, Bai C, Wang X, Liu H, Zhu Y, Wei L, Cui Z and Yao L. 2022. Potassium sulfate spray promotes fruit color preference via regulation of pigment profile in litchi pericarp. *Frontiers in Plant Sci*ences **13**:925609.

Subbiah BV and Asija GL. 1956. Rapid procedure for the estimation of the available nitrogen in soils. *Current Science* **25**:259-60.

Sun J, Li W, Li C, Chang W, Zhang S, Zeng Y, Zeng C and Peng M. 2020. Effect of different rates of nitrogen fertilization on crop yield, soil properties and leaf physiological attributes in banana under subtropical regions of China. *Frontiers in Plant Science* **11**:613760.

Sürücü O and Küçükyumuk Z. 2023. Effect of foliar potassium and calcium applications on the nutrient status, fruit quality and yield of apple tree varieties. *Journal of Elementology* **28**(1):173-187.

Świątkiewicz D and Błaszczyk J. 2009. Effect of calcium nitrate spraying on mineral contents and storability of 'Elise' apples. *Polish Journal of Environmental Studies* **18**(5):971-976.

Taha RA, Hassan HSA and Shaaban EA. 2014. Effect of different potassium fertilizer forms on yield, fruit quality and leaf mineral content of Zebda mango trees. *Middle East J Scientific Res* **12**:123-129.

Tehranifar A and S Mahmoodi Taber. 2009. Foliar application of potassium and boron during pomegranate (*Punica granatum*) fruit development can improve fruit quality. *Hort. Environ. Biotechnol* **50**:1-6.

Tejashvini A and Thippeshappa GN. 2019. Effect of foliar application of different sources and levels of calcium on physico-chemical properties of harvested soil and correlation of calcium nutrition with fruit quality. *International Journal of Current Microbiology and Applied Sciences* **8**(02): 1447-1455.

Tohidloo G, Souri MK and Eskandarpour S. 2018. Growth and fruit biochemical characteristics of three strawberry genotypes under different potassium concentrations of nutrient solution. *Open Agriculture* **3**:356-362.

Tuckey RB. 1983. Calcium spray for sweet cherries. (In) *'Proceedings of Washington State Horticulture Association'* **79**:194-98.

Tzoutzoukou CG and Bouranis DL. 1997. Effect of preharvest application of calcium on the postharvest physiology of apricot fruit. *Journal of Plant Nutrition* **20**(2-3):295-309.

Uçgun K and Altindal Mesut. 2021. Effects of increasing doses of nitrogen, phosphorus and potassium on the uptake of other nutrients in Sweet Cherry Trees. *Communications in Soil Science and Plant Analysis* 1-7.

Usherwood NR. 1985. The role of potassium in crop quality. In: Munson RD (ed) Potassium in Agriculture. Pp. 489-13. ASA-CSSA-SSSA, Madison, WI.

Verma ML and Bhardwaj SP. 2005. Organic farming for apple production using ramban organic manure in temperate zone of Himachal Pradesh. *The Horticultural Journal* **18**: 94-97.

Verma ML, Sharma R, Singh C and Rathore AC. 2010. Influence of organic manuring on apple performance and soil properties in temperate zone of Himachal Pradesh. *Indian Journal of Soil Conservation* **38**(3):212- 216.

Verma ML, Singh C and Bhardwaj SP. 2009. Effects of Bioferlilizers on soil moisture, nutrient status and fruit productivity Himachal Pradesh. *Indian Journal of Soil Conservation* **37**(3): 201-205.

Verma ML. 2008. Effect of organic manures on growth and yield of apple in temperate zone of Himachal Pradesh. *The Horticultural Journal* **21**(3): 113-116.

Vijay, Dalal RPS, Beniwal BS and Saini H. 2017. Effect of foliar application of potassium and its spray schedule on yield and yield parameters of sweet orange (*Citrus sinensis* Osbeck) cv. Jaffa. *Journal of Applied and Natural Science* **9**(2):786-790.

Vishekaii ZR, Soleimani A, Ghasemnezhad M and Hasani A. 2019. The feasibility for replacement of urea with nitrogen nano-chelated fertilizer in olive (*Olea europaea* L.) orchards. *Iranian Journal of Plant Physiology* **10**:3047-3058.

Vishekaii ZR, Soleimani A, Ghasemnezhad M and Hasani A. 2024. Effect of foliar application of different sources of nano-chelate fertilizer (Nitrogen and Potassium) and chemical fertilizers (Urea and Potassium Nitrate) on yield and oil's quantity attributes of olive tree cv. Zard. *Journal of Horticultural Science* **38**(1):147-164.

Vishekaii ZR, Soleimani A, Hasani A, Ghasemnezhad M, Rezaei K and Kalanaky S. 2021. Nano-chelated nitrogen fertilizer as a new replacement for urea to improve olive oil quality. *International Journal of Horticultural Science and Technology* **8**:191-201.

Vogel AL. 1978. Practical Organic Chemistry (4th edition). Longman-ELBS, London.

Walkley AJ and Black LA. 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Science* **37**:259-260.

Walsch CS, Allnutt FJ, Miller AN and Thompson AH. 1989. Nitrogen level and time of mechanized summer shearing influence long term performance of a high density Red skin peach orchard. *Journal of the American Society for Horticultural Science* **114**:373-377.

Wargo JM, Merwin IA and Watkins CB. 2003. Fruit size, yield and market value of 'Gold Rush' apple are affected by amount, timing and method of nitrogen fertilization. *Hort. Technology* **13**(1):153-161.

Weber NC, Koron D, Jakopic J, Veberic R, Hudina M and Cesuk H B. 2021. Influence of nitrogen, calcium and nano-fertilizer on strawberry (*Fragaria* × *ananassa* Duch.) fruit inner and outer quality. *Agronomy* **11:**997-1015.

Westwood MN. 1978. Plant efficiency, growth and yield measurements. **In**: Temperate Zone Pomology. WH Freeman and company, San Fransisco. pp.119-20.

Widmer A, Stadler W and Krebs E. 2006. Effect of foliar applications of urea and boron on *Malus domestica* and *Pyrus communis*. *Acta Horticulturae* **721**:227-233.

Wilson RW. 1941. Horticultural Colour Charts I and II. Wilson Colour Ltd. In collaboration with the Royal Horticultural Society. England.

Wójcik P and Lewandowski L. 2003. Effect of calcium and boron sprays on yield and quality of "Elsanta" strawberry. *Journal of Plant Nutrition* **26**(3):671-682.

Wrona D, Sadowski A, Ostrowski J, Taglivini M, Neilsen GH and Millard P. 1995. Potassium fertilization trials in commercial apple orchards. *Acta Horticulturae* **383**:481-486.

Xia G, Cheng L, Lakso A and Goffinet M. 2009. Effects of nitrogen supply on source-sink balance and fruit size of 'Gala' apple trees. *Journal of the American Society for Horticultural Science* **134**:126-133.

Xie HS and Cummings GA. 1995. Effect of soil pH and nitrogen source on nutrient status in peach. *Journal of Plant Nutrition* **18**:541-551.

Xu X, Du X, Wang F, Sha J, Chen Q, Tian G, Zhu Z, Ge S and Jiang Y. 2020. Effects of potassium levels on plant growth, accumulation and distribution of carbon, and nitrate metabolism in apple dwarf rootstock seedlings. *Front Plant Sci* **11**(904):1-13.

Yahmed JB and Mimoun MB. 2019. Effects of foliar application and fertigation of potassium on yield and fruit quality of 'Superior Seedless' grapevine. *Acta Horticulturae* **1253**:367-372.

Yathish C, Fathima PS, Pushpa K, Krupashree R and Theerthana T. 2021. Effect of foliar application of calcium nitrate, boron and on growth, yield and economics of transplanted pigeonpea. *International Journal of Current Microbiology and Applied Sciences* **10**(05): 68-78.

Youssef SMS, Abd El-Hady SA, Abu NAI, El-Azm and El-Shinawy MZ. 2017. Foliar application of salicylic acid and calcium chloride enhances growth and productivity of Lettuce (*Lactuca sativa*). *Egyptian Journal of Horticulture* **44**(1):1-16.

Zargar M, Tumanyan A, Ivanenko E, Dronik A, Tyutyuma N and Pakina E. 2019. Impact of foliar fertilization on apple and pear trees in reconciling productivity and alleviation of environmental concerns under arid conditions. *Communicative and Integrative Biology* **12**(1): 1-9.

APPENDIX -I

Weekly meteorological data for the year 2022

Standard Meteorological Week	Temperature ºC		Relative Humidity (%)		Sunshine (hr)	Rainfall (mm)
	Maximum	Minimum	I	II		
1	10.06	2.40	50.43	57.29	3.89	31.20
2	7.23	-0.14	67.57	70.29	3.99	41.80
3	11.09	3.06	44.00	51.00	4.13	1.00
4	4.31	-1.43	74.00	71.71	1.69	34.40
5	9.76	1.77	47.86	44.00	5.74	23.00
6	9.84	-0.04	37.86	27.43	6.10	13.50
7	11.54	2.93	24.71	28.14	8.01	0.00
8	12.37	2.66	46.71	40.86	6.79	19.90
9	11.66	3.26	46.57	58.00	4.09	23.00
10	17.26	8.24	33.14	36.86	6.41	0.00
11	21.51	12.34	48.29	50.57	8.16	0.00
12	21.43	15.17	69.57	78.71	6.41	1.00
13	22.33	11.91	88.00	89.43	8.56	0.00
14	23.91	12.17	90.57	85.57	8.86	0.00
15	24.93	13.80	89.43	87.57	7.80	0.00
16	23.90	13.59	89.71	91.86	8.06	0.00
17	24.33	12.13	89.71	85.29	9.37	0.00
18	24.11	12.83	90.71	92.29	6.39	22.80
19	23.99	12.39	86.14	89.00	8.89	8.40
20	26.86	16.17	87.71	63.71	9.20	3.20
21	22.67	10.77	80.43	61.14	6.39	62.10
22	25.41	12.21	83.00	73.57	8.49	2.40
23	27.50	17.93	36.86	32.43	9.97	0.00
24	27.44	15.74	58.14	54.14	7.87	44.70
25	21.91	12.77	87.29	90.86	3.70	17.50
26	24.59	15.07	93.00	91.43	3.39	10.40
27	24.39	15.91	90.00	85.86	2.64	89.60
28	22.74	16.19	84.57	87.14	1.83	47.30
29	23.66	16.17	84.86	81.57	3.33	40.00
30	20.97	15.61	88.71	90.29	0.54	63.40
31	20.79	15.67	91.86	85.86	0.89	132.80
32	23.04	16.30	83.43	84.14	1.80	58.80
33	24.27	16.07	91.57	89.29	3.44	78.30
34	21.46	16.36	87.86	86.71	2.24	135.70
35	22.39	15.87	88.86	80.57	3.69	13.90
36	21.47	14.66	82.00	76.86	3.69	3.00
37	21.51	14.73	84.29	81.29	2.63	9.60
38	20.57	15.29	83.14	86.43	1.96	132.70
39	20.30	12.74	76.86	83.00	3.73	73.10
40	22.30	13.11	75.00	87.00	6.96	2.00

Weekly meteorological data for the year 2023

Standard Meteorological Week	Temperature ºC		Relative Humidity (%)		Sunshine (hr)	Rainfall (mm)
	Maximum	Minimum	I	II		
1	11.19	1.09	84.86	87.57	5.90	0.00
2	14.29	0.53	36.43	41.29	4.20	15.60
3	9.00	0.21	48.86	52.43	4.99	8.90
4	11.67	1.29	46.00	48.43	5.20	6.30
5	13.31	1.66	32.00	33.29	5.60	16.10
6	13.60	3.53	50.43	43.71	5.81	3.70
7	16.40	3.83	31.29	26.00	7.79	0.00
8	17.71	6.13	23.71	27.86	6.83	23.40
9	15.16	4.77	43.43	36.57	5.84	5.20
10	16.59	6.49	48.29	44.71	6.81	28.30
11	16.89	7.50	54.43	51.43	5.49	34.40
12	12.80	4.93	70.14	68.14	2.67	44.20
13	15.49	5.77	56.29	58.14	3.54	51.70
14	14.64	4.14	53.14	55.71	5.77	48.00
15	20.59	10.26	43.29	32.71	9.00	0.00
16	20.10	9.43	46.00	42.14	5.21	104.30
17	18.04	8.31	46.57	43.86	4.20	34.00
18	15.24	8.14	72.57	73.86	3.80	120.60
19	20.71	11.29	41.00	34.71	8.77	10.30
20	23.53	11.63	50.00	32.71	9.03	0.30
21	23.51	10.06	50.29	46.00	7.57	45.50
22	19.46	9.53	55.43	71.71	4.54	54.20
23	23.27	9.89	44.71	52.57	8.70	2.00
24	24.51	13.19	58.71	54.00	7.63	9.10
25	24.44	16.03	82.71	76.00	3.69	71.50
26	22.17	15.74	84.14	84.71	1.56	132.50
27	22.71	15.40	82.14	85.71	2.43	60.60
28	22.14	14.37	94.29	90.14	0.69	258.60
29	22.53	16.24	87.86	89.14	0.80	56.60
30	22.66	16.00	85.29	84.14	2.31	16.80
31	22.14	15.79	90.57	83.43	1.54	66.70
32	22.43	15.94	93.00	87.14	3.24	74.60
33	20.97	15.43	88.14	89.57	1.47	187.80
34	21.53	15.43	89.29	85.29	2.87	117.30
35	23.40	14.93	77.57	70.86	6.53	0.00
36	24.03	15.61	72.43	67.29	6.80	14.30
37	22.74	15.56	84.29	82.29	1.90	0.00
38	21.43	14.94	83.14	78.71	3.20	50.50
39	22.51	13.43	56.57	55.57	6.00	1.10
40	22.94	12.89	53.43	50.00	6.86	3.40

APPENDIX –II

Effect of graded level of N and nano-N on tree height (m) and tree spread (m)

Treatment	Tree Height (m)			Tree Spread (m)		
	2021	**2022**	**2023**	**2021**	**2022**	**2023**
T_1- Soil application of 100% RDN + 0.5% urea at Pink bud stage- **Control**	3.24	3.46	3.69	2.38	2.57	2.77
T_2- Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage	3.21	3.42	3.64	2.34	2.52	2.71
T_3- Soil application of 25% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage	3.15	3.36	3.57	2.27	2.45	2.63
T_4- Soil application of 25% RDN + nN @ 500 ppm split at Pink bud and Fruit Set stage	3.32	3.54	3.77	2.43	2.62	2.82
T_5- Soil application of 25% RDN + nN @ 500 ppm split at Pink bud, Fruit Set and Walnut stage	3.08	3.29	3.50	2.24	2.42	2.60
T_6- Soil application of 50% RDN + nN @ 175 ppm split at Pink bud and Fruit Set stage	3.25	3.47	3.70	2.39	2.58	2.78
T_7- Soil application of 50% RDN + nN @ 175 ppm split at Pink bud, Fruit Set and Walnut stage	3.16	3.38	3.60	2.28	2.47	2.66
T_8- Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage	3.28	3.51	3.76	2.39	2.59	2.80
T_9- Soil application of 50% RDN + nN @ 250 ppm split at Pink bud, Fruit Set and Walnut stage	3.22	3.45	3.69	2.35	2.55	2.75
T_{10}- Soil application of 50% RDN + nN @ 350 ppm split at Pink bud and Fruit Set	3.30	3.53	3.77	2.41	2.61	2.82
T_{11}- Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage	3.20	3.42	3.65	2.34	2.53	2.73

Effect of graded level of N and nano-N on tree girth (cm) and tree volume (m^3)

Treatment	Tree Girth (cm)			Tree Volume (m^3)		
	2021	2022	2023	2021	2022	2023
T_1- Soil application of 100% RDN + 0.5% urea at Pink bud stage- **Control**	40.29	41.36	42.47	7.77	11.96	16.94
T_2- Soil application of 25% RDN+ nN @ 350 ppm split at Pink bud and Fruit Set stage	38.42	39.54	40.51	7.58	11.36	15.86
T_3- Soil application of 25% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage	35.34	36.22	37.13	6.62	10.47	15.02
T_4- Soil application of 25% RDN + nN @ 500 ppm split at Pink bud and Fruit Set stage	37.77	38.71	39.68	8.81	12.72	17.33
T_5- Soil application of 25% RDN + nN @ 500 ppm split at Pink bud, Fruit Set and Walnut stage	34.58	35.47	36.37	6.11	10.08	14.77
T_6- Soil application of 50% RDN + nN @ 175 ppm split at Pink bud and Fruit Set stage	40.75	41.82	42.91	7.96	12.09	16.89
T_7- Soil application of 50% RDN + nN @ 175 ppm split at Pink bud, Fruit Set and Walnut stage	35.67	36.63	37.62	6.60	10.79	15.69
T_8- Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage	36.82	37.86	38.95	7.88	12.32	17.54
T_9- Soil application of 50% RDN + nN @ 250 ppm split at Pink bud, Fruit Set and Walnut stage	39.86	40.97	42.13	7.37	11.74	16.86
T_{10}- Soil application of 50% RDN + nN @ 350 ppm split at Pink bud and Fruit Set	37.22	38.24	39.30	8.25	12.58	17.67
T_{11}- Soil application of 50% RDN + nN @ 350 ppm split at Pink bud, Fruit Set and Walnut stage	38.59	39.63	40.71	7.17	11.45	16.47

Effect of foliar application of K and Ca on tree height (m) and tree spread (m)

Treatment	Tree Height (m)			Tree Spread (m)		
	2021	2022	2023	2021	2022	2023
T_1- Water spray- **Control**	3.28	3.48	3.69	2.38	2.56	2.74
T_2- KNO_3 @ 0.5% at Walnut stage	3.34	3.56	3.80	2.44	2.64	2.84
T_3- K_2SO_4 @ 0.5% (45 days before harvesting)	3.14	3.34	3.55	2.25	2.42	2.60
T_4- $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)	3.25	3.47	3.70	2.37	2.56	2.75
T_5- KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting)	3.11	3.32	3.54	2.23	2.41	2.60
T_6- KNO_3 @ 0.5% at Walnut stage + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)	3.34	3.58	3.83	2.45	2.66	2.88
T_7- K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)	3.14	3.36	3.56	2.26	2.45	2.64
T_8- KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)	3.19	3.43	3.69	2.31	2.52	2.74
T_9- KNO_3 @ 0.5% at Walnut stage + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)	3.22	3.45	3.70	2.33	2.53	2.74
T_{10}- K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)	3.31	3.54	3.79	2.42	2.62	2.83
T_{11}- KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)	3.14	3.38	3.63	2.27	2.47	2.68

Effect of foliar application of K and Ca on tree girth (cm) and tree volume (m^3)

Treatment	Tree Girth (cm)			Tree Volume (m^3)		
	2021	2022	2023	2021	2022	2023
T_1- Water spray- **Control**	40.62	41.66	42.74	8.15	11.93	16.30
T_2- KNO_3 @ 0.5% at Walnut stage	41.26	42.35	43.48	9.01	12.98	17.53
T_3- K_2SO_4 @ 0.5% (45 days before harvesting)	37.36	38.33	39.34	6.37	10.23	14.39
T_4- $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)	40.14	41.18	42.27	7.98	11.90	16.41
T_5- KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting)	37.90	38.91	39.97	6.01	10.09	14.75
T_6- KNO_3 @ 0.5% at Walnut stage + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)	41.94	43.12	44.36	9.02	13.26	18.09
T_7- K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)	38.67	39.72	40.82	6.40	10.55	15.29
T_8- KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)	38.92	40.08	41.29	7.04	11.40	16.37
T_9- KNO_3 @ 0.5% at Walnut stage + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)	39.39	40.53	41.72	7.28	11.56	16.45
T_{10}- K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)	41.71	42.86	44.06	8.52	12.72	17.51
T_{11}- KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (30, 45 and 60 days before harvesting)	38.35	39.47	40.64	6.47	10.79	15.73

APPENDIX - III

ANALYSIS OF VARIANCE FOR DIFFERENT PARAMETERS

EXPERIMENT - I

1. Analysis of variance for soil pH, EC and organic carbon status

Source of variation	DF	Mean sum of square					
		Soil pH		Soil EC (dS/m)		Organic Carbon (g kg^{-1})	
		2022	2023	2022	2023	2022	2023
Replication	2	0.003	0.003	0.001	0.001	0.689	0.542
Treatment	10	0.125	0.146	0.081	0.083	3.470	3.885
Error	20	0.139	0.140	0.075	0.079	3.228	3.514
Total	32	0.267	0.289	0.157	0.163	7.387	7.942

Source of variation	DF	Mean sum of square		
		Soil pH	Soil EC (dS/m)	Organic Carbon (g kg^{-1})
		Pooled	Pooled	Pooled
Replication	2	0.006	0.001	1.23
Year (Y)	1	0.001	0.001	0.269
Treatment (T)	10	0.268	0.165	7.315
Y× T	10	0.003	0	0.042
Error	42	0.279	0.154	6.745
Total	65	0.556	0.321	15.60

2. Analysis of variance for available soil N, P and K status

Source of variation	DF	Mean sum of square					
		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
		2022	2023	2022	2023	2022	2023
Replication	2	421.211	359.491	32.418	19.040	167.220	182.625
Treatment	10	7001.789	6825.69	112.572	121.068	221.889	254.722
Error	20	1407.186	1242.42	127.573	128.277	289.879	265.438
Total	32	8830.186	8427.60	272.563	268.384	678.988	702.785

Source of variation	DF	Mean sum of square		
		Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
		Pooled	Pooled	Pooled
Replication	2	777.117	50.438	345.058
Year (Y)	1	949.13	322.09	2177.55
Treatment (T)	10	13815.11	224.95	471.105
Y× T	10	12.469	8.698	6.993
Error	42	2653.00	256.86	560.158
Total	65	18206.82	863.03	3560.87

3. Analysis of variance for exchangeable soil Ca, Mg and available S status

Source of variation	DF	Mean sum of square					
		Exchangeable Ca [cmol (p+) kg^{-1}]		Exchangeable Mg [cmol (p+) kg^{-1}]		Available S (kg ha^{-1})	
		2022	2023	2022	2023	2022	2023
Replication	2	0.022	0.027	0.001	0.002	589.059	800.719
Treatment	10	5.327	5.461	0.736	0.757	78.976	160.871
Error	20	0.082	0.084	0.254	0.258	1730.25	1653.78
Total	32	5.431	5.572	0.991	1.017	2398.29	2615.37

Source of variation	DF	Mean sum of square		
		Exchangeable Ca [cmol (p+) kg^{-1}]	Exchangeable Mg [cmol (p+) kg^{-1}]	Available S (kg ha^{-1})
		Pooled	Pooled	Pooled
Replication	2	0.049	0.002	1379.11
Year (Y)	1	0.122	0.109	38.613
Treatment (T)	10	10.774	1.492	230.108
Y× T	10	0.014	0.001	9.742
Error	42	0.167	0.512	3394.72
Total	65	11.125	2.117	5052.28

4. Analysis of variance for soil DTPA extractable Fe and Cu status

Source of variation	DF	Mean sum of square			
		DTPA extractable Fe (mg kg^{-1})		DTPA extractable Cu (mg kg^{-1})	
		2022	2023	2022	2023
Replication	2	0.488	0.328	0.004	0.004
Treatment	10	236.527	246.434	0.635	0.238
Error	20	20.715	23.704	0.698	0.250
Total	32	257.731	270.466	1.338	0.492

Source of variation	DF	Mean sum of square	
		DTPA extractable Fe (mg kg^{-1})	DTPA extractable Cu (mg kg^{-1})
		Pooled	Pooled
Replication	2	0.73	0.008
Year (Y)	1	19.148	0.108
Treatment(T)	10	482.31	0.807
Y× T	10	0.651	0.066
Error	42	44.504	0.949
Total	65	547.34	1.938

5. Analysis of variance for soil DTPA extractable Zn and Mn status

Source of variation	DF	Mean sum of square			
		DTPA extractable Zn (mg kg^{-1})		DTPA extractable Mn (mg kg^{-1})	
		2022	2023	2022	2023
Replication	2	0.029	0.027	2.211	2.316
Treatment	10	0.133	0.076	46.478	47.043
Error	20	0.420	0.339	28.806	28.251
Total	32	0.582	0.441	77.496	77.610

Source of variation	DF	Mean sum of square	
		DTPA extractable Zn (mg kg^{-1})	DTPA extractable Mn (mg kg^{-1})
		Pooled	Pooled
Replication	2	0.056	4.52
Year (Y)	1	0.02	0.719
Treatment(T)	10	0.204	93.515
Y× T	10	0.005	0.007
Error	42	0.759	57.064
Total	65	1.044	155.83

6. Analysis of variance for leaf NPK content

Source of variation	DF	Mean sum of square					
		Leaf N (%)		Leaf P (%)		Leaf K (%)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.007	0.005	0.003	0.003	0.022	0.022
Treatment	10	2.486	2.532	0.010	0.010	0.100	0.101
Error	20	0.127	0.132	0.020	0.019	0.075	0.071
Total	32	2.620	2.669	0.033	0.032	0.197	0.195

Source of variation	DF	Mean sum of square		
		Leaf N (%)	Leaf P (%)	Leaf K (%)
		Pooled	Pooled	Pooled
Replication	2	0.013	0.007	0.044
Year (Y)	1	0.067	0.002	0.032
Treatment (T)	10	5.015	0.02	0.201
Y× T	10	0.004	0	0
Error	42	0.259	0.039	0.147
Total	65	5.357	0.067	0.425

7. Analysis of variance for leaf Ca, Mg and S content

Source of variation	DF	Mean sum of square					
		Leaf Ca (%)		Leaf Mg (%)		Leaf S (%)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.047	0.043	0.011	0.016	0.009	0.012
Treatment	10	0.144	0.144	0.062	0.061	0.054	0.057
Error	20	0.278	0.269	0.061	0.059	0.056	0.056
Total	32	0.469	0.456	0.135	0.137	0.119	0.125

Source of variation	DF	Mean sum of square		
		Leaf Ca (%)	Leaf Mg (%)	Leaf S (%)
		Pooled	Pooled	Pooled
Replication	2	0.09	0.027	0.02
Year (Y)	1	0.058	0.02	0.024
Treatment (T)	10	0.286	0.123	0.111
Y× T	10	0.001	0	0.001
Error	42	0.547	0.121	0.112
Total	65	0.983	0.292	0.268

8. Analysis of variance for leaf Fe and Cu content

Source of variation	DF	Mean sum of square			
		Leaf Fe (ppm)		Leaf Cu (ppm)	
		2022	2023	2022	2023
Replication	2	1205.961	1210.392	0.552	0.577
Treatment	10	232.943	154.699	2.027	2.057
Error	20	958.818	890.570	2.016	2.066
Total	32	2397.722	2255.662	4.595	4.700

Source of variation	DF	Mean sum of square	
		Leaf Fe (ppm)	Leaf Cu (ppm)
		Pooled	Pooled
Replication	2	2415.93	1.129
Year (Y)	1	224.926	0.178
Treatment(T)	10	381.432	4.08
Y× T	10	6.432	0.006
Error	42	1849.85	4.082
Total	65	4878.57	9.474

9. Analysis of variance for leaf Zn and Mn content

Source of variation	DF	Mean sum of square			
		Leaf Zn (ppm)		Leaf Mn (ppm)	
		2022	2023	2022	2023
Replication	2	3.963	1.727	1.664	0.966
Treatment	10	178.778	190.904	539.761	479.434
Error	20	226.158	247.349	95.179	107.794
Total		408.899	439.980	636.603	588.194

Source of variation	**DF**	**Mean sum of square**	
		Leaf Zn (ppm)	**Leaf Mn (ppm)**
		Pooled	**Pooled**
Replication	2	4.942	2.659
Year (Y)	1	26.827	32.58
Treatment(T)	10	365.7	1014.69
Y× T	10	3.992	4.52
Error	42	474.26	202.938
Total	65	875.71	1257.38

10. Analysis of variance for increase in tree height, tree spread and trunk girth

Source of variation	**DF**	**Mean sum of square**					
		Increase in tree height (%)		**Increase in tree spread (%)**		**Increase in trunk girth (%)**	
		2022	**2023**	**2022**	**2023**	**2022**	**2023**
Replication	2	0.045	0.024	0.010	0.005	0.003	0.006
Treatment	10	1.312	1.503	1.507	1.634	0.529	0.592
Error	20	0.299	0.352	0.148	0.085	0.106	0.099
Total	32	1.656	1.879	1.665	1.724	0.638	0.698

Source of variation	**DF**	**Mean sum of square**		
		Increase in tree height (%)	**Increase in tree spread (%)**	**Increase in trunk girth (%)**
		Pooled	**Pooled**	**Pooled**
Replication	2	0.065	0.008	0.009
Year (Y)	1	0.127	0.146	0.035
Treatment (T)	10	2.791	3.116	1.114
Y× T	10	0.023	0.025	0.007
Error	42	0.655	0.24	0.205
Total	65	3.661	3.534	1.371

11. Analysis of variance for increase in tree volume, annual shoot growth and leaf area

Source of variation	**DF**	**Mean sum of square**					
		Increase in tree volume (m^3)		**Annual shoot growth (cm)**		**Leaf area (cm^2)**	
		2022	**2023**	**2022**	**2023**	**2022**	**2023**
Replication	2	0.010	0.038	26.716	24.036	0.211	0.187
Treatment	10	1.487	1.847	227.343	225.323	112.148	140.399
Error	20	0.193	0.227	138.239	133.718	9.973	10.390
Total	32	1.690	2.112	392.298	383.077	122.331	150.976

Source of variation	DF	Mean sum of square		
		Increase in tree volume (m^3)	Annual shoot growth (cm)	Leaf area (cm^2)
		Pooled	Pooled	Pooled
Replication	2	0.022	50.714	0.225
Year (Y)	1	8.844	162.19	8.575
Treatment (T)	10	3.313	452.56	250.73
Y× T	10	0.02	0.112	1.818
Error	42	0.446	271.99	20.535
Total	65	12.646	937.56	281.89

12. Analysis of variance for fruit length, fruit diameter and fruit weight

Source of variation	DF	Mean sum of square					
		Fruit length (mm)		Fruit diameter (mm)		Fruit weight (g)	
		2022	2023	2022	2023	2022	2023
Replication	2	104.878	95.733	83.765	62.369	8.313	46.102
Treatment	10	651.034	671.136	659.031	813.353	1570.47	1335.59
Error	20	73.195	65.948	66.253	54.017	310.731	309.433
Total	32	829.108	832.818	809.049	929.739	1889.52	1691.12

Source of variation	DF	Mean sum of square		
		Fruit length (mm)	Fruit diameter (mm)	Fruit weight (g)
		Pooled	Pooled	Pooled
Replication	2	199.551	145.254	47.12
Year (Y)	1	427.272	439.562	731.74
Treatment (T)	10	1313.03	1462.38	2833.25
Y× T	10	9.159	9.985	72.768
Error	42	140.203	121.155	627.468
Total	65	2089.22	2178.33	4312.34

13. Analysis of variance for fruit volume and fruit firmness

Source of variation	DF	Mean sum of square			
		Fruit volume (cc)		Fruit firmness (kg cm^{-2})	
		2022	2023	2022	2023
Replication	2	14.957	41.642	0.024	0.013
Treatment	10	1650.027	1813.408	2.043	2.675
Error	20	337.797	430.618	0.141	0.171
Total	32	2002.781	2285.668	2.208	2.859

Source of variation	DF	Mean sum of square	
		Fruit volume (cc)	Fruit firmness (kg cm^{-2})
		Pooled	Pooled
Replication	2	52.138	0.038
Year (Y)	1	6755.71	1.582
Treatment(T)	10	3454.26	4.643
Y× T	10	9.011	0.074
Error	42	772.92	0.311
Total	65	11044.05	6.648

14. Analysis of variance for TSS, titratable acidity and TSS:acid ratio

Source of variation	DF	Mean sum of square					
		TSS (°B)		Titratable acidity (%)		TSS: acid ratio	
		2022	2023	2022	2023	2022	2023
Replication	2	0.015	0.017	0.003	0.003	46.699	90.139
Treatment	10	1.957	1.924	0.050	0.048	1179.11	1734.66
Error	20	0.142	0.143	0.039	0.040	822.987	1386.87
Total	32	2.115	2.084	0.093	0.091	2048.79	3211.67

Source of variation	DF	Mean sum of square		
		TSS (°B)	Titratable acidity (%)	TSS: acid ratio
		Pooled	Pooled	Pooled
Replication	2	0.037	0.006	133.323
Year (Y)	1	0.202	0.01	414.935
Treatment (T)	10	3.881	0.098	2865.50
Y× T	10	0.001	0	48.264
Error	42	0.281	0.079	2213.38
Total	65	4.402	0.194	5675.40

15. Analysis of variance for total sugars, reducing sugars and non-reducing sugars

Source of variation	DF	Mean sum of square					
		Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.001	0.001	0.001	0.002	0.0001	0.0002
Treatment	10	1.753	2.580	0.889	0.869	0.143	0.412
Error	20	0.045	0.021	0.014	0.018	0.015	0.003
Total	32	1.799	2.602	0.904	0.890	0.157	0.415

Source of variation	DF	Mean sum of square		
		Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
		Pooled	Pooled	Pooled
Replication	2	0.002	0.004	0
Year (Y)	1	0.639	0.042	0.32
Treatment (T)	10	4.285	1.758	0.511
Y× T	10	0.047	0	0.044
Error	42	0.066	0.031	0.018
Total	65	5.039	1.836	0.893

16. Analysis of variance for leaf chlorophyll content, anthocyanin content and yield

Source of variation	DF	Mean sum of square					
		Leaf chlorophyll content (mg g^{-1})		Anthocyanin content (mg/ 100 g)		Yield (kg tree^{-1})	
		2022	2023	2022	2023	2022	2023
Replication	2	0.024	0.010	0.021	0.018	0.033	1.276
Treatment	10	2.196	2.216	7.292	10.997	677.627	538.689
Error	20	0.329	0.458	0.469	0.457	12.434	11.768
Total	32	2.549	2.685	7.783	11.473	690.093	551.733

Source of variation	DF	Mean sum of square		
		Leaf chlorophyll content (mg g^{-1})	Anthocyanin content (mg/ 100 g)	Yield (kg tree^{-1})
		Pooled	Pooled	Pooled
Replication	2	0.032	0.042	0.86
Year (Y)	1	0.097	148.35	171.985
Treatment (T)	10	4.408	17.509	1207.40
Y× T	10	0.005	0.781	8.91
Error	42	0.79	0.923	24.651
Total	65	5.332	167.61	1413.81

APPENDIX - IV

ANALYSIS OF VARIANCE FOR DIFFERENT PARAMETERS

EXPERIMENT - II

1. Analysis of variance for leaf N, P and K content

Source of variation	DF	Mean sum of square					
		Leaf N (%)		Leaf P (%)		Leaf K (%)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.021	0.019	0.004	0.004	0.015	0.014
Treatment	10	0.152	0.132	0.011	0.013	0.177	0.178
Error	20	0.072	0.079	0.031	0.031	0.119	0.127
Total	32	0.244	0.230	0.046	0.047	0.311	0.319

Source of variation	DF	Mean sum of square		
		Leaf N (%)	Leaf P (%)	Leaf K (%)
		Pooled	Pooled	Pooled
Replication	2	0.04	0.007	0.029
Year (Y)	1	0.074	0.002	0.044
Treatment (T)	10	0.283	0.024	0.355
Y× T	10	0.001	0	0
Error	42	0.15	0.061	0.246
Total	65	0.548	0.094	0.674

2. Analysis of variance for leaf Ca, Mg and S content

Source of variation	DF	Mean sum of square					
		Leaf Ca (%)		Leaf Mg (%)		Leaf S (%)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.039	0.036	0.010	0.009	0.002	0.002
Treatment	10	0.173	0.174	0.045	0.057	0.077	0.075
Error	20	0.133	0.135	0.082	0.080	0.030	0.038
Total	32	0.345	0.346	0.137	0.147	0.109	0.115

Source of variation	DF	Mean sum of square		
		Leaf Ca (%)	Leaf Mg (%)	Leaf S (%)
		Pooled	Pooled	Pooled
Replication	2	0.075	0.019	0.004
Year (Y)	1	0.064	0.033	0.114
Treatment (T)	10	0.347	0.101	0.152
Y× T	10	0	0.001	0
Error	42	0.268	0.163	0.068
Total	65	0.755	0.316	0.338

3. Analysis of variance for leaf Fe and Cu content

Source of variation	DF	Mean sum of square			
		Leaf Fe (ppm)		Leaf Cu (ppm)	
		2022	2023	2022	2023
Replication	2	746.781	952.156	0.431	0.509
Treatment	10	883.650	989.268	5.783	6.042
Error	20	1102.569	1073.536	1.741	1.600
Total	32	2733.00	3014.969	7.955	8.150

Source of variation	DF	Mean sum of square	
		Leaf Fe (ppm)	Leaf Cu (ppm)
		Pooled	Pooled
Replication	2	1690.38	0.943
Year (Y)	1	2475.81	0.154
Treatment(T)	10	1851.44	11.829
Y× T	10	21.592	0.004
Error	42	2184.66	3.337
Total	65	8223.88	16.258

4. Analysis of variance for leaf Zn and Mn content

Source of variation	DF	Mean sum of square			
		Leaf Zn (ppm)		Leaf Mn (ppm)	
		2022	2023	2022	2023
Replication	2	1.085	2.105	4.396	3.839
Treatment	10	757.172	890.720	1017.822	1013.286
Error	20	82.822	71.458	99.415	91.367
Total	32	841.079	964.283	1121.633	1108.492

Source of variation	DF	Mean sum of square	
		Leaf Zn (ppm)	Leaf Mn (ppm)
		Pooled	Pooled
Replication	2	2.948	8.275
Year (Y)	1	47.039	151.442
Treatment(T)	10	1642.47	2030.43
Y× T	10	5.43	0.663
Error	42	154.522	190.742
Total	65	1852.41	2381.55

5. Analysis of variance for increase in tree height, tree spread and trunk girth

Source of variation	DF	Mean sum of square					
		Increase in tree height (%)		Increase in tree spread (%)		Increase in trunk girth (%)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.162	0.132	0.027	0.028	0.023	0.026
Treatment	10	5.853	6.157	6.643	6.729	0.672	0.684
Error	20	0.499	0.297	0.290	0.227	0.085	0.086
Total	32	6.514	6.587	6.961	6.984	0.779	0.796

Source of variation	DF	Mean sum of square		
		Increase in tree height (%)	Increase in tree spread (%)	Increase in trunk girth (%)
		Pooled	Pooled	Pooled
Replication	2	0.292	0.057	0.049
Year (Y)	1	0.667	0.362	0.072
Treatment (T)	10	12.004	13.372	1.356
Y× T	10	0.006	0	0.001
Error	42	0.799	0.517	0.171
Total	65	13.768	14.307	1.648

6. Analysis of variance for increase in tree volume, annual shoot growth and leaf area

Source of variation	DF	Mean sum of square					
		Increase in tree volume (m^3)		Annual shoot growth (cm)		Leaf area (cm^2)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.028	0.037	7.739	5.221	1.771	3.280
Treatment	10	1.191	1.264	460.576	482.432	330.905	321.324
Error	20	0.172	0.194	86.123	90.621	20.275	23.352
Total	32	1.391	1.495	554.438	578.274	352.951	347.956

Source of variation	DF	Mean sum of square		
		Increase in tree volume (m^3)	Annual shoot growth (cm)	Leaf area (cm^2)
		Pooled	Pooled	Pooled
Replication	2	0.065	12.857	4.91
Year (Y)	1	5.839	156.727	18.244
Treatment (T)	10	2.453	942.42	651.94
Y× T	10	0.002	0.58	0.28
Error	42	0.366	176.848	43.768
Total	65	8.724	1289.43	719.14

7. Analysis of variance for fruit length, fruit diameter and fruit weight

Source of variation	DF	Mean sum of square					
		Fruit length (mm)		Fruit diameter (mm)		Fruit weight (g)	
		2022	2023	2022	2023	2022	2023
Replication	2	39.583	36.361	67.139	62.976	22.162	22.773
Treatment	10	732.363	652.045	670.384	756.00	616.029	611.092
Error	20	127.577	115.902	86.243	68.895	303.969	311.668
Total	32	899.523	804.308	823.766	887.871	942.160	945.533

Source of variation	DF	Mean sum of square		
		Fruit length (mm)	Fruit diameter (mm)	Fruit weight (g)
		Pooled	Pooled	Pooled
Replication	2	73.147	130.134	42.853
Year (Y)	1	367.609	585.927	2143.06
Treatment (T)	10	1372.85	1422.47	1220.67
Y× T	10	11.587	3.928	6.451
Error	42	246.267	155.129	617.732
Total	65	2071.45	2297.59	4030.76

8. Analysis of variance for fruit volume and fruit firmness

Source of variation	DF	Mean sum of square			
		Fruit volume (cc)		Fruit firmness (kg cm^{-2})	
		2022	2023	2022	2023
Replication	2	9.132	18.434	0.014	0.017
Treatment	10	772.469	777.112	4.506	4.613
Error	20	149.595	170.711	0.136	0.197
Total	32	931.196	966.257	4.656	4.828

Source of variation	DF	Mean sum of square	
		Fruit volume (cc)	Fruit firmness (kg cm^{-2})
		Pooled	Pooled
Replication	2	27.578	0.03
Year (Y)	1	7479.95	2.561
Treatment(T)	10	1544.64	9.062
Y× T	10	5.034	0.058
Error	42	320.303	0.335
Total	65	9377.51	12.047

9. Analysis of variance for TSS, titratable acidity and TSS:acid ratio

Source of variation	DF	Mean sum of square					
		TSS (°B)		Titratable acidity (%)		TSS: acid ratio	
		2022	2023	2022	2023	2022	2023
Replication	2	0.000	0.007	0.002	0.002	12.012	21.227
Treatment	10	3.122	3.057	0.061	0.059	1325.36	1684.86
Error	20	0.134	0.153	0.037	0.036	583.763	769.923
Total	32	3.257	3.218	0.100	0.098	1921.14	2476.01

Source of variation	DF	Mean sum of square		
		TSS (°B)	Titratable acidity (%)	TSS: acid ratio
		Pooled	Pooled	Pooled
Replication	2	0.004	0.004	32.598
Year (Y)	1	0.187	0.007	165.065
Treatment (T)	10	6.176	0.121	2996.37
Y× T	10	0.004	0	13.859
Error	42	0.291	0.073	1354.33
Total	65	6.662	0.205	4562.22

10. Analysis of variance for total sugars, reducing sugars and non-reducing sugars

Source of variation	DF	Mean sum of square					
		Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.020	0.028	0.014	0.026	0.007	0.000
Treatment	10	2.852	2.997	1.911	2.523	0.250	0.142
Error	20	0.313	0.491	0.136	0.141	0.245	0.228
Total	32	3.184	3.516	2.061	2.690	0.503	0.371

Source of variation	DF	Mean sum of square		
		Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
		Pooled	Pooled	Pooled
Replication	2	0.048	0.04	0.005
Year (Y)	1	1.649	0.328	0.44
Treatment (T)	10	5.842	4.397	0.356
Y× T	10	0.007	0.037	0.037
Error	42	0.803	0.278	0.476
Total	65	8.349	5.079	1.314

11. Analysis of variance for leaf chlorophyll content, anthocyanin content and yield

Source of variation	DF	Mean sum of square					
		Leaf chlorophyll content (mg g^{-1})		Anthocyanin content (mg/ 100 g)		Yield (kg $tree^{-1}$)	
		2022	2023	2022	2023	2022	2023
Replication	2	0.015	0.013	0.007	0.142	0.057	1.179
Treatment	10	4.670	4.487	6.355	24.263	76.743	96.644
Error	20	0.313	0.282	0.304	1.261	10.352	17.552
Total	32	4.998	4.782	6.665	25.667	87.152	115.376

Source of variation	DF	Mean sum of square		
		Leaf chlorophyll content (mg g^{-1})	Anthocyanin content (mg/ 100 g)	Yield (kg $tree^{-1}$)
		Pooled	Pooled	Pooled
Replication	2	0.028	0.104	0.383
Year (Y)	1	0.213	117.6	140.56
Treatment (T)	10	9.153	26.64	171.119
Y× T	10	0.004	3.977	2.2
Error	42	0.595	1.61	28.758
Total	65	9.993	149.93	343.08

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Title of Thesis : **Impact of foliar applications of nano-nitrogen, potassium and calcium on growth, yield and quality of apple (*Malus x domestica* Borkh.)**
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ABSTRACT

The present study entitled **"Impact of foliar applications of nano-nitrogen, potassium and calcium on growth, yield and quality of apple (*Malus x domestica* Borkh.)"** was undertaken during two consecutive years 2022 and 2023 at Experimental Farm of Krishi Vigyan Kendra, Shimla at Rohru, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Himachal Pradesh. Two field experiments were conducted in the same orchard wherein, different nano-N, potassium and calcium treatments were laid out in Randomised Block Design with eleven treatments each. In the first experiment, application of T_8 treatment (Soil application of 50% RDN + nN @ 250 ppm split at Pink bud and Fruit Set stage) exhibited remarkable superiority in increase in tree height (7.05%), tree spread (8.19%), trunk girth (2.85%), tree volume (4.83 m^3), annual shoot growth (31.75 cm), leaf area (32.40 cm^2), fruit length (67.77 mm), fruit diameter (73.27 mm), fruit weight (147.48 g), fruit volume (169.79 cc), fruit firmness (9.08 kg cm^{-2}), fruit TSS (11.10 °B), TSS: acid ratio (51.96), total sugars (10.84%), reducing sugars (6.90%), non- reducing sugars (3.74%), anthocyanin content (14.27 mg/ 100 g) and yield (36.68 kg $tree^{-1}$). In the second experiment, foliar applications of potassium and calcium at different doses were evaluated. The T_8 treatment (KNO_3 @ 0.5% at Walnut stage+ K_2SO_4 @ 0.5% (45 days before harvesting) + $CaCl_2$ @ 0.5% (45 and 60 days before harvesting)) gave best results in terms of increase in tree height (7.55%), tree spread (8.70%), trunk girth (3.01%), tree volume (4.67%), annual shoot growth (39.05 cm), leaf area (31.72 cm^2), fruit length (68.92 cm), fruit diameter (76.45 mm), fruit weight (153.02 g), fruit volume (172.02 cc), fruit firmness (9.24 kg cm^{-2}), fruit color, TSS (11.31 °Brix), TSS: acid ratio (49.13), total sugars (10.81%), reducing sugars (7.12 %), leaf chlorophyll content (3.31 mg g^{-1}), anthocyanin content (14.12 mg $100g^{-1}$) and yield (35.73 kg $tree^{-1}$). The study concluded that the combination of 50% recommended dose of nitrogen as soil-application through urea with foliar nano-nitrogen at 250 ppm split at Pink bud and Fruit Set stage significantly boosted soil and leaf nutrient contents, plant growth, fruit quality and yield in apple trees. Additionally, foliar potassium and calcium applications, especially KNO_3, K_2SO_4 and $CaCl_2$ @ 0.5% improved leaf nutrient contents, overall tree performance and yield in apple under wet temperate conditions in Himachal Pradesh.

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