

**STUDIES ON THE EFFECT OF FOLIAR APPLICATION OF
UREA AND NANO UREA ON GROWTH AND QUALITY
OF APPLE NURSERY cv. RED VELOX**

Thesis

by

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(H-2021-53-M)**

submitted to



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CERTIFICATE - I

This is to certify that the thesis titled “**Studies on the effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox**” submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture) Seed Science and Technology** in the discipline of **Plant Sciences** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) – 173 230 is a bonafide research work carried out by **Ms Rewa Dhiman (H-2021-53-M)** daughter of Shri Rakesh Kumar Dhiman 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 this investigation have been fully acknowledged.

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CERTIFICATE-II

This is to certify that the thesis titled, “**Studies on the effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox**” submitted by **Ms Rewa Dhiman (H-2021-53-M)** daughter of Shri Rakesh Kumar Dhiman 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 **Master of Science (Agriculture) Seed Science and Technology** in the discipline of **Plant Sciences** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Without a doubt, I take full responsibility for any errors and omissions that may be present.

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ABBREVIATIONS USED

%	:	Per cent
&	:	And
/	:	Per
@	:	At the Rate
+	:	Plus
=	:	Equal to
µg	:	Micro gram
AGR	:	Absolute Growth Rate
AI	:	Active Tillering
ANOVA	:	Analysis of Variance
AVG	:	Aminoethoxyvinylglycine
CD	:	Critical Difference
CGR	:	Crop Growth Rate
cm	:	Centimeter
cm ²	:	Square centimeter
cv.	:	Cultivar
DAP	:	Days after Planting
DAS	:	Days after Sowing
DAT	:	Days after Transplanting
df	:	Degree of Freedom
DMSO	:	Dimethyl sulphoxide
ed.	:	Edition
eds.	:	Editors
et al.	:	Co-workers
etc.	:	Et cetera
F-cal	:	F-calculated

FSNU	:	Foliar spray of nano urea
g	:	Gram
g L ⁻¹	:	Gram per litre
i.e.	:	That is
IFFCO	:	Indian Farmers Fertilizer Cooperative Limited
kg	:	Kilogram
kg ha ⁻¹	:	Kilogram per hectare
LAI	:	Leaf Area Index
m	:	Meter
mg	:	Milligram
ml	:	Millilitre
mM	:	Millimolar
mm	:	Millimeter
MOP	:	Muriate of Potash
NAR	:	Net Assimilation Rate
NDVI	:	Normalized Difference Vegetation Index
nN	:	Nano nitrogen
PI	:	Panicle Initiation
RCBD	:	Randomized Complete Block Design
RDF	:	Recommended dose of fertilizers
RDN	:	Recommended dose of nitrogen
RGR	:	Relative Growth Rate
SPAD	:	Soil Plant Analysis Development
TSP	:	Triple superphosphate
var.	:	Variety
viz.	:	Videlicet (namely)

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Chapter-1

INTRODUCTION

Apple (*Malus × domestica* Borkh.) a member of family Rosaceae is one of the important temperate fruit crop grown widely throughout the world. It is a source of carbohydrate, protein and nutrients like K, P and Ca. In India, apple cultivation is confined to North Western Himalayan regions occupying an area of about 3,13,000 hectares with annual production of 24,37,000 MT and productivity of 7.7 MT/ha (Anonymous, 2022). Apple is cultivated on a commercial scale in Jammu and Kashmir, Himachal Pradesh and Uttarakhand. Besides, it is also cultivated on a minimal scale in North-Eastern states like Arunachal Pradesh, Meghalaya, Sikkim, Nagaland and Manipur. China is the leading apple producer country worldwide.

Himachal Pradesh has been recognized as the "Apple state of India" as it produces best quality apples. Apple cultivation in Himachal Pradesh was first established in Bundrole in Kullu tehsil by Capt. RC Lee. Apple is the principal fruit crop of Himachal Pradesh, which comprises about 49 per cent of the total area under fruit crops and about 85 per cent of the total fruit production. In Himachal Pradesh, the major apple producing districts are Shimla, Kullu, Chamba, Sirmour, Lahul-Spiti and Kinnaur occupying an area of about 1,14,650 hectares with annual production of 4,81,060 MT (Anonymous, 2022).

Apple plantations are raised either on seedling or clonal rootstocks. Seeds of crab apple or self- pollinizing varieties having good seed viability are used for raising seedlings. As the seedling show immense variability, clonal rootstocks which are genetically uniform, control size of the tree, enhance precocity, fruit quality and nutrient uptake efficiency beside resistance to various biotic and abiotic factors, should be preferred. Clonal rootstock can be propagated through stem cuttings, mound layering (stooling) or tissue culture but most commonly used method is mound layering. Tongue grafting, cleft grafting, T-budding or chip budding can be employed for propagation of apple but Tongue grafting is the most ideal method of grafting scion cultivar on the rootstock with more than 90 per cent bud take success.

Nursery plants are the foundation of the orchard. The quality and authenticity of the planting materials are key factors in determining an orchard eventual success. Therefore, attention should be focussed on faster and larger scale multiplication of true-to-type planting

materials. Fertilizers play a vital role in plant growth and development and are intimately linked to the quality of nursery plants. Nitrogen is one of the most important mineral nutrient, improving growth, yield and quality in many horticulture crops globally. It has a crucial impact on fruit yield and quality and also affects the taking up and distribution of other nutrients in fruit trees. Nitrogen application is of vital importance for inducing optimum vegetative growth in the nursery, for plant growth and development, being required for chlorophyll and enzyme synthesis and constituting a component of proteins, metabolites and nucleic acids. Therefore, deficiency of nitrogen leads to limited growth of plant organs such as roots, stems, leaves, flowers and fruits (Barker and Pilbeam, 2015).

Urea is the most commonly used source of nitrogen for foliar application due to its high solubility in water, nonpolarity, rapid leaf absorption and low phytotoxicity. It is usually taken up rapidly through the leaf cuticle. Foliar application of urea facilitates optimal nitrogen management, which minimizes nitrogen losses to the environment. Once urea is absorbed it is changed into ammonium and carbon dioxide by an enzyme called urease, found in the leaves of many plants. Actively growing tissues contain more urease activity than senescing (dying) tissues. Foliar nitrogen uptake can occur any time when leaves are present. Urea is one of the most commercial and cheap source of nitrogen. It also stimulates absorption of other nutrients by increasing the permeability of leaf tissue. In nursery production, foliar nitrogen fertilization is most effective in spring and fall. Several researchers have shown that foliar application of nitrogen have a high recovery rate than soil application (Rosecrance et al., 1998).

In the present scenario, nanotechnology opens a wide range of opportunities in the field of agriculture and other fields. Use of nanofertilizers instead of traditional fertilizers has a major impact on crop nutrition (Rameshaiah et al., 2015). Nanofertilizers are the nutrient carriers developed using substrates of 1-100 nm nano-dimensions used solely or in combination to improve plant growth, yield and performance of plant. These are made from conventional fertilizers extracted from different plants or plant parts by coating them with nanomaterials. Nanofertilizers have many other names like nano-carriers, nano-enabled fertilizers, bio-nanofertilizers, controlled released nanofertilizers, nano-particles based nutrient and nano-based delivery systems of micronutrients, which delivers nutrients at the right time and in the right place.

Nanofertilizers increases the nutrient use efficiency by making nutrients more available to leaves (Suppan, 2013). These have an important role in physiological and

biochemical processes by increasing nutrient availability, which can aid in metabolic processes enhancement and stimulate meristematic activities, resulting in increased apical growth and photosynthetic area. It is critical for enhancing vegetative development, improving reproductive growth and flowering, resulting in increased output, product quality, and fruit shelf life. Some properties of nano particles such as large surface area, unique magnetic/optical properties, electronic states and catalytic reactivity confer nanoparticles a better reactivity than the equivalent bulk materials (Agrawal and Rathore, 2014). Application of nanotechnology provide fertilizers that release nitrogen when crop needs it, consequently increasing nitrogen efficiency through reduction in nitrogen leaching and emissions and long term incorporation by soil microorganisms (Naderi and Shahraki, 2013; Suman et al., 2010). Nanofertilizers control the delivery of the fertilizers to such an extent that the nutrients are taken up by the plant, and not lost to non-targeted soil, water or microorganisms (Kopittke et al., 2019). The large surface area to volume of the nanomaterials helps in rapid response and hence high plant growth effectiveness (Zahedi et al., 2020). Nano structures leads to easier absorption and increased nutrient absorption through the leaves or roots (Soliman et al., 2015).

Nano urea is a source of nitrogen, which is an essential component for crop growth and development. When sprayed at critical crop growth stages, nano urea successfully meets crop nitrogen requirements. It is used to improve the environment, soil health and farmer profitability by replacing conventional urea and other nitrogenous fertilizers. In its nano form, nano urea (IFFCO) comprises 4 per cent nitrogen by weight. One nano urea liquid particle is 30 nm in size and has approximately 10,000 times the surface area to volume size of regular granular urea. Because of its ultra small size and surface characteristics, nano urea liquid is more effectively absorbed by plants when sprayed on their leaves.

Nitrogen application is crucial for inducing vegetative growth in the nursery, which is a critical phase of plant. Foliar application of urea produces greater total leaf area at each given nitrogen fertigation concentrations (Cheng and Fuchigami, 2002). Foliar application of urea leads to increase in vegetative growth (Amiri, 2008). Foliar sprays with urea promotes shoot growth and leaf extension (Pares et al., 2010). Foliar fertilization of nano nitrogen shows a significant impact on shoot diameter, leaf area, leaf N, P and K concentrations (Doaa and Raesa, 2020). With the use of nano nitrogen, the quantity of urea being applied by farmers to supply nitrogen to their crops can be successfully reduced to half (Kumar et al., 2020).

Keeping in view the above points, the current studies have been carried out with the following objectives:

- i) To study the effect of foliar application of urea and nano urea on growth and rooting of Red Velox plants on Bud 9 rootstock in nursery condition
- ii) To study their effect on leaf N, P and K content.

Chapter-2

REVIEW OF LITERATURE

The literature pertaining to the present study is scanty. However, following sub-heads evaluate the studies done on several aspects related to the "**Effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox**":

2.1 Effect of foliar application of urea on growth and quality

2.2 Effect of foliar application of nano urea on growth and quality

2.1 Effect of foliar application of urea on growth and quality

2.1.1 Plant Height

El-Otmani et al. (2002) reported that foliar applied urea represents an effective and most efficient method as a source of nitrogen in sustainable citrus production system encouraging vegetative growth.

Dong et al. (2005) evaluated the effect of timing of urea application on leaf and root nitrogen uptake in young Fuji/M.9 apple trees. 1 per cent ¹⁵N-labelled urea was supplied to one year old potted Fuji/M.9 trees either by foliar or soil applications. The study revealed that the highest ¹⁵N recovery (48%) was found in September with foliar nitrogen application resulting in greater shoot and root development and total biomass as compared to the soil N application with lowest ¹⁵N recovery (11%).

Rozek and Wojciechowska (2005) stated that the application of 2 per cent urea to broccoli foliage, drastically strengthened total plant biomass and marketable output. Furthermore nitrogen fertilizer treatments had a substantial effect on the content of soluble sugars, phenols, ascorbic acid, dry matter and nitrates.

Narayanamma et al. (2006) observed that all treatments getting foliar sprays of water soluble fertilizer had higher plant heights, main branch counts, fruit counts and individual fruit weights than treatments receiving no spray in brinjal.

Robinson (2006) discovered a substantial rootstock-fertilizer interaction. Increased fertilization resulted in greater tree growth compared to the unfertilized control with M7 rootstock, but did not result in greater tree growth compared to the unfertilized control with

M.9. The results demonstrated that foliar or soil applied nutrients such as N, P, K and B promoted tree development in young apple trees, resulting in large trees with the largest bearing potential.

Asma et al. (2007) investigated that high nitrogen application considerably increased vegetative growth of apricot cv. Hacihalilglue, however high potassium application had no effect on vegetative growth at all.

Yildirim et al. (2007) assessed the influence of foliar urea treatments on broccoli quality, growth, mineral content and yield. Foliar urea administrations, particularly 0.8 and 1.0 per cent, resulted in larger heads, heavier heads and plants, as well as higher plants. SPAD chlorophyll values increased with increasing urea concentrations in the third year. In terms of nutritional content, soil nitrogen fertilization and foliar urea sprays enhanced the content of practically all nutrients in both broccoli cultivars leaves and heads during three experiment years. In general, 1.0 per cent urea administration yielded the highest values for both cultivars. According to the findings of the study, 0.61 and 0.96 per cent doses of urea sprays might be successfully used to achieve increased growth and yield in broccoli cultivars AG 3317 and AG 3324, respectively.

Jat et al. (2007) evaluated the influence of foliar urea and zinc sulphate (0, 0.5, 1.0, and 1.5%) applications on african marigold (*Tagetes erecta*) growth, flowering and flower yield parameters. Foliar applications of urea at 1.0 per cent and zinc sulphate at 0.5 per cent were shown to be the most beneficial in improving african marigold growth, floral characteristics and flower output.

Amiri (2008) conducted an experiment to examine the efficacy of foliar and soil nitrogen treatments on plant tissue, soil nitrogen status and growth of 'Golden Delicious'. Both soil nitrogen treatment alone and soil-foliar combination application greatly boosted vegetative growth (shoot length). Foliar nitrogen application had proved more efficient than soil nitrogen application.

Khan et al. (2009) reported that foliar spraying of urea significantly enhanced plant height, spike length, number of grains spike⁻¹, hundred grain weight, biological yield, grain yield and crop nitrogen uptake of wheat. When treated at tillering, stem elongation and boot stage, a foliar spray of 4 per cent urea solution was shown to be most efficient for improving quantitative and qualitative features. When a 4 per cent urea solution was administered as a foliar spray, grain yield was raised by 32 per cent. Increased urea spray concentrations were

not proven to be beneficial or economical, as they reduced grain production by 25 per cent or more, most likely due to toxicity.

El-Kobbia et al. (2011) investigated the influence of spraying trees with various agrochemicals on vegetative growth, fruit drop, fruit retention and yield. It was discovered that spraying urea at pea stage alone considerably accelerated vegetative growth (shoot length).

Jafarpour and Poursakhi (2011) performed a study on concurrent effect of using nutrients through soil and foliar application on yield and quality of the Red Delicious apple. Solutions of urea, boric acid and zinc sulphate were sprayed on the trees each at a concentration of 0.5 per cent. The results showed that there was an improvement in generative growth and yield.

Kumar et al. (2012) carried out research to determine the optimal NPK chemical dose for increasing the growth of jatti khatti seedlings. Nitrogen, phosphorus and potassium were supplied by 0.5 per cent concentrations of urea, diammonium phosphate and muriate of potash. The seedlings were sprayed 90 days after seed sowing and again three and six months later. Among all treatments, the urea foliar spray (0.5%) was found to be the most efficient in raising plant height (53.00 cm) and number of branches per plant (9.75).

Yadav et al. (2014) explored the effect of foliar nitrogen and zinc applications on the growth and yield of cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. Snowball-16. The experiment was set up in RBD with four nitrogen levels (0, 1.0, 1.5 and 2.0%) and four zinc levels (0, 20, 30 and 40 ppm) applied as foliar application. The results demonstrated that nitrogen (1.5%) considerably enhanced plant height, plant spread, number of unfolded leaves, days needed for curd initiation, curd complete maturity, curd diameter, fresh weight of plant (curd, shoots, and roots) and yield.

Jatav et al. (2016) studied the response of foliar spray of urea and zinc sulphate on plant growth, fruit set and quality of guava (*Psidium guajava* L.) cv. "Apple Colour". Results indicated that foliar spray of 2.0 per cent urea treatment showed maximum plant height (0.42 m) and canopy height (0.36 m).

Khan et al. (2016) found that fertilizing peach saplings with foliar urea (2%) and ammonium sulphate as a soil application resulted in maximum plant height (151.67 cm) and stem diameter (15.98 mm).

Sharma (2016) investigated the influence of nutrient sprays on the growth, production and fruit quality of the apple cultivar Red Delicious. Sprays of boric acid (0.1%), urea (0.5%), boric acid (0.1%) + urea (0.5%) and multiplex (250ml/100 litres of water) were used as treatments. In terms of shoot length, urea (0.5%) produced the greatest growth.

Wagan et al. (2017) performed a study on the effect of foliar applied urea on growth and yield of wheat (*Triticum Aestivium* L.). Six treatments used were T₁(Control), T₂ (Urea @ 1%), T₃ (Urea @ 2%), T₄ (Urea @ 3%), T₅ (Urea @ 4%), T₆(Urea @ 5%). It was found that foliar applied urea @ 5% showed maximum plant height (97.1 cm), number of tillers plant⁻¹ (10.0), spike length (12.4 cm), spikelets spike⁻¹ (22.5), number of grains spike⁻¹ (65.4), grain weight spike⁻¹ (26.4) seed index (73.2 g), straw yield (6275.3 kg ha⁻¹) and grain yield (5774.6 kg ha⁻¹).

Zubair et al. (2017) conducted a study on impact of foliar application of urea on fruit set, return bloom and growth of apple cv. Red Delicious and results revealed that maximum tree spread (2.99 cm), tree volume (21.51 m³), tree cross sectional area (14.63 and 14.46 cm²), trunk girth (76.98 cm) and shoot extension growth (55.49 cm) was increased by 2 and 5 per cent urea applied at 10 per cent leaf fall.

Oad et al. (2018) investigated the effect of foliar applied urea on the growth and yield of sunflower and found that foliar urea spraying had a substantial effect on sunflower growth and yield characteristics as well as oil yield. The most effective treatment, which included foliar application of urea (1%) after 35 days of sowing in addition to the recommended soil applied urea (130 kg ha⁻¹) yielded promising results, including 89.61 per cent seed germination, 179.65 cm plant height, 5.39 cm stem girth, 22.43 cm head diameter, 2063.25 grains head⁻¹, 68.51 g seed index/1000 seed weight and 2211.90 kg seed yield ha⁻¹.

Banyal and Banyal (2019) observed that under rain-fed conditions in the mid himalayas, the application of Urea @ 1.0% + Agromin 0.5% produced the maximum plant height (29.17 cm), girth (1.10 mm), shoot extension growth (45.25 cm) and tree spread (14.23 cm) of apple trees.

Saritha et al. (2021) showed that foliar application of urea @ 0.1 per cent improved growth parameters viz., shoot length (76.07 cm), number of shoots of branch (26.64) of apple ber (*Zizyphus mauritiana*).

Gharaei et al. (2022) conducted a study on the effect of repeated foliar application of urea on growth and fruit quantity of *Pistacia vera* cv. "Kalleh-Ghuchi". The impact of

repeated foliar applications of 0.5 percent urea on pistachio growth and yield was examined at three different periods of fruit development (including commencement of embryo growth, fast growth of embryo and during flower bud abscission with two weeks interval). Growth characteristics such as shoot length, leaf number and the length of internode were increased by increasing urea application events. By increasing urea application events, growth traits including shoot length, leaf number and internode length were enhanced.

2.1.2 Leaf Area

Cheng and Fuchigami (2002) discovered that fertilizing bench-grafted Fuji/M.26 apple (*Malus × domestica* Borkh.) trees with a nutrient solution (fertigation) containing 0, 2.5, 5, 7.5, 10, 15 or 20 mM nitrogen (N) resulted in greater total leaf area at each N fertigation dosage.

Dubey et al. (2003) evaluated the effect of growth acceleration in *Citrus latipes* rootstock seedlings by foliar application of gibberellic acid and urea. It was observed GA₃ @ 50 ppm + 1% Urea sprays significantly increased plant height, leaves per plant, leaf area, fresh and dry weight of shoots and root growth.

Govind and Singh (2003) reported that in the circumstances of Meghalaya, phosphorus treatment followed by nitrogen considerably improved the number of leaves per plant in khasi mandarin seedlings. The vigour of the seedlings was also found to be greatest with urea spray at 0.5 per cent concentration.

Rackso et al. (2005) examined the effect of nutrient supply on apple fruit quality. Base fertilization and granular formulation (100% P, K and 50 kg ha⁻¹ N) was applied in January and liquid foliar formulation (25 kg ha⁻¹) was applied at weekly interval in May. It was discovered that nutrient supply increased vegetative area. The results also revealed that increasing nitrogen dosages enhanced leaf density.

Rohela (2005) observed that a 1.5 per cent foliar spray increased leaf size in rough lemon seedlings. It was further discovered that rough lemon seedlings with foliar spray of 1.0 percent urea + 100 ppm GA₃ at fortnightly intervals, up to buddable stage, showed the highest shoot dry weight.

Jamwal et al. (2007) studied the effect of urea foliar treatment on gladiolus. Urea (2%) sprays and their combinations were applied at 20, 40, 60 and 80 days after planting. The number of shoots per plant increased drastically as the number of urea (2%) sprays increased. A delayed urea spray reduced the number of leaves per plant. The leaf area per plant

increased substantially as the quantity of sprays increased. With increasing urea frequency, the number and weight of corms and cormels generated per plant, as well as the propagation coefficient, decreased. The floral growth characteristics improved dramatically as the frequency of urea administration increased. The early and frequent spraying resulted in a considerable increase in spike length.

Amanullah et al. (2009) found that up to 6 per cent urea level, the plant height, leaf area, number of grains per cob and per line (1000), grain weight and grain and stover yields were significantly increased in maize.

Al-Imam (2010) observed that varying nitrogen levels have a substantial effect on leaf area in an experiment to evaluate the effect of nitrogen fertilization on vegetative growth and yield of the Anna apple cultivar. The maximum value was obtained after fertilizing with 120 kg N ha⁻¹, whereas the lowest value was obtained in the control. The increase in leaf area could be attributable to nitrogen treatment improving cell size and cell number, as well as an increase in net photosynthesis and leaf growth.

Pares et al. (2010) conducted an experiment in apple trees to investigate the effect of nitrogen fertiliser by foliar sprays or fertigation. Foliar sprays enhanced shoot and leaf extension development, however soil treatments had little influence on growth or cropping metrics.

Verma and Chauhan (2013) evaluated the effect of integrated nutrient application on apple yield and soil fertility in Himachal Pradesh temperate zone. The results showed that increasing the nitrogen dosage promoted plant development, particularly leaf size in apples.

Mahmoodabad et al. (2014) performed an experiment to study the changes in yield and growth of green mint under foliar application of urea and soil application of vermicompost. They used different concentrations of urea foliar spray (1, 2 and 3%). It was found that urea foliar spray @ 3 per cent exhibited maximum stem diameter and plant fresh weight and urea foliar spray @ 2 per cent resulted in maximum leaf area.

Singh and Singh (2014) studied the effect of different foliar urea applications on growth and essential oil accumulation in lemon grass (*Cymbopogon flexuosus* L.) to estimate the yield components, namely, plant height, tillers per plant, biomass yield, essential oil accumulation, with treatment of different urea doses, namely, 1, 1.25, 1.5, 1.75 and 2 g/plant compared to the untreated control. Foliar application of urea at 2 g/plant resulted in the greatest plant height (92.7 cm), number of tillers per plant (106.05) and herb production

(357.1 g/plants), whereas 1.5 g urea/plant resulted in the greatest increase in essential oil content and leaf area.

Bani and Salih (2020) investigated the response of some vegetative growth characteristics of peach (*Prunus persica* L) cv. Dixired transplants to foliar spray with urea and some growth regulators. Urea was applied with different concentrations (0, 1% and 2%). Results showed that the transplants spray with urea concentrations significantly gave the best increase in length of shoots, leaf area, increase in number of shoots and height of transplants.

2.1.3 Leaf chlorophyll content

Kannan et al. (2002) discovered that foliar application of urea at a rate of 1.5 per cent at monthly intervals from March to December resulted in the greatest increase in leaf number (385.26%) in rough lemon seedlings. They observed the greatest increase (60.68%) in leaf length with 1.0 per cent foliar spray, followed by 1.5 per cent (60.09%) and the least increase (37.35%) with control. It was found that 1.5 per cent urea foliar spray resulted in the highest total chlorophyll synthesis (1.48 mg g^{-1}) in rough lemon seedlings. Foliar applications of urea at rates of 1.0 and 1.5 per cent increased the nitrogen content of leaves in rough lemon seedlings by 2.8 per cent, while the control had the lowest nitrogen content (1.68%). They also determined that the control treatment had the greatest phosphorus level (0.21%), whereas the 0.5 percent foliar spray of urea had the highest potassium concentration (1.75%). The highest increase in dry weight (63.76%) was obtained with a 1 per cent urea foliar spray.

Bi et al. (2008) investigated the rate of nitrogen fertigation during vegetative growth and spray applications of urea in the fall on growth and flowering of florists Hydrangeas. Plants were fertigated with 0, 70, 140, 210 or 280 mg L^{-1} nitrogen (N) from and sprayed with 0 per cent or 3 per cent urea. It was found that 3 per cent urea significantly increased the nitrogen concentration (%) of stems and leaves leading to improved growth and also increased the leaf chlorophyll content.

Venkatesh and Basu (2011) conducted a study on the effect of foliar application of urea on chickpea under rainfed condition. In contrast to no spray or water spray, the results showed that foliar application of urea increased branching in chickpea by 8-23 per cent. At 75 days after sowing (DAS), 2 per cent urea spray showed the highest grain production and yield characteristics. Additionally, the findings revealed that 2 per cent foliar urea application at 75 DAS significantly enhanced seed size, leaf and seed nitrogen contents, as well as seed protein content. Significant correlations were found between the growth of seed protein and leaf

nitrogen content and the SPAD chlorophyll metre value. Under rainfed conditions, the urea applications increased the number of branches and also aided in the generation of overall biomass.

Rahman et al. (2014) envisaged that there was a substantial effect in total dry matter output, leaf area index and SPAD values for chlorophyll content with 2 per cent urea foliar spray in wheat. It was established that foliar sprays of 1 per cent urea solution at the tillering, jointing and booting stages, along with 20 kg ha⁻¹ of N at crop emergence, aided in increasing wheat yield and yield components.

Aggarwal et al. (2015) conducted a study to determine how the chickpea would react to foliar applications of nitrogen using urea at various growth stages. With foliar spraying of 2 per cent urea at various growth stages of the crop, plant nodule counts, nodule dry weight and leghaemoglobin concentration considerably increased over unsprayed control. With a foliar spray of 2 per cent urea during pod initiation stage, the maximum quantum efficiency of Photosystem II and chlorophyll kinetics were observed. With 2 per cent urea foliar spray applied at various growth phases, yield parameters like pods/plant dramatically increased in comparison to no spray treatment. The maximum gross returns, net returns and benefit cost ratio over unsprayed control were obtained from foliar spraying with urea (2%) at the pod start stage.

2.1.4 Leaf N, P and K content

Johnson and Amdris (2000) conducted a research to show that nitrogen (N) supplied to peach and nectarine trees as foliar urea in the fall is quickly taken up by leaves and disseminated throughout the trees organs, including the roots. The application of urea to the leaves raised the nitrogen content in the leaves.

Kolota and Osinska (2001) observed that supplemental foliar nitrogen fertilization at varying rates (1.5% and 3.0%) during cabbage crop growth considerably improved the plants mineral status and enhanced cabbage production.

Fallahi et al. (2002) investigated the effect of foliar urea treatment on tree development and fruit quality of 'Fuji' apple and the distribution of urea-derived nitrogen (N) in shoots and branches of 'Golden Delicious' apple under two different studies. Three rates of urea (46% real N) were administered as foliar sprays (S₁, S₂ and S₃) as well as one ground treatment of urea at the lowest rate was commonly used on young apple plants. During 1992, trees were sprayed at following rates: 3.2 g urea per litre (S₁), 9.6 g urea per litre (S₂) and

16.0 g urea per litre. During 1993 and 1994, trees were sprayed at following rates: 1.6 g urea per litre (S₁), 4.8 g urea per litre (S₂) and 8.01 g urea per litre (S₃). The results revealed that as the overall amount of nitrogen applied increased, the leaf nitrogen also increased. Leaves from trees treated with ground treatment showed lower per cent dry weights than leaves from all other foliar treatments.

Furuya and Umemiya (2002) conducted a study to evaluate the most efficient chemical form of foliar nitrogen (N) treatment for peach (*Prunus persica* Batsch.) trees and discovered that peach leaf treatment with urea was more successful than other inorganic forms of nitrogen in increasing nitrogen content.

Porro et al. (2002) concluded that foliar spray of F₂ (8% MgO, 4% CaO, 3% N + B, Zn, Fe) and F₃ (15% CaO, 3% N + B, Zn, Fe) alone or in combination enhanced the concentration of nitrogen and potassium but decreased the concentration of phosphorous and magnesium in the leaf relative to the control when studying the nutritional status of apples in northeast Italy.

Dong et al. (2004) assessed the effect of foliar and soil nitrogen treatments on apple tree development and soil nitrogen status. There were four treatments and one control in which the same quantity of nitrogen as urea was administered once every two weeks beginning when shoot growth surpassed 5 cm. The results revealed that foliar nitrogen spraying in the early and late seasons, as well as soil fertilization in the middle of the season enhanced nitrogen fertilizer absorption and vegetative growth.

Wargo et al. (2004) conducted a study on the effect of nitrogen fertilization, mid-summer trunk girdling and AVG treatments on maturity and quality of jonagold apples. They discovered that soil applied N @ 30 kg ha⁻¹ and foliar urea sprays @ 1 per cent in apple enhanced the amount of nitrogen in the leaves.

Ehsan (2007) revealed that nitrogen fertilizer application resulted in a considerable increase in tree height of 'Anna' and 'Vistabelle' apple cultivars while examining the influence of sulphur and nitrogen on vegetative development and mineral content of apple trees.

El-Tanany et al. (2009) revealed that valencia orange trees budded on volkameriana rootstock received foliar applications of urea at 1.5 per cent or 3.0 per cent in mid-December or mid-January, which improved the number of flowers/branch, fruit set/branch and number of fruits/tree. The results also showed that trees sprayed with 1.5 per cent urea solution in mid-January had higher average fruit weight, length and yield than controls, but that varied

urea treatments only had an impact on fruit diameter in the second season. For most urea treatments, juice volume per fruit also increased. The application of urea to trees raised the leaf nitrogen and ammonium contents while also affecting total acidity and vitamin C levels.

Chermahini et al. (2010) concluded that using urea in the winter enhanced the level of nitrogen for two weeks in orange cv. 'Valencia'. Different urea concentrations improved the number of flowers, ovary diameter and fruit set. The higher the urea concentration (1%), the greater the effect. When it came to timing, urea spray 9 weeks before full bloom had the greatest influence on flowering, whereas urea spray 6 weeks before full bloom resulted in greater ovary diameter and fruit set.

Brunetto et al. (2012) found that while the foliar nitrogen applications increased the nitrogen contents in the entire leaves, they had no effect on the nitrogen contents in the annual offshoots in a study on the nitrogen content and reserves in annual leaves and offshoots of apple trees that were receiving foliar nitrogen fertilization.

Raiesi and Moradi (2019) found that 0.5 per cent solution of urea when sprayed on to 20 years old orange trees during January, March and June resulted in greater leaf nitrogen content.

Masta et al. (2022) performed a study where thirteen treatment combinations, including two nitrogen levels—N0.5 (0.5% urea) and N1.0 (1.0% urea); two potassium levels—K1.0 (1.0% KNO₃) and K2.0 (2.0% KNO₃) and two application times—September and January were arranged in a Randomised Block Design. N1.0 + K2.0 (2 sprays at 15-day intervals in September) (2.71%), N1.0 + K1.0 (1 spray in September and 1 in January) (2.55%) and N1.0 + K2.0 (1 spray in September and 1 in January) (2.52%) were the treatments that produced the highest levels of leaf N. Treatment N1.0 + K2.0 produced a maximum (0.34%) phosphorus concentration (1 spray each in September and January).

Mohammadi and Khezri (2018) studied the effect of foliar applications of urea (46% nitrogen), zinc chelate (40% zinc) and boric acid (17% boron) on the growth parameters, photosynthesis and leaf nutrients of 'Mazafati' date palm offshoots. The experiment was conducted in a controlled greenhouse using a thoroughly Randomised Block Design with seven treatments and ten repetitions. Control, urea (0.5 and 1%), zinc chelate (1000 and 2000 ppm) and boric acid (2000 and 4000 ppm) were the treatments. The results showed that foliar application of fertilizers increased the growth characteristics of date palm offshoots. The highest leaf and root development was seen with urea 1 per cent and zinc chelate 1000 ppm.

2.2 Effect of foliar application of nano urea on growth and quality

2.2.1 Plant height

Rathnayaka et al. (2018) examined the effects of urea and nano-nitrogen fertilizers on rice (*Oryza sativa* L.) cultivar 'Bg 250'. T₁-Control (No fertiliser), T₂-100% recommended fertiliser (Urea, TSP and MOP), T₃-75% Urea + 25% Nano-Nitrogen (Usual TSP and MOP) fertiliser, T₄-50% Urea + 50% of Nano- Nitrogen (Usual TSP and MOP) fertilizer and T₅-100% Nano-Nitrogen (Usual TSP and MOP) five treatments were applied. The use of 100 per cent nano-nitrogen fertilizer resulted in the best growth performance in terms of plant height (57.9 cm), tillers per plant (6) and plant dry weight throughout the ripening period (9.9 g).

Vishekaii et al. (2019) conducted a study where foliar applications with two sources of nitrogen (urea and nano-chelated nitrogen fertilizer) were given to 15-year-old 'Zard' olive tree. Fertilizers were used at the concentration of 2.21g (U₁) and 2.95 g (U₂) urea, 6 g (nano-N₁) and 8 g (nano-N₂) nano-chelated nitrogen, corresponding to 1.02 g (U₁ and nano-U₁) and 1.36 g (U₂ and nano-N₂) pure nitrogen per litre. Results revealed that U₁ and nano-N₂ treatments increased both the shoot length and the number of leaves per shoot when compared with the other treatments in the first and second years, respectively while the minimum values for those traits were found in control.

Zahedi et al. (2020) depicted that nanofertilizers (NFs) plays very important role in increasing vegetative growth, improving reproductive growth and flowering, thereby increasing productivity, product quality and ultimately increasing shelf-life and decreasing fruit waste when sprayed at low concentrations on fruit trees at different time intervals and in frequent sessions and also considered these as growth stimulants.

Midde et al. (2021) conducted a study on the effect of nano nitrogen on growth and yield attributes of rice. Results showed that using half the recommended amount of nano urea resulted in the highest plant height (104.7 cm), number of tillers (348), LAI (5.73) and yield attributes including filled grains per panicle (165.9) and grain yield (7056 kg ha⁻¹), as well as straw yield (8342 kg ha⁻¹). The current situation suggests that chemical fertilizers encourage soil evaporation and eventually the soil may no longer be suitable for agricultural production. To sum up, nano fertilizers are an effective substitute for chemical fertilizers.

Rajesh et al. (2021) studied the impact of foliar applications of nano-nitrogen and nano-zinc on the growth and yield of sweet corn crops and found that the values of plant height (225.7 cm), green leaves per plant (12.60), leaf area (7130 cm² plant⁻¹), leaf area index

(5.94), total dry matter accumulation ($295.2 \text{ g plant}^{-1}$), SPAD (61.74) and NDVI (0.80) were all significantly influenced. With 75% N + foliar applications of chemically produced nano N @ 4 ml L^{-1} and chemically synthesised nano Zn @ 2 ml L^{-1} at 25 and 50 DAS, respectively, nitrogen absorption (246.2 kg ha^{-1}) was greater.

Velmurugan et al. (2021) studied the effect of nano urea on growth and yield of rice under island conditions. Different treatments given were N_0PK (T_1); N_{100}PK (T_2); N_{50}PK (T_3); N_{66}PK (T_4); T_3 + nano urea @ 0.2% (T_5); T_3 + nano urea @ 0.4% (T_6); T_4 + nano urea @ 0.2% (T_7) and T_4 + nano urea @ 0.4% (T_8). It was observed that plant growth parameters like plant height, number of leaves, number of tillers, root length, root mass and shoot mass was found maximum in treatment T_4 + nano urea @ 0.4%.

Samanta et al. in (2022) conducted a study to compare the effectiveness of applying urea and nano urea to the leaves of finger millet. The results showed that in terms of growth, yield characteristics and finger millet yield, the treatment consisting of 40 kg N ha^{-1} + 2 sprays of nano urea @ 4 ml L^{-1} administered at tillering and pre-flowering stage was superior to the other treatments.

Arya et al. (2022) performed a study to assess the impact of various nano urea doses on pearl millet yield characteristics and yield. The study found that the treatments used had a substantial impact on the production of pearl millet. A significantly higher number of productive tillers plant^{-1} (3.79), earhead length (26.82 cm), earhead girth (7.9 cm), number of grains earhead $^{-1}$ (2,462), test weight (15.64 g), grain yield ($3,314 \text{ kg ha}^{-1}$) and stover yield ($5,136 \text{ kg ha}^{-1}$) were observed with the application of 50% RDN as basal + 0.5% Nano-urea foliar spray at panicle initiation and booting stage.

Gangwar et al. (2022) assessed the effect of foliar application of nano-fertilizers on growth and yield treatment on yield of wheat variety HD 2967. T_2 (N, P, K and Zn of 60, 60, 40, 5 kg ha^{-1} applied in combination with nano urea in the ratio of 500 ml ha^{-1}) and T_5 (N, P, K and Zn of 60, 60, 40, 10 kg ha^{-1} applied in combination with nano urea in the ratio of 500 ml ha^{-1}) significantly increased plant height, tillers per plant, grains per plant, grain yield, straw yield and harvest index as compared to T_1 (control).

Goud et al. (2022) found that foliar application of nano urea @ $2\text{-}4 \text{ ml L}^{-1}$ significantly improved growth and yield of rabi sunflower when compared to no nitrogen application treatment. Application of nano urea @ 4 ml L^{-1} showed higher growth response (Plant height, LAI, dry matter (g) per plant) as compared to other nano urea treatments.

Pandav et al. (2022) conducted a study on the effect of nitrogen levels and nano urea on mustard (*Brassica juncea*) growth, yield and quality under lateritic soils of Konkan. The treatments comprised of various levels of 0, 100, 75% of RDN and sub factor (nano urea) 0, 20, 40, 60, 80 ppm at 30 and 60 DAS. The results indicated positive effects and higher values on plant height, number of branches plant⁻¹, number of functional leaves plant⁻¹ and dry matter production at 40, 60, and 80 DAS (Days after sowing) of mustard crop with the application of 75% RDN and two spray of nano urea @ 40 ppm whereas, least values were recorded with untreated control (F₁N₁) treatment combination.

Samui et al. (2022) carried out an investigation on rabi maize growth and productivity as impacted by foliar application of urea and nano urea. Results revealed that adoption of 100% RDN + foliar spray of nano urea @ 4ml L⁻¹, twice at knee stage and tasseling stage significantly influenced morphology, yield attributes and yield of rabi maize. Adoption of 75% RDN + foliar spray of nano-urea @ 4ml L⁻¹ at knee and tasseling stage was found to be an ideal technological adjunct to achieve sustainability in irrigated maize, as this treatment was found to be on par with 100% RDN in terms of growth, yield attributes and maize yield.

Priyadarshana et al. (2022) performed a study where three distinct techniques of N application were used at fortnightly intervals: N₁-Granular application at 4g/m², N₂-2% foliar spray and N₃-IFFCO nano urea at 5 ml L⁻¹ of water in bermuda grass. Plots treated with nano urea outperformed plots treated with granular urea in terms of growth response. Treatment S₁N₃ (10 × 10 cm spacing with 5 ml L⁻¹ of water nano urea foliar spray) had the greatest values for practically all morphological parameters (leaf length 3.43 cm, internodal length 3.63 cm, shoot length 52.46 cm, root length 11.51 cm and percent cover 101.25%).

Rathod et al. (2022) investigated the influence of nano urea on the growth of french basil (*Ocimum basilicum* L.) cultivars in Southern Telangana. The highest plant height, highest number of branches per plant, highest number of leaves per plant, highest plant spread N-S and highest plant spread E-W were observed in F₁ - 75% RDN+ Nano Urea @ 2 ml L⁻¹ (2 sprays at 30, 60 DAT), respectively as compared to other treatments and control.

Rawate et al. (2022) assessed the effect of nano urea on productivity of wheat under irrigated condition. It was found that treatment T₄ (100 percent N + 2 spray of urea (5%) at tillering and jointing stages) recorded the highest plant height, total tiller count, dry matter accumulation (g plant⁻¹), ear length (10.59 m⁻²), number of grains ear head⁻¹ (28.10), test weight (43.65 g), grain yield (42.76 q ha⁻¹) and straw yield (40.32 q ha⁻¹). This treatment was

superior over other treatments but was at par with T₃ (100% N + 2 spray of nano urea at tillering and jointing stages).

Vinayaka et al. (2022) evaluated the effect of nano urea on the growth and yield of jamun cv. AJG-85 under the HDP system and found that treatment T₈ (75% RDN through urea + 0.4% nano urea) was the most effective, with the maximum incremental plant height of 0.42 m, incremental stem girth (0.48 cm), incremental plant spread [(E-W) and (N-S) of Jamun, i.e., 0.80 m and 0.53 m respectively] and incremental canopy volume (8.70 m³) was recorded nine months after foliar spray.

Bhakher et al. (2023) carried out an investigation on the effects of sulphur and foliar spraying of nano urea on sunflower development and yield. The results indicated that the application of sulphur at a rate of 40 kg ha⁻¹ along with nano urea (3ml L⁻¹) produced the highest diameter of capitulum (14.85 cm), number of seeds per capitulum (453.67), test weight (44.58 g), seed yield (1.70 t ha⁻¹), oil content (37.73%) and B:C ratio (2.54), while the application of sulphur at a rate of 40 kg ha⁻¹ along with nano urea 4ml L⁻¹ produced the higher plant height (118.83 cm), plant dry weight (70.08 g) and stover yield (3.36 t ha⁻¹).

Bhatti et al. (2023) studied the effect of different doses of urea and nano urea on growth and yield of guava (*Psidium guajava* L.) cv. Lucknow-49. Factor A comprised of two nitrogen fertilizer doses: U₁-100% RDN and U₂-80% RDN. Whereas, factor B comprised of different nano urea concentrations: N₁-0.1% nano urea, N₂-0.2% nano urea, N₃-0.4% nano urea, N₄-0.5% nano urea, N₅-0.6% nano urea and control (RDF). Results revealed that maximum incremental plant height (0.82 m) and incremental plant spread (N-S) (1.03 m) were observed in 0.5 per cent nano urea (N₄) which was at par with 0.6 per cent nano urea (N₅). In case of incremental plant spread (E-W) (0.89 m), the result was found maximum in 0.6 per cent nano urea (N₅) followed by 0.4 per cent nano urea (N₃).

Choudhary et al. (2023) carried out a study to determine the effectiveness of nano-nitrogen on various growth parameters of oats that affect growth and yield, including plant height, population, number of leaves, leaf length, leaf width and the total number of tillers per plant. They found that 30 days after seeding (DAS), applying 100 per cent of the recommended dose of nitrogen (RDN) through urea and 75 per cent RDN with 25 per cent nitrogen through nano-nitrogen produced the best results.

Islam et al. (2023) studied the effect of nano urea foliar spray on yield and yield attributes of black gram (*Vigna mungo* L.). Under a Randomised Block Design, three

different treatments were used: Control (no fertilizer) (T₁), Farmers Practice (recommendation to apply fertilizer as a basal dose and top dressing during active growth) (T₂) and nano urea (2-4 ml of nano urea (4% N) in one litre of water and sprayed on crop leaves at its active growth stages) (T₃). Different types of nitrogen (urea) had a considerable impact on yield and yield-contributing traits. Treatment T₃ produced the maximum plant height, number of primary branches per plant, largest yield of grain (1587.33 kg ha⁻¹), whereas T₁ produced the lowest (983.33 kg ha⁻¹). It was clear that by using nano urea as a foliar spray during active growth stages, black gram grain production significantly enhanced.

Sannathimmappa et al. (2023) revealed that higher plant height (220.00 cm), number of green leaves plant⁻¹ (12.9) and dry matter per plant (358.00 g) were recorded in the treatment which received RDN (100%) along with two sprays of 0.4 per cent nano N and nano Zn @ 35 and 45 DAT in maize.

Ranjan et al. (2023) assessed the effect of foliar spray of nano urea on yield and economics of rice. Results revealed that treatment T₂-100% RDN through urea along with 2 foliar sprays of nano urea (4ml L⁻¹) at AT (Active Tillering) and PI (Panicle Initiation) significantly produced the highest number of tillers, panicles, filled grains, 1000-grain weight, grain yield and straw yield in rice. Under control, the lowest grain and straw yields were observed.

2.2.2 Leaf Area

Roshdy and Refaai (2016) compared the effects of nano NPK fertilisers and traditional NPK fertilisers on the growth and fruiting of the zaghoul date palm. N, P and K were added as nano and conventional at 500 and 1000; 250 and 500; 250 and 500 g/palm/year, respectively. Results showed that nano technology application of N at 500 and 1000 g/palm/year, as well as P and K each at 250 and 500 g/palm/year significantly improved the leaf area and its content of chlorophylls a, b, total chlorophylls and the maximum values for leaf N, P and K content (%) were recorded with the application of NPK via nano technology at 1000, 500 and 500 g/palm /year, respectively.

Jassim et al. (2019) studied the effect of foliar application of nano fertilizer with three levels (0, 1 and 2 g/l) super micro plus that contains (N 5%, P 3%, K 3%, Fe 4.5%, Zn 8%, Ca 6%, Mg 6%, Mn 0.7%, Cu 0.65 %, B 0.65%, Mo 0.1%) and three times of application at (tillering stage, booting stage, flowering stage) on some components of growth and yield of rice (*Oriza sativa* L.) Amber 33 variety. Results indicated that 2 g/l of nano fertilizer showed

maximum plant height (125.67 cm), panicle length (25.22 cm), flag leaf area (26.53 cm²), number of seeds per panicle (123.33), number of panicle per m² (323.8), fertility (16.67%), weight of 1000 seed (20.31 gm) and grain yield (540 gm.m⁻²). However, application at tillering stage resulted in maximum panicle length (24.78 cm), flag leaf area (25.34 cm²), number of seeds per panicle (119.22), fertility percentage (18.67%) and weight of 1000 seeds (19.64 gm). The interaction of foliar treatment levels and times in level 2g/l at tillering stage resulted in highest plant height (127.67 cm), panicle length (26 cm), flag leaf area (27.11 cm²), number of seeds per panicle (125.67), number of panicle per m² (329), percent of fertility (15.67 %), weight of 1000 seed (20.53 gm) and grain yield (547 gm.m⁻²).

Al-Asally and Al-Hijemy (2022) carried out an investigation to evaluate the effect of soil application of Bio-Stimulator and the foliar application of nano-nitrogen in improving vegetative characteristics of mandarin seedlings. Three concentrations of nano-nitrogen were applied to the leaves (0, 2, 4 ml L⁻¹). The results revealed that, in contrast to the treatment control, the foliar application of nano nitrogen fertilizer at N₂ (4 ml L⁻¹) improved the branch length, secondary shoots number, stem diameter, leaves area, dry weight of vegetative growth and chlorophyll content of leaves.

El-Rahman and Abd-Elkarim (2022) carried a study on the impact of using nano nitrogen fertilizer compare to conventional form on the growth, yield and nutritive value of the fruits of zaghoul date palm grown under Qena, Egypt condition. Results indicated that nitrogen fertilization as nano form significantly affected the vegetative growth of zaghoul date palm i.e. leaf area and leaf N and K contents in both seasons. Increasing the N fertilization dose of nano formulation from 20 to 80 per cent of recommended dose increased the leaf area and leaf content of N and K while, did not affect the leaf phosphorous content.

Kaviyazhagan et al. (2022) showed that by applying 25% N as granular urea (GU) at the base, 25% N as nano urea (NU) at the four-leaf stage, 25% N as nano urea at the eight-leaf stage and 25% N as nano urea at the tasseling stage (T₈) proved superior by registering better growth characters like plant height, dry matter production, leaf area index, crop growth rate (CGR), absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR), green cob yield and green fodder yield as compared to other treatments and control.

Abobatta and Fatma (2023) studied the effect of urea and nano-nitrogen spray treatments on some citrus rootstock seedlings. Different treatments given were control, nitrogen nano particles (Nn) at 500 ppm, nitrogen nano particles (Nn) at 750 ppm, urea at 500

ppm, urea at 750 ppm. Results revealed that foliar application with nitrogen nano at 750 ppm showed maximum values for all growth parameters i.e. plant height, stem diameter, number of leaves per seedling, leaf area, fresh and dry weights of three plant organs (shoots, leaves, roots) total plant dry weight and top/root ratio.

Chavan et al. (2023) examined the effect of foliar application of nano nitrogen fertilizer on growth and yield of sorghum (*Sorghum bicolor* L.). The study findings showed that treating 100% RDN with commercial urea in two equal splits at sowing and 30 DAS produced greater growth attributes i.e. plant height, number of functional leaves at 90 DAS, leaf area per plant, dry matter per plant at 90 DAS, number of internodes per plant at harvest, days to 50% flowering and circumference of stem. It was followed by foliar sprays of 125% RDN with nano urea in three equal splits -15, 30 and 45 DAS.

Salim et al. (2023) conducted an experiment entitled enhancing nutrient use efficiency through nano fertilizers in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt.). Treatments nano-N and nano-Zn were applied at 15 DAS, 30 DAS and 45 DAS in various treatment combinations. Treatment T₅ (50 percent RDN + nano-N at 30 DAS + nano-Zn at 30 DAS) was determined to be the best treatment in terms of plant height, number of branches, number of leaves and leaf area per plant. This treatment also had higher yield qualities such as pod weight, number of pods per plant, pod yield per plant, haulm yield per plant, pod yield per hectare and haulm yield per hectare.

2.2.3 Leaf chlorophyll content

Merghany et al. (2019) carried out a study on the effect of nano fertilizers on cucumber plant growth, fruit yield and its quality. Different concentrations (3, 4.5, 6 and 9 ml) of liquid nano NPK were used. Results indicated that nanofertilizer treatments significantly enhanced the growth and yield of cucumber compared with control treatment. All nanofertilizer treatments substantially increased plant height, number of leaves/plant, chlorophyll content, yield and NPK per cent in leaves and fruits.

Nandhinidevi and Ruban (2022) investigated the effect of foliar application of nano nutrients (Nano Nitrogen, Zinc and Copper) on capsicum yield. The experiment used an RBD (Randomised Block Design) with three replications and thirteen treatments. The treatment with 100% RDF (P:K) + 100% Nano N + Nano Zn + Nano Cu (T₁₁) showed the best results as compared to other treatments and control, leading to the conclusion that nano nitrogen

substituted for the 50 per cent urea recommendation in conventional fertilizer and also had enhanced effect than control.

Sharma et al. (2022) investigated the impact of foliar application of nano urea at different nitrogen levels on productivity and quality of pearl millet (*Pennisetum glaucum* L.). Three nitrogen levels (50% RDN, 75% RDN and 100% RDN) and three treatment of nano urea (control, one spray of nano urea at 4 ml L⁻¹ water at 30 DAS and two spray of nano urea at 4 ml L⁻¹ water at 30 and 45 DAS) were administered. The results revealed that foliar spraying with nano-urea (4 ml L⁻¹ water) at 30 and 45 DAS enhanced plant height, dry matter accumulation, chlorophyll content, nitrogen content, phosphorus content and potassium content in pearl millet grain and straw compared to the control.

Khule et al. (2023) investigated the impact of foliar application of nano-nitrogen fertilizer on linseed (*Linum usitatissimum* L.) growth, yield and quality. Treatment T₇-50% N (RDN) and 100% P and K through soil + two foliar sprays of 0.4% nano-N at 20 and 40 DAS recorded the highest plant height, number of capsules plant⁻¹, fresh and dry weight (g plant⁻¹), total chlorophyll content, grain yield (1440.33 kg ha⁻¹) and straw yield (2894.92 kg ha⁻¹) that was significantly superior over all other treatments.

Yadav et al. (2023) investigated the combined effects of nano urea and boron foliar spray on wheat (*Triticum aestivum* L.) growth, yield characteristics and yield. The experiment included three levels of nitrogen (nano urea) at 2000 ppm, 2500 ppm and 3000 ppm as well as three levels of boron at 0.20 kg ha⁻¹, 0.25 kg ha⁻¹ and 0.3 kg ha⁻¹. The results showed that foliar nitrogen (nano urea) application at 3000 ppm improved growth, yield characteristics and yield as shown in plant height (82.23 cm), dry weight plant⁻¹ (22.41 g), number of leaves plant⁻¹ (27.17), leaf area plant⁻¹ (433.69 cm²), chlorophyll intensity (45.13) at the start of flowering and (40.32) at the end of flowering, days to heading (78.96), days to maturity (123.40), number of tillers plant⁻¹ (6.15) at maturity and seed yield plant⁻¹ (14.34 g).

2.2.4 Leaf N, P and K content

Doaa and Raeesa (2020) observed that the application of nano nitrogen foliar fertilizer had a significant impact on shoot diameter, leaf area, N, P and K concentration in leaf petioles, yield and cluster physical and chemical characteristics as compared to control treatment. Furthermore, among all treatments the foliar application of 1000 ppm nano nitrogen fertilizer along with 50 per cent reduction of soil added nitrogen fertilizer than the

recommended level improved vegetative growth, as well as yield and fruit quality of 'King Ruby seedless' grapevines as it recorded the highest values of the tested parameters.

Naim et al. (2020) investigated the effect of nano urea added in two different doses (3 g and 5 g per kg substrate), once (at spawning or after first flush) or twice (at spawning and after first flush) to the growing substrate consisting of wheat straw and spent oyster substrate (1:1, w/w). The results showed that, regardless of the amount used, applying nano urea once caused the largest number of mushroom flushes (four flushes). In contrast to early findings, which showed that high nitrogen concentrations inhibited the growth and output of mushrooms, twice-applied nano-urea had better results. The shortest time (15 days) between the first and third flushes was induced at 5 g/kg. At the third flush, 3 g/kg produced the best biological and economic yields (332.7 g/bag and 283.1 g/bag, respectively), as well as the maximum biological efficiency (109.6%) and pileus diameter/stipe length ratio (2.8).

Nikbakht et al. (2021) performed an experiment to study the effect of foliar treatment of nitrogen using nano-nitrogen and urea chemical fertilizers on the quantitative and qualitative traits of bitter apples. The results revealed that foliar application of nitrogen has little effect on fruit average weight, fruit length or fruit diameter, but significantly affects yield, number of fruits per bush and shoot length. The largest amount of fruit per bush (12) was observed in nano-N at 2000 mg L⁻¹ concentration, which also has the highest yield per bush (961.08g) and urea at 2% concentration (864.66g). The foliar application of nano-N at a concentration of 2000 mg L⁻¹ and urea at a concentration of 2 per cent yields the highest weight of 100 seeds and seed protein. The concentration of nitrogen in leaves increased as a result of foliar treatment, whereas P, K and Zn concentrations in leaves did not change. Results showed that application of nano-nitrogen fertilizer at a concentration of 2000 mg L⁻¹ produces better outcomes than other treatments for the majority of measured quantitative and qualitative features, this therapy can be suggested to lower financial and environmental costs.

Enigi et al. (2022) observed that the treatment 75% RDF (63 N kg ha⁻¹) of N through prilled urea + 0.4% nano urea foliar spray at 45 and 60 days after sowing (DAS) recorded significantly higher total NPK content of leaves after third spray (N-3.20%, P-0.52%, K-2.56%) and total NPK content of whole plant at 60 days after sowing (N-3.12%, P-0.47%, K-2.52%) in french bean.

Sahu et al. (2022) evaluated the effect of nano urea application on growth and productivity of rice under midland situation of Bastar region. Results showed that the highest

number of panicles m^{-2} , total number of grains panicle^{-1} , number of filled grains panicle^{-1} , test weight (g), grain and straw yield and nutrient uptake were significantly higher under treatment T₅ (75% of RDN + two foliar sprays of nano urea), which was statistically at par with the treatment T₄ (50% of RDN + two foliar sprays of nano urea) and T₆ (100% of RDN + two foliar sprays of nano urea).

Sharaf-Eldin et al. (2022) conducted a study to evaluate the effect of nano nitrogen (nN) under different water regimes and assessed the growth attribute and other essential nutrient uptake by lettuce plant in different combination of bulk and nano nitrogen forms with surface and drip irrigation method. Among all nitrogen (N) fertiliser combinations, applying 75% nN via drip irrigation and 25% nN via foliar application has the greatest effect on plant biomass, leaf area, absolute growth rate, net assimilation rate, carotene, crude protein and yield. Similarly, as compared to lower N rates, this combination boosted N uptake, N use efficiency and apparent N recovery. The results showed that applying nN as a soil and foliar treatment was more efficient than applying bN as a soil treatment. Furthermore, it has the potential to reduce the needed N fertilisation rate while maintaining yield.

Kanno et al. (2022) revealed that nanofertilizer treatment was more practicable and efficient than traditional fertilizer in boosting nutrient content, absorption and economics of black wheat.

Saitheja et al. (2022) studied that 100 per cent RDN and nano urea foliar spray @ 4ml L^{-1} of water greatly increased fertility co-efficient (71.2%), pods plant^{-1} (38.5), seeds pod^{-1} (12.7) and maximum grain production (1291 kg ha^{-1}) as well as the number of plants and seeds per plant of greengram (*Vigna radiata* L.). However, it was comparable to the application of 80 per cent RDN and nano urea foliar spray at 4 ml L^{-1} of water, which had fertility co-efficient results of 70.6 per cent, 38.0 pods plant^{-1} , 12.6 seeds pod^{-1} and grain yield results of 1289 kg ha^{-1} . Based on the findings of the experiment, it was concluded that a reduced application of base nitrogen or 80 per cent RDN, with a foliar spray of nano urea at 4ml L^{-1} was discovered to be the ideal nitrogen dose and nano urea foliar nutrition for maximising the productivity and profitability of summer irrigated greengram.

Aher and Umesha (2023) evaluated the response of nano urea and zinc on growth and yield of baby corn (*Zea mays* L.). Three different concentrations of nano urea: N₁ (1 ml L^{-1} foliar spray nano urea), N₂ (2 ml L^{-1} foliar spray nano urea) and N₃ (3 ml L^{-1} foliar spray nano urea) were used. In contrast, three levels of zinc: Z₁ (20 kg ha^{-1}), Z₂ (25 kg ha^{-1}) and Z₃ (30

kg ha⁻¹) were used. From the results of the experiment, it was found that ZnSO₄ @ 30 kg ha⁻¹ + nano urea 3 ml L⁻¹ resulted in the profitable production of baby maize. With the use of ZnSO₄ @ 30 kg ha⁻¹ and nano urea 3 ml L⁻¹, the highest gross returns (92087.17 ha), net returns (61352.17 ha) and B:C ratio (2.00) were very high.

Chapter-3

MATERIALS AND METHODS

The present investigations entitled, “**Studies on the effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox**” were undertaken at Pandah Experimental Farm of Department of Seed Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during 2022-23. The details of material used and methodologies employed are presented in this chapter.

3.1 LOCATION AND CLIMATE OF EXPERIMENTAL SITE:

The experimental farm of department is located at latitude of 30°85’8” North and longitude 77°15’8” East in the hilly regions of the Western Himalayas. The area falls in the mid hill zone (Sub Mountain to sub humid *i.e.* zone II) of Himachal Pradesh. The climate of this area in general is typically sub-temperate, where summers are moderately hot during May-June and winters during December-January are severe. The annual rainfall of the area ranges between 800 and 1500 mm, major amount of which is received during monsoon period from July to September.

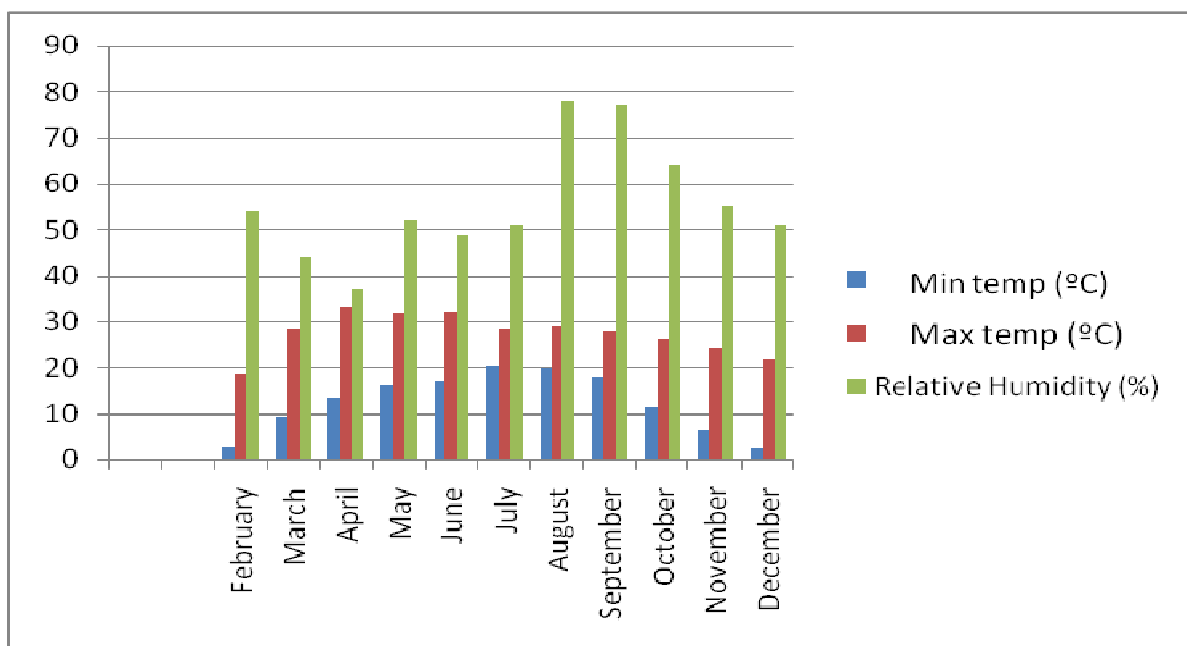


Figure 3.1: Graphical representation of monthly meteorological data pertaining to the temperature and relative humidity during the crop season (February–December, 2022)

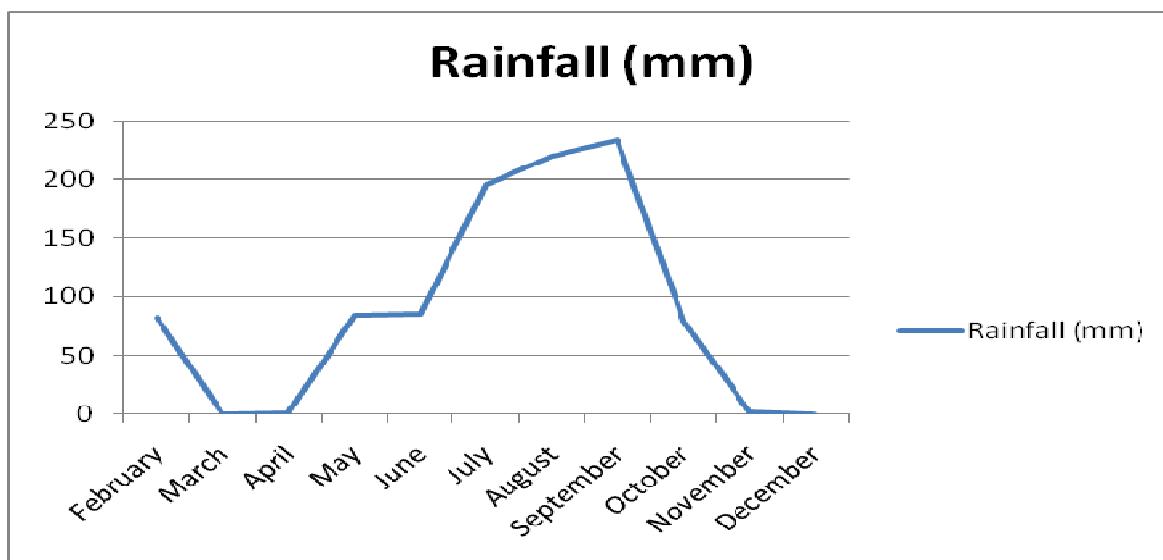


Figure 3.2: Graphical representation of monthly meteorological data pertaining to the rainfall during the crop season (February–December, 2022)

Source: Meteorological Observatory, Department of Environment Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) 173 230

3.2 EXPERIMENTAL DETAILS

The detailed technical programme of present investigation is as under:

3.2.1 TECHNICAL PROGRAMME

Fruit crop	Apple
Cultivar	Red Velox
Rootstock	Bud 9
Treatments	7
Replications	3
Number of applications	3 (Weekly interval in July)
Total number of plots	21
Plants per replication	20
Spacing	20 cm × 20 cm
Design of experiment	Randomized Complete Block Design (RCBD)

3.2.2 TREATMENT DETAILS

Treatment Code	Treatment Details
T ₁	Urea @ 0.3%
T ₂	Urea @ 0.4%
T ₃	Urea @ 0.5%
T ₄	Nano urea @ 0.3%
T ₅	Nano urea @ 0.4%
T ₆	Nano urea @ 0.5%
T ₇	Control



Plate 1: General view of experimental field at different stages of plant growth

3.2.3 PLANTING MATERIAL

One year old clonal rootstock of Bud 9 raised through cuttings and planted at a spacing of 20 cm × 20 cm in beds. The scion wood of Red Velox cultivar was taken from bud wood bank of Department of Fruit Science. Tongue grafting was performed on Bud 9 rootstock by healthy and disease free scion wood during first week of March at 15 cm height from ground level.

3.2.4 TIME AND METHOD OF APPLICATION

The foliar application of urea and nano urea treatments were given to the apple nursery cv. Red Velox during the month of July at weekly interval. In case of urea, for 0.3 per cent, 0.4 per cent and 0.5 per cent urea foliar sprays: 3 g, 4 g and 5 g urea was dissolved in one litre of water, respectively. In case of nano urea (w/v), for 0.3 per cent, 0.4 per cent and 0.5 per cent foliar sprays: 3 ml, 4 ml and 5 ml nano urea was dissolved in one litre of water, respectively.

3.3 OBSERVATIONS RECORDED

3.3.1 Plant height

Five plants from each replication were randomly selected in the month of December. The plant height was measured from soil surface to tip with the help of graduated flag staff in centimetre (cm).

3.3.2 Stem diameter

The diameter of five shoots from each replication was recorded in the month of December with the help of 'Digital Vernier Calliper' (Mitutoyo Corporation- Digimatic Calliper) at the height of 5 cm above the ground level and the average was expressed in millimetre (mm).

3.3.3 Number of branches

Five plants from each replication were randomly selected in the month of December and number of branches per plant was recorded by counting them and data was recorded as average number of branches.

3.3.4 Number of leaves

Five plants from each replication were randomly selected and the observations on leaf number were recorded during the month of October. All the leaves, irrespective of their size were counted and average number of leaves per plant was calculated.

3.3.5 Leaf area

The data on leaf area was recorded during first week of October when leaves were fully developed. Ten fully expanded leaves were collected at random from different plants per replication and area of these leaves was measured with the help of Leaf Area Meter (LICOR Model-3100) and expressed in square centimeters per leaf (cm²).

3.3.6 Leaf chlorophyll content

Five fully expanded and mature leaves from each replicated bed were collected in the month of October during morning hours, immediately placed in ice box and brought to the laboratory. The samples were then kept in the refrigerator to avoid degradation of chlorophyll pigments.

Extraction

Leaves from five samples were washed and chopped into fine pieces under subdued light and 100 mg of chopped material was placed in vial containing 7 ml of dimethyl sulphoxide (DMSO). The contents of the vial were incubated at 65°C temperature for 30 minutes and then extract was transferred to graduated test tube and the final volume was made to 10 ml with dimethyl sulphoxide.

ESTIMATION

Optical density of the above extract was recorded on Spectronic 20D at 645 nm and 663 nm wavelength against a DMSO blank and total chlorophyll content was calculated by using the following formula:

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

Where,

- V = Volume of extract used
- A = Length of the light path in cell (1cm)

W = Weight of the sample (g)

A₆₄₅ = Absorbance at 645 nm wavelength

A₆₆₃ = Absorbance at 663 nm wavelength

The results were expressed as chlorophyll content in mg g⁻¹ of fresh weight.

3.3.7 Leaf N, P and K content

3.3.7.1 Collection and preparation of leaf samples

Leaves including petioles from each experimental nursery plant were collected during the first week of October from the middle part of the plant and composite sample of individual replication was prepared.

The leaf samples collected, were brought directly to the laboratory, thoroughly washed first under tap water, followed by 0.1 N HCl and distilled water as suggested by Chapman (1964). The washed leaf samples were spread on filter paper sheets for surface drying and were subsequently put into paper bags which were kept in hot air oven at 65 ± 5°C for 48 hours for final drying. The dried samples were crushed, ground and stored in butter paper bags for the estimation of various nutrient elements.

3.3.7.2 Determination of nutrient elements

Digestion of the leaf samples

The digestion of dried leaf sample (1 g) for the estimation of nitrogen was carried out in concentrated H₂SO₄ in the presence of a digestion mixture of following chemicals:

Potassium sulphate : 400 parts

Copper sulphate : 20 parts

Mercuric oxide : 3 parts

Selenium powder : 1 part

For the estimation of P and K the leaf samples (0.5 g) were digested in di-acid mixture prepared by mixing HNO₃ and HClO₄ in the ratio of 4:1 taking all the precautions suggested by Piper (1966).

3.3.7.2.1 Nitrogen

Total nitrogen was determined by micro-Kjeldhal's method (Jackson, 1973) and results were expressed in per cent nitrogen on dry weight basis.

3.3.7.2.2 Phosphorus

Total phosphorus was estimated by vanado molybdate phosphoric yellow colour method (Jackson, 1973). Five millilitre of aliquot (digested) was pipette out in a 25 ml volumetric flask and 5 ml of vanado molybdate 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 the solution was recorded on Thermo-Scientific Spectronic 20 D+ at 470 nm wavelength and a blank was run simultaneously to adjust zero absorbance. Leaf phosphorus was expressed in per cent on dry weight basis.

3.3.7.2.3 Potassium

Total potassium content was estimated using Flame Photometer (MODEL TMF-45) as suggested by Jackson (1973) and the results were expressed in per cent.

3.3.8 Fresh weight of shoots

The grafted plants were uprooted in the month of December. The shoot portion of five plants per replication used for recording the data on fresh weight of shoots. The shoot was cut into pieces and the fresh weight was recorded on top pan electronic balance and expressed in grams per shoot (g).

3.3.9 Dry weight of shoots

The shoots cut for recording the fresh weight were dried in an oven at a temperature of 65°C for about 72 hours. The dry weight of shoots was recorded on top pan electronic balance and expressed in grams per shoot (g).

3.3.10 Number of roots

From plants uprooted in December, five plants from each replication were randomly selected and the data on number of roots was recorded by counting all the roots emerging out directly from the planted clonal rootstocks and expressed as average number of roots per plant.

3.3.11 Total root length

Five plants from each replication were selected with entire root system. The root system was washed with tap water under pressure and then roots were cut into small pieces. The total length of roots was measured with the help of root length scanner (Comair root length scanner) and was expressed in meters (m).

3.3.12 Fresh weight of roots

The root portion of five plants per replication was used for the recording the data on fresh weight of roots (g). The entire roots were cut into small pieces and the fresh weight was weighed on top pan electronic balance and expressed in gram (g).

3.3.13 Dry weight of roots

The roots cut for recording the fresh weight were dried in an oven at a temperature of 65°C for about 72 hours. The dry weight of roots was weighed on top pan electronic balance and expressed in grams (g).

3.3.14 Biomass of plant (dry weight basis)

The total biomass of plant was calculated on dry weight basis by adding the dry weight of entire shoots and root system of each plant. The results were expressed in grams (g).

3.3.15 Shoot: Root ratio

Shoot root ratio was calculated by the given formula:

$$\text{Shoot root ratio} = \frac{\text{Dried weight of shoot (g)}}{\text{Dried weight of root (g)}}$$

3.4 STATISTICAL ANALYSIS

The experiment was laid out in Randomized Complete Block Design (RCBD) and the data obtained on various parameters from the present investigation was subjected to statistical analysis in accordance with the method described by Gomez and Gomez (1984). The level of significance was tested for different variable at 5 per cent level of significance.

ANOVA shall be as follows:

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-Cal. Value
Treatments	(t-1)	S_t	$M_t = \frac{S_t}{(t-1)}$	$\frac{M_t}{M_g}$
Replications	(r-1)	S_r	$M_r = \frac{S_r}{(r-1)}$	$\frac{M_r}{M_g}$
Error	(r-1)(t-1)	S_e	$M = \frac{S_e}{(r-1)(t-1)}$	
Total	(rt-1)	S_T		

Where,

r	=	Number of replications
t	=	Number of treatments
S _r	=	Sum of squares due to replications
S _t	=	Sum of squares due to treatments
S _e	=	Sum of squares due to error
S _T	=	Total sum of squares
M _r	=	Mean sum of squares due to replications
M _t	=	Mean sum of squares due to treatments
M _e	=	Mean sum of squares due to error

The replication and treatment mean sum of square shall be tested against mean sum of squares due to error by 'F' test at (r-1), (r-1) (t-1) and (t-1), (r-1) (t-1) degree of freedom for RCBD at 5% level of significance. The calculated F-values shall be compared with tabulated F- value. When F- test will be found significant, critical difference will be calculated to find out the superiority of one treatment over the other.

The standard error and critical differences were calculated as follows:

$$\begin{aligned} \text{SE (m) } \pm &= \pm \sqrt{M_e / r} \\ \text{SE (d) } \pm &= \pm \sqrt{2 M_e / r} \\ \text{CD}_{0.05} &= \text{SE (d) } \times t_{0.05} (r-1) (t-1) \text{ df} \end{aligned}$$

where,

SE (m) ±	=	Standard error of mean
SE (d) ±	=	Standard error of differences of means
CD _{0.05}	=	Critical difference at 5 per cent level of significance

Chapter-4

RESULTS AND DISCUSSION

The present investigations entitled “**Studies on the effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox**” were carried out at the Experimental Farm and Laboratory of Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the session 2022-23. The findings of the current study have been provided and discussed with appropriate explanations in this chapter as follows:

4.1 PLANT HEIGHT

The data pertaining to the effect of foliar application of urea and nano urea on plant height of apple nursery cv. Red Velox are given in Table 4.1 and Figure 4.1.

Table 4.1: Effect of foliar application of urea and nano urea on plant height of apple nursery cv. Red Velox

Treatment	Plant height (cm)
T ₁ – Urea @ 0.3%	169.55
T ₂ – Urea @ 0.4%	170.22
T ₃ – Urea @ 0.5%	170.99
T ₄ – Nano urea @ 0.3%	181.99
T ₅ – Nano urea @ 0.4%	183.21
T ₆ – Nano urea @ 0.5%	172.33
T ₇ – Control	167.22
CD _{0.05}	2.21

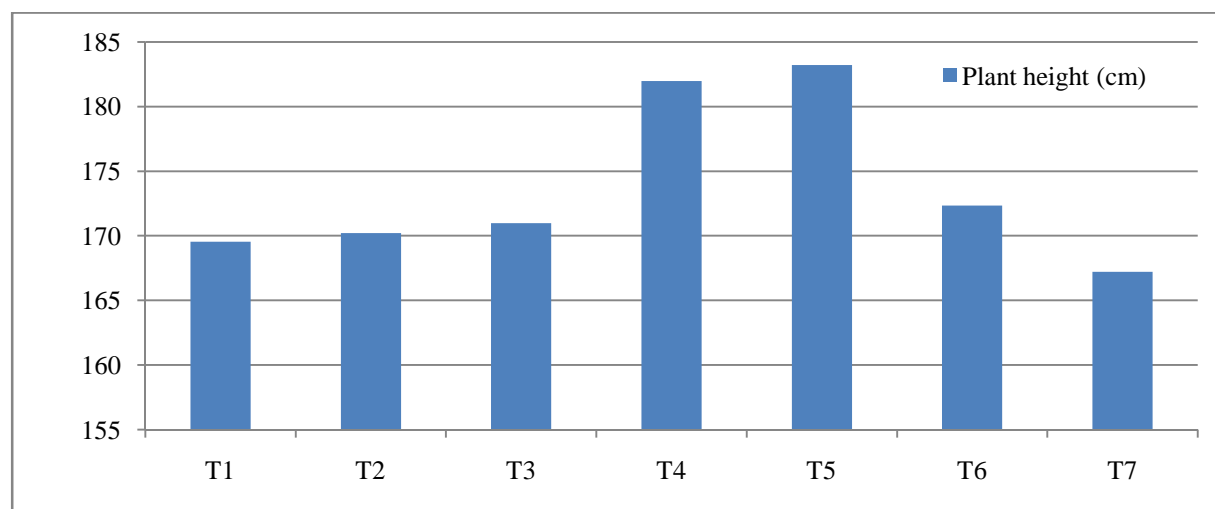


Figure 4.1: Effect of foliar application of urea and nano urea on plant height of apple nursery cv. Red Velox

The perusal of data reveals that plant height of apple nursery was significantly affected by different treatments of urea and nano urea (Table 4.1 and Figure 4.1). The maximum plant height (183.21 cm) was observed in treatment T₅ (Nano urea @ 0.4%) which was statistically at par with the treatment T₄ (Nano urea @ 0.3%) resulting into plant height of 181.99 cm and was significantly higher over all the other treatments including control. Minimum plant height (167.22 cm) was recorded in treatment T₇ (Control).

This might be due to the fact that foliar application of nano urea helps in the efficient absorption and translocation of nitrogen to different plant parts due to their small size which helps in easy penetration through stomatal openings and effective distribution throughout the plant system, enough nitrogen supply might have enhanced the activity of enzymes and auxin metabolism in plants, leading to larger cells and cell elongation, resulting in taller plants (Rajesh et al., 2021).

These results are in conformity with the findings of Sharma et al. (2022) who observed that foliar spraying with nano urea (4 ml L⁻¹ water) at 30 and 45 DAS enhanced plant height of pearl millet. Velmurugan et al. (2021) showed that maximum plant height was observed in the treatment N₆₆PK + nano urea @ 0.4% in rice. Goud et al. (2022) observed that application of nano urea @ 4 ml L⁻¹ showed numerically higher growth response (plant height) than other nano urea treatments in rabi sunflower. Samanta et al. (2022) recorded maximum plant height in the treatment which received 40 kg N ha⁻¹ + 2 sprays of nano urea @ 4 ml L⁻¹ in finger millet. Samui et al. (2022) also found maximum plant height with 100% RDN + FSNU @ 4 ml L⁻¹ which was statistically at par with 100% RDN + FSNU @ 2 and 3 ml L⁻¹ applied at knee and tasseling stage in rabi maize. Sannathimmappa et al. (2023) observed that higher plant height was recorded in the treatment which received RDN (100%) along with two foliar sprays of 0.4 per cent nano N and nano Zn @ 35 and 45 DAT in maize. Similarly, Khule et al. (2023) recorded the highest plant height in the treatment which received 50% N (RDN) and 100% P and K through soil + two foliar sprays of 0.4% nano N at 20 and 40 DAS in linseed. Al-Asally and Al-Hijemy (2022) showed that foliar application of nano nitrogen @ 4 ml L⁻¹ significantly increased branch length of mandarin seedlings. Our findings were also similar to the results of Vinayaka et al. (2022) who found that treatment 75% RDN through urea + 0.4% nano urea resulted in maximum plant height in Jamun and Bhakher et al. (2023) who recorded maximum plant height in treatment receiving 40 kg ha⁻¹ sulphur + 4 ml L⁻¹ nano urea in sunflower.

4.2 STEM DIAMETER

The data related to the effect of foliar application of urea and nano urea on stem diameter of apple nursery cv. Red Velox are shown in Table 4.2.

Table 4.2: Effect of foliar application urea and nano urea on stem diameter of apple nursery cv. Red Velox

Treatment	Stem diameter (mm)
T ₁ – Urea @ 0.3%	12.55
T ₂ – Urea @ 0.4%	12.77
T ₃ – Urea @ 0.5%	13.66
T ₄ – Nano urea @ 0.3%	14.22
T ₅ – Nano urea @ 0.4%	15.70
T ₆ – Nano urea @ 0.5%	13.99
T ₇ – Control	11.99
CD _{0.05}	1.58

The data presented in Table 4.2 reveals that stem diameter of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum stem diameter (15.70 mm) was observed in treatment T₅ (Nano urea @ 0.4%) which was statistically at par with the treatment T₄ (Nano urea @ 0.3%) resulting into stem diameter of 14.22 mm and was significantly higher over all the other treatments including control. Minimum stem diameter (11.99 mm) was recorded in treatment T₇ (Control).

Influence of foliar spray of nano urea on stem diameter could be attributed to important function of nitrogen in protein and nucleic acid synthesis, as well as protoplasm production. This results in role-induced cell division and the initiation of meristematic activity, which leads to the production of more tissues and organs. Also, increased nitrogen availability can stimulate photosynthetic processes in plants. Higher photosynthetic rates might have resulted in enhanced production of sugars and other growth promoting compounds, providing the necessary energy and building blocks for stem growth and expansion.

These findings are in concomitant with those of Al-Asally and Al-Hijemy (2022) who showed that foliar application of nano nitrogen @ 4 ml L⁻¹ significantly increased stem diameter of mandarin seedlings. Doa and Raeesa (2020) also found that foliar application of nano nitrogen fertilizer increased stem diameter of ‘King Ruby Seedless’ grapevines.

4.3 NUMBER OF BRANCHES

The data associated to the effect of foliar application of urea and nano urea on number of branches of apple nursery cv. Red Velox are presented in Table 4.3.

Table 4.3: Effect of foliar application of urea and nano urea on number of branches of apple nursery cv. Red Velox

Treatment	Number of branches per plant
T ₁ – Urea @ 0.3%	1.55
T ₂ – Urea @ 0.4%	1.78
T ₃ – Urea @ 0.5%	2.00
T ₄ – Nano urea @ 0.3%	2.33
T ₅ – Nano urea @ 0.4%	3.00
T ₆ – Nano urea @ 0.5%	2.11
T ₇ – Control	1.22
CD _{0.05}	0.70

The perusal of data (Table 4.3) indicates that number of branches of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum number of branches (3.00) per plant was observed in treatment T₅ (Nano urea @ 0.4%) which was statistically at par with the treatment T₄ (Nano urea @ 0.3%) resulting into 2.33 number of branches per plant and was significantly higher over all the other treatments including control. Minimum number of branches (1.22) per plant was recorded in treatment T₇ (Control).

Plants receiving foliar spray of nano urea may have the most branches per plant, because at a critical stage, they received enough nitrogen through nano urea, which would have maintained a constant supply of nitrogen, stimulated cell elongation and meristematic activity in plants and ultimately resulted in more branches.

These findings are in consonance with those of Al-Asally and Al-Hijemy (2022) who showed that foliar application of nano nitrogen @ 4 ml L⁻¹ significantly increased secondary shoot number of mandarin seedlings. Islam et al. (2023) found that numbers of primary branches per plant were significantly influenced by the nano urea spray at active growth phases of black gram, 2-4 ml of nano urea (4% N) in one litre of water and sprayed on crop leaves at its active growth stages and recorded maximum branching (2.33) with application of nano urea @ 4 ml L⁻¹ compared to control (1.33). Our findings were also similar to the results of Rathod et al. (2022) who recorded maximum number of branches with the treatment 75%

RDN + nano urea @ 2 ml L⁻¹ in french basil and Pandav et al. (2022) who found that 75% RDN and two sprays of nano urea @ 40 ppm registered maximum number of branches per plant in mustard.

4.4 NUMBER OF LEAVES

The data showing the effect of foliar application of urea and nano urea on number of leaves of apple nursery cv. Red Velox are depicted in Table 4.4.

Table 4.4: Effect of foliar application of urea and nano urea on number of leaves of apple nursery cv. Red Velox

Treatment	Number of leaves per plant
T ₁ – Urea @ 0.3%	39.27
T ₂ – Urea @ 0.4%	41.47
T ₃ – Urea @ 0.5%	45.93
T ₄ – Nano urea @ 0.3%	57.73
T ₅ – Nano urea @ 0.4%	62.07
T ₆ – Nano urea @ 0.5%	47.00
T ₇ – Control	33.27
CD _{0.05}	1.23

It is evident from data (Table 4.4) that number of leaves per plant of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum number of leaves (62.07) per plant was observed in treatment T₅ (Nano urea @ 0.4%) which was significantly higher over all the other treatments including control. Minimum number of leaves (33.27) per plant was recorded in treatment T₇ (Control).

The increase in number of leaves per plant may be due to the abundant supply of nitrogen through foliar spray of nano urea, as nano urea particles have a smaller size which allows for better penetration through leaf cuticles and increased absorption by plant. The abundant supply of nitrogen could have increased protoplasmic constituents and accelerated cell division and elongation process (Choudhary et al., 2023).

These findings are in accordance with those of Velmurugan et al. (2021) who observed maximum number of leaves with treatment N₆₆PK + nano urea @ 0.4% in rice. Sannathimmappa et al. (2023) recorded maximum number of green leaves per plant (12.9) in the treatment which received RDN (100%) along with two sprays of 0.4% nano- N and nano- Zn @ 35 and 45 DAT in maize. Rajesh et al. (2021) showed that number of green leaves per plant (12.60) were significantly influenced with 75% N + foliar applications of chemically

produced nano N @ 4 ml L⁻¹ and chemically synthesised nano Zn @ 2 ml L⁻¹ at 25 and 50 DAS in sweet corn. The findings were also similar to the results of Rathod et al. (2022), Pandav et al. (2022), Choudhary et al. (2023) and Vishekaii et al. (2019).

4.5 LEAF AREA

The data pertaining to the effect of foliar application of urea and nano urea on leaf area of apple nursery cv. Red Velox are given in Table 4.5.

Table 4.5: Effect of foliar application of urea and nano urea on leaf area of apple nursery cv. Red Velox

Treatment	Leaf area (cm ²)
T ₁ – Urea @ 0.3%	27.10
T ₂ – Urea @ 0.4%	27.50
T ₃ – Urea @ 0.5%	28.31
T ₄ – Nano urea @ 0.3%	29.80
T ₅ – Nano urea @ 0.4%	33.51
T ₆ – Nano urea @ 0.5%	28.49
T ₇ – Control	23.01
CD _{0.05}	1.91

It is pertinent from data that leaf area of apple nursery was significantly affected by different treatments of urea and nano urea (Table 4.5). The maximum leaf area (33.51 cm²) was observed in treatment T₅ (Nano urea @ 0.4%) which was significantly higher over all the other treatments including control. Minimum leaf area (23.01 cm²) was recorded in treatment T₇ (Control).

The chief function of nitrogen is multiplication, cell elongation and tissue differentiation that ultimately enhanced vegetative growth through number and size of leaves (more leaf area). Foliar spray of nano urea resulted in large leaf area which enhanced the capacity of the plants to intercept adequate sunlight, that might have resulted in the production of more assimilate thereby enhancing growth and development of the crop.

These findings are in agreement with those of Al-Asally and Al-Hijemy (2022) who showed that the foliar application of nano nitrogen fertiliser at 4 ml L⁻¹ improved the leaves area of mandarin seedlings. Goud et al. (2022) observed that application of nano urea @ 4 ml L⁻¹ showed numerically higher growth response (LAI) than other nano urea treatments in rabi sunflower. Similarly, Samanta et al. (2022) showed that maximum LAI was recorded by 40 kg N ha⁻¹ + 2 sprays of nano urea @ 4 ml L⁻¹ in finger millet. Similar findings were also

reported by Rajesh et al. (2021) who found that leaf area significantly increased with application of 75% N + foliar application of chemically produced nano N @ 4 ml L⁻¹ and chemically synthesised nano Zn @ 2 ml L⁻¹ at 25 and 50 DAS in sweet corn. Our findings were also in accordance with the findings of Yadav et al. (2023), El-Rahman and Abd-Elkarim (2022) and Priyadarshana et al. (2022).

4.6 LEAF CHLOROPHYLL CONTENT

The data on the effect of foliar application of urea and nano urea on leaf chlorophyll content of apple nursery cv. Red Velox are presented in Table 4.6 and Figure 4.2.

Table 4.6: Effect of foliar application of urea and nano urea on leaf chlorophyll content of apple nursery cv. Red Velox

Treatment	Leaf chlorophyll content (mg g ⁻¹)
T ₁ – Urea @ 0.3%	2.36
T ₂ – Urea @ 0.4%	2.43
T ₃ – Urea @ 0.5%	2.49
T ₄ – Nano urea @ 0.3%	2.60
T ₅ – Nano urea @ 0.4%	2.76
T ₆ – Nano urea @ 0.5%	2.54
T ₇ – Control	2.21
CD _{0.05}	0.06

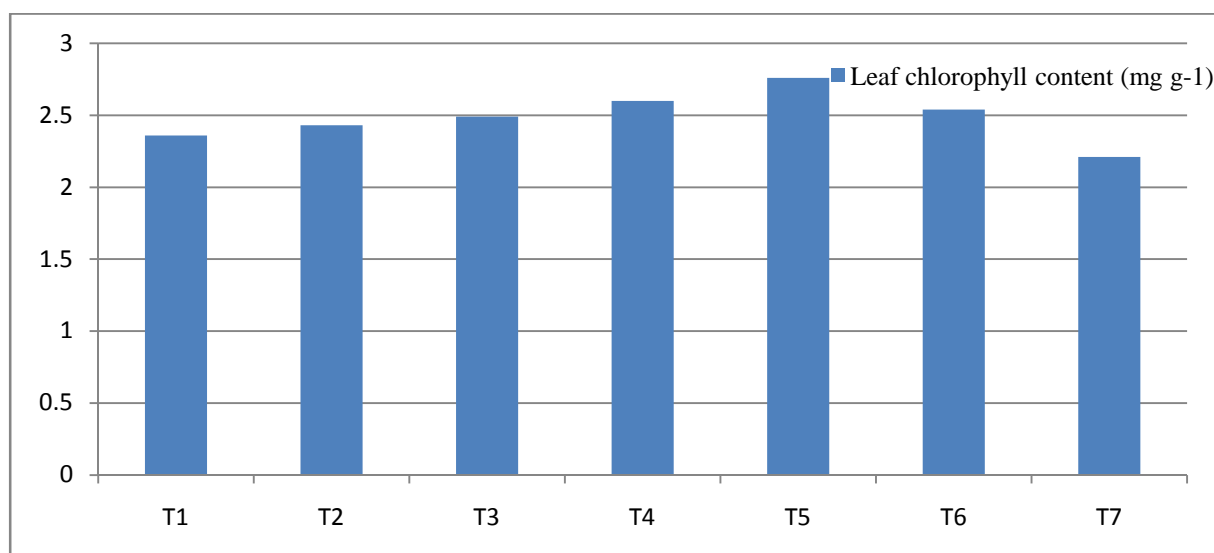


Figure 4.2: Effect of foliar application of urea and nano urea on of leaf chlorophyll content of apple nursery cv. Red Velox

It is apparent from the (Table 4.6 and Figure 4.2) that leaf chlorophyll content of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum leaf chlorophyll content (2.76 mg g^{-1}) was observed in treatment T₅ (Nano urea @ 0.4%) which was significantly higher over all the other treatments including control. Minimum leaf chlorophyll (2.21 mg g^{-1}) was recorded in treatment T₇ (Control).

Chlorophyll is an important photosynthetic pigment in the plant, largely determining photosynthetic capacity and hence plant growth. Effective absorption of nitrogen through nano urea might have enhanced the chlorophyll synthesis which contributed to higher photosynthesis.

These findings are in concomitant with those of Al-Asally and Al-Hijemy (2022) who showed that the foliar application of nano nitrogen fertiliser at 4 ml L^{-1} improved the chlorophyll content of leaves of mandarin seedlings. Sharma et al. (2022) showed that the foliar application of nano urea @ 4 ml L^{-1} at 30 and 45 DAS enhanced chlorophyll content (2.69 mg g^{-1}) in pearl millet. Khule et al. (2023) also observed that the treatment of 50% N (RDN) and 100% P and K through soil + two foliar sprays of 0.4% nano N at 20 and 40 DAS recorded the highest total chlorophyll content in linseed. Similarly, Priyadarshana et al. (2022) found that treatment S₁N₃ ($10 \times 10 \text{ cm}$ spacing with 5 ml L^{-1} of water nano urea foliar spray) resulted in highest values for total chlorophyll content in bermuda grass.

4.7 LEAF N, P and K content

The data related to the effect of foliar application of urea and nano urea on leaf N, P and K content of apple nursery cv. Red Velox are shown in Table 4.7 and Figure 4.3.

Table 4.7: Effect of foliar application of urea and nano urea on leaf N, P and K content of apple nursery cv. Red Velox

Treatment	Leaf N P K content (%)		
	Leaf N (%)	Leaf P (%)	Leaf K (%)
T ₁ – Urea @ 0.3%	2.02	0.23	1.40
T ₂ – Urea @ 0.4%	2.04	0.22	1.43
T ₃ – Urea @ 0.5%	2.13	0.21	1.47
T ₄ – Nano urea @ 0.3%	2.19	0.23	1.56
T ₅ – Nano urea @ 0.4%	2.43	0.21	1.63
T ₆ – Nano urea @ 0.5%	2.12	0.20	1.52
T ₇ – Control	1.97	0.19	1.38
CD _{0.05}	0.12	NS	0.05

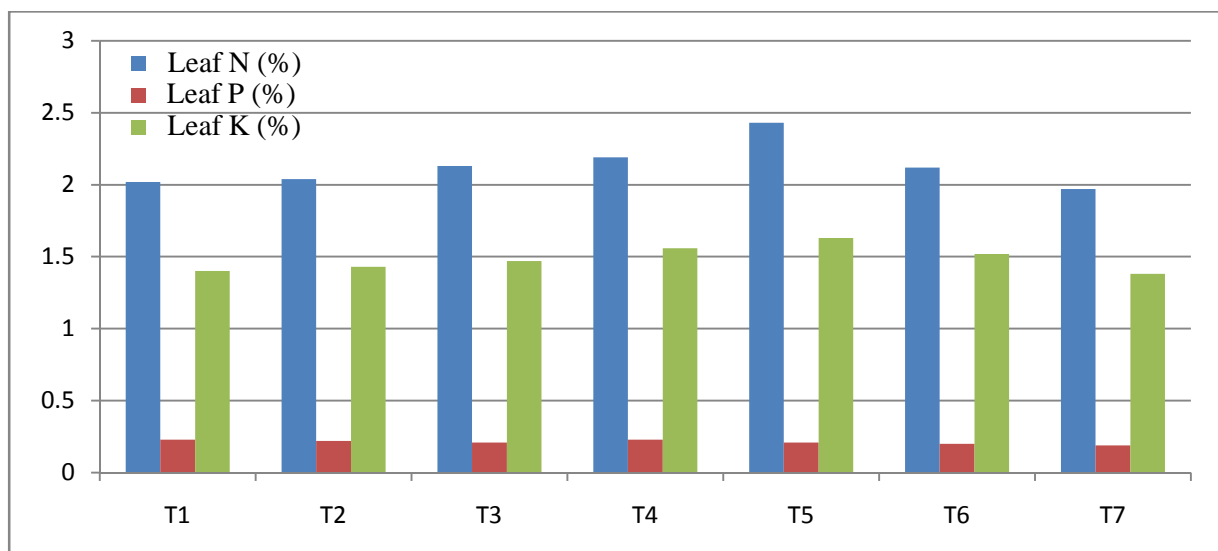


Figure 4.3: Effect of foliar application of urea and nano urea on of leaf N, P and K content of apple nursery cv. Red Velox

The data (Table 4.7 and Figure 4.3) indicates that leaf N and K content of apple nursery was significantly affected by different treatments of urea and nano urea. The significantly higher leaf N (2.43%) was observed in treatment T₅ (Nano urea @ 0.4%) and lower leaf N (1.97%) was observed in treatment T₇ (Control). Leaf P was not significantly influenced by different urea and nano urea treatments. The significantly higher leaf K (1.63%) was also observed in treatment T₅ (Nano urea @ 0.4%) and lower leaf K (1.38%) was recorded in treatment T₇ (Control).

This could be attributed to the fact that nano fertilisers have a large surface area and particle size smaller than the pore size of leaves, which can increase penetration into the plant from the applied surface and improve uptake and nutrient use efficiency. Reduced particle size results in increased specific surface area and number of particles per unit area of a fertilizer, which provides more opportunity for nano fertilizer contact, resulting in greater nutrient penetration and thus high nutrient content and uptake (Sharma et al., 2022).

Our findings are in accordance with those of Sharma et al. (2022) who observed that the foliar application of nano urea @ 4 ml L⁻¹ at 30 and 45 DAS enhanced nitrogen content, phosphorus content and potassium in pear millet grain. Enigi et al. (2022) showed that the treatment 75% RDF (63 N kg ha⁻¹) of N through prilled urea + 0.4% nano urea foliar spray at 45 and 60 days after sowing (DAS) recorded significantly higher total N, P and K content of leaves after third spray in french bean.

4.8 FRESH WEIGHT OF SHOOTS

The effect of foliar application of urea and nano urea on fresh weight of shoots of apple nursery cv. Red Velox is depicted in Table 4.8.

Table 4.8: Effect of foliar application of urea and nano urea on fresh weight of shoots of apple nursery cv. Red Velox

Treatment	Fresh weight of shoots (g)
T ₁ – Urea @ 0.3%	129.13
T ₂ – Urea @ 0.4%	153.82
T ₃ – Urea @ 0.5%	164.31
T ₄ – Nano urea @ 0.3%	187.07
T ₅ – Nano urea @ 0.4%	246.30
T ₆ – Nano urea @ 0.5%	174.50
T ₇ – Control	101.27
CD _{0.05}	5.94

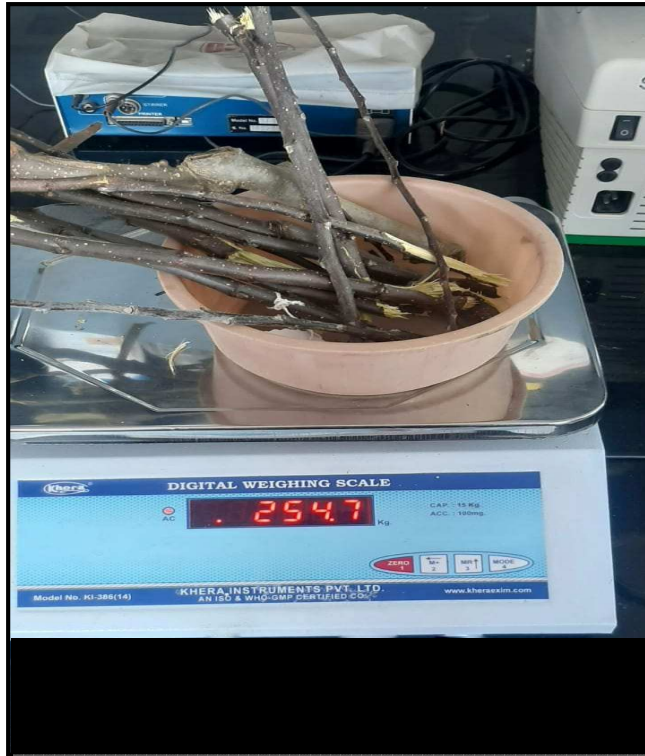
The data presented in Table 4.8 reveals that fresh weight of shoots of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum fresh weight of shoots (246.30 g) was observed in treatment T₅ (Nano urea @ 0.4%) which was significantly higher over all the other treatments including control. Minimum fresh weight of shoots (101.27 g) was recorded in treatment T₇ (Control).

The increase in fresh weight of shoots might be due to better growth, higher leaf area and more number of branches which resulted in higher photosynthetic activity and formation of more photosynthate (Khule et al., 2023).

These findings are in concomitant with those of Velmurugan et al. (2021) who showed that maximum shoot weight was observed in the treatment N₆₆PK + nano urea @ 0.4% in rice. Khule et al. (2023) observed that the treatment of 50% N (RDN) and 100% P and K through soil + two foliar sprays of 0.4% nano N at 20 and 40 DAS recorded the highest fresh weight of plants in linseed.

4.9 DRY WEIGHT OF SHOOTS

The data showing the effect of foliar application of urea and nano urea on dry weight of shoots of apple nursery cv. Red Velox are given in Table 4.9.



T₅: Nano urea @ 0.4 %



T₇: Control

Plate 2: Fresh weight of shoot (g)

Table 4.9: Effect of foliar application of urea and nano urea on dry weight of shoots of apple nursery cv. Red Velox

Treatment	Dry weight of shoots (g)
T ₁ – Urea @ 0.3%	62.96
T ₂ – Urea @ 0.4%	72.43
T ₃ – Urea @ 0.5%	76.23
T ₄ – Nano urea @ 0.3%	101.90
T ₅ – Nano urea @ 0.4%	116.56
T ₆ – Nano urea @ 0.5%	84.66
T ₇ – Control	51.56
CD _{0.05}	4.97

The perusal of data (Table 4.9) shows that dry weight of shoots of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum dry weight of shoots (116.56 g) was observed in treatment T₅ (Nano urea @ 0.4%) which was significantly higher over all the other treatments including control. Minimum fresh weight of shoots (51.56 g) was recorded in treatment T₇ (Control).

It can be postulated that foliar application of nano urea improved the physiology of plant leaves by increasing chlorophyll contents. Chlorophyll contents enhanced the rate of photosynthesis, increased the accumulation of glucose and improved fresh and dry weight of plants consequently

These findings are in conformity with those of Al-Asally and Al-Hijemy (2022) who showed that the foliar application of nano nitrogen fertiliser at 4 ml L⁻¹ improved the dry weight of vegetative growth of mandarin seedlings. Khule et al. (2023) also observed that the treatment of 50% N (RDN) and 100% P and K through soil + two foliar sprays of 0.4% nano N at 20 and 40 DAS recorded the highest dry weight of plants in linseed. Bhakher et al. (2023) recorded that the application of sulphur @ 40 kg ha⁻¹ along with nano urea 4 ml L⁻¹ resulted in highest plant dry weight in sunflower.

4.10 NUMBER OF ROOTS

The data pertaining to the effect of foliar application of urea and nano urea on number of roots of apple nursery cv. Red Velox are presented in Table 4.10.

It is evident from the data (Table 4.10) that number of roots of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum number of roots (23.00) per plant of was observed in treatment T₅ (Nano urea @ 0.4%) which was

statistically at par with the treatment T₄ (Nano urea @ 0.3%) resulting into 22.33 number of roots per plant and was significantly higher over all the other treatments including control. Minimum number of roots (17.00) per plant was recorded in treatment T₇ (Control).

Table 4.10: Effect of foliar application of urea and nano urea on number of roots of apple nursery cv. Red Velox

Treatment	Number of roots per plant
T ₁ – Urea @ 0.3%	20.00
T ₂ – Urea @ 0.4%	20.67
T ₃ – Urea @ 0.5%	21.00
T ₄ – Nano urea @ 0.3%	22.33
T ₅ – Nano urea @ 0.4%	23.00
T ₆ – Nano urea @ 0.5%	18.67
T ₇ – Control	17.00
CD _{0.05}	0.90

The higher number of roots in the present studies might be due to the more vegetative growth by appropriate nano urea applications, which in turns enhanced the more production and translocation of photosynthates to the root formation.

Dubey et al. (2003) also reported that GA₃ 50 ppm + 1% Urea exhibited in higher number of secondary roots in *Citrus latipes* rootstock seedlings.

4.11 TOTAL ROOT LENGTH

The observations regarding the effect of foliar application of urea and nano urea on total root length of apple nursery cv. Red Velox are given in Table 4.11 and Figure 4.4.

Table 4.11: Effect of foliar application of urea and nano urea on total root length of apple nursery cv. Red Velox

Treatment	Total root length (m)
T ₁ – Urea @ 0.3%	3.87
T ₂ – Urea @ 0.4%	4.36
T ₃ – Urea @ 0.5%	3.37
T ₄ – Nano urea @ 0.3%	5.37
T ₅ – Nano urea @ 0.4%	5.47
T ₆ – Nano urea @ 0.5%	5.29
T ₇ – Control	2.50
CD _{0.05}	0.12



T₅: Nano urea @ 0.4 %



T₇: Control

Plate 3: Number of roots per plant



T₅: Nano urea @ 0.4 %



T₇: Control

Plate 4: Total root length (m)

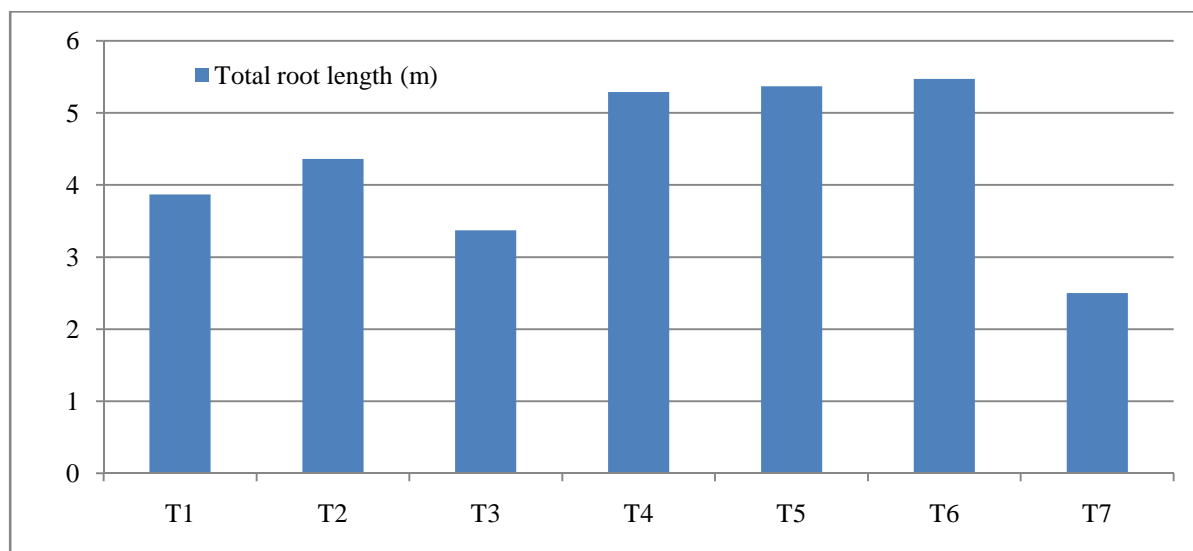


Figure 4.4: Effect of foliar application of urea and nano urea on of total root length of apple nursery cv. Red Velox

The perusal of data (Table 4.11 and Figure 4.4) clearly indicates that total root length of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum total root length (5.47 m) was observed in treatment T₅ (Nano urea @ 0.4%) which was statistically at par with the treatment T₄ (Nano urea @ 0.3%) resulting into total root length of 5.37 metre and was significantly higher over all the other treatments including control. Minimum total root length (2.50 m) was recorded in treatment T₇ (Control).

Nitrogen is the builder of protein and is the main constituent of the protoplasm in plants. Thus, with an increase in nitrogen supply through nano urea spray the synthesis of amino acids in plants is accelerated, which might have indirectly exhibited by enhanced growth. The immediate and efficient absorption of nano urea might have caused the rapid growth of vegetative part. Thus by increased synthesis of photo assimilates and more translocation to roots might have resulted into more length of roots.

These findings are in acquiescence with those of Al-Asally and Al-Hijemy (2022) who found that foliar spray of nano urea @ 4 ml L⁻¹ recorded highest values for root length (cm) in mandarin seedlings. Velmurugan et al. (2021) also showed that treatment N₅₀PK + nano urea @ 0.4% resulted in maximum root length (cm) in rice. Priyadarshana et al. (2022) recorded maximum root length (cm) in treatment S₁N₃ (10 × 10 cm spacing with 5 ml L⁻¹ of water nano urea foliar spray) in bermuda grass.

4.12 FRESH WEIGHT OF ROOTS

The data related to the effect of foliar application of urea and nano urea on fresh weight of roots of apple nursery cv. Red Velox are presented in Table 4.12.

Table 4.12: Effect of foliar application of urea and nano urea on fresh weight of roots of apple nursery plants cv. Red Velox

Treatment	Fresh weight of roots (g)
T ₁ – Urea @ 0.3%	21.35
T ₂ – Urea @ 0.4%	24.10
T ₃ – Urea @ 0.5%	25.43
T ₄ – Nano urea @ 0.3%	34.34
T ₅ – Nano urea @ 0.4%	38.23
T ₆ – Nano urea @ 0.5%	28.99
T ₇ – Control	14.17
CD _{0.05}	3.48

It is pertinent from the data (Table 4.12) that fresh weight of roots of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum fresh weight of roots (38.23 g) was observed in treatment T₅ (Nano urea @ 0.4%) which was significantly higher over all the other treatments including control. Minimum fresh weight of roots (14.17 g) was recorded in treatment T₇ (Control).

The higher fresh weight of root might be attributed to the more translocation of photo assimilates to the root portion from increased vigour of vegetative part. This might have resulted into more number of roots with appropriate growth.

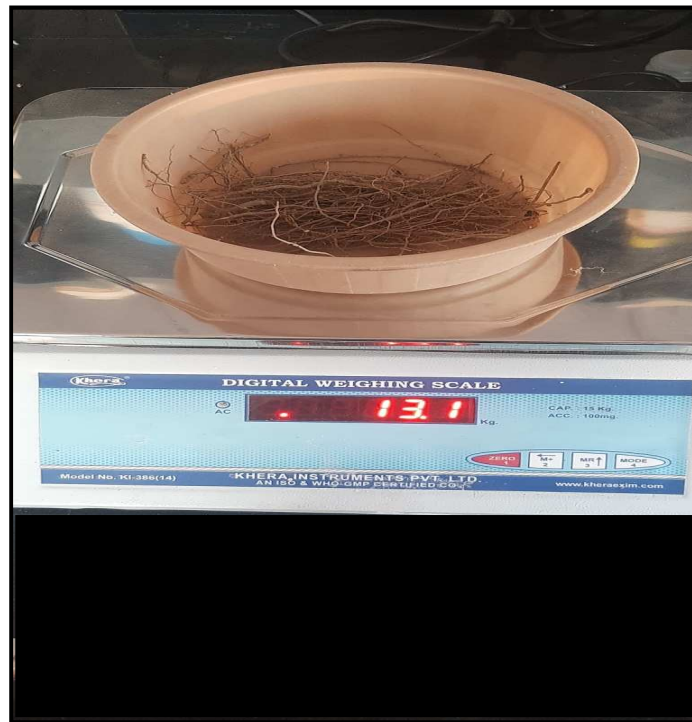
These findings are in concomitant with those of Velmurugan et al. (2021) who showed that treatment N₅₀PK + nano urea @ 0.4% significantly increased the fresh weight of roots in rice. Abobatta and Fatma (2023) recorded maximum fresh weight of roots with nano nitrogen spray @ 750 ppm in citrus rootstock seedlings.

4.13 DRY WEIGHT OF ROOTS

The data pertaining to the effect of foliar application of urea and nano urea on dry weight of roots of apple nursery cv. Red Velox are depicted in Table 4.13.



T₅: Nano urea @ 0.4 %



T₇: Control

Plate 5: Fresh weight of roots (g)

Table 4.13: Effect of foliar application of urea and nano urea on dry weight of roots of apple nursery cv. Red Velox

Treatment	Dry weight of roots (g)
T₁ – Urea @ 0.3%	10.29
T₂ – Urea @ 0.4%	11.58
T₃ – Urea @ 0.5%	12.22
T₄ – Nano urea @ 0.3%	17.76
T₅ – Nano urea @ 0.4%	22.13
T₆ – Nano urea @ 0.5%	13.68
T₇ – Control	6.80
CD_{0.05}	2.24

The perusal of data (Table 4.13) reveals that dry weight of shoots (g) of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum dry weight of roots (22.13 g) was observed in treatment T₅ (Nano urea @ 0.4%) which was significantly higher over all the other treatments including control. Minimum dry weight of roots (6.80 g) was recorded in treatment T₇ (Control).

The higher dry weight of roots may be attributed to the effective absorption of nano urea thus increasing the vegetative growth parameters. The increased photo assimilate production and assimilation and further translocation to root parts might have contributed to the increased dry weight of roots.

These findings are in concomitant with those of Abobatta and Fatma (2023) who recorded maximum dry weight of roots with nano nitrogen spray @ 750 ppm in citrus rootstock seedlings.

4.14 BIOMASS OF PLANT (dry weight basis)

The data depicting the effect of foliar application of urea and nano urea on biomass of plant of apple nursery cv. Red Velox are presented in Table 4.14 and Figure 4.5.

The data (Table 4.14 and Figure 4.5) shows that biomass of plant of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum biomass of plant (138.69 g) was observed in treatment T₅ (Nano urea @ 0.4%) which was significantly higher over all the other treatments including control. Minimum biomass of plant (58.36 g) was recorded in treatment T₇ (Control).

Table 4.14: Effect of foliar application of urea and nano urea on biomass of plant of apple nursery cv. Red Velox

Treatment	Biomass of plant (g)
T ₁ – Urea @ 0.3%	73.25
T ₂ – Urea @ 0.4%	84.01
T ₃ – Urea @ 0.5%	88.45
T ₄ – Nano urea @ 0.3%	119.66
T ₅ – Nano urea @ 0.4%	138.69
T ₆ – Nano urea @ 0.5%	98.34
T ₇ – Control	58.36
CD _{0.05}	5.65

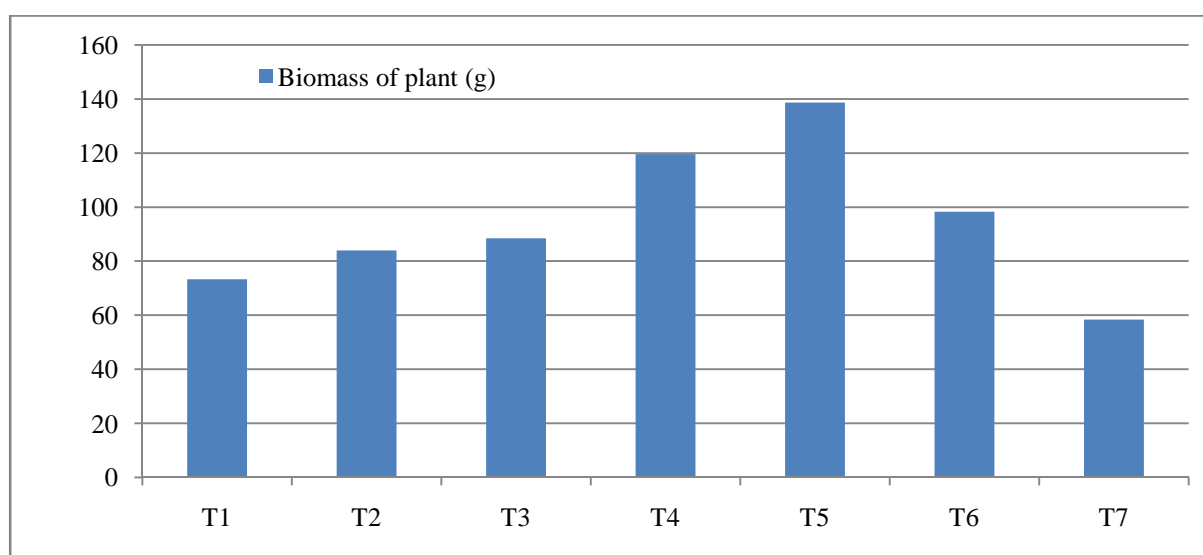


Figure 4.5: Effect of foliar application of urea and nano urea on biomass of plant of apple nursery cv. Red Velox

The nano-fertilizers, efficacy may be attributed as these fertilizers have unique properties due to their small surface area with high absorption ability and ease of entry into plant cells. This contributes to accelerate the plant's growth because of activating the carbonic metabolism process and increasing the produced substances inside the plant, which is positively reflected on the vegetative growth increment in the plant. Dry weight of the plant increased due to better growth and greater number of branches which might have resulted in higher photosynthetic activity and formation of more photosynthate.

These findings are in consonance with Al-Asally and Al-Hijemy (2022) who showed that the foliar application of nano nitrogen fertiliser at 4 ml L⁻¹ improved the dry weight of vegetative growth of mandarin seedlings. Rathnayaka et al. (2018) showed that application of

100% nano-nitrogen resulted in best growth performance in terms of plant dry weight in rice. Sharaf-Eldin et al. (2022) observed that foliar application of nano urea has the greatest effect on plant biomass in lettuce plant. Khule et al. (2023) observed that the treatment of 50% N (RDN) and 100% P and K through soil + two foliar sprays of 0.4% nano N at 20 and 40 DAS recorded the highest dry weight of plants in linseed. Yadav et al. (2023) recorded improved dry weight plant⁻¹ with foliar application of nano urea @ 3000 ppm in wheat. Bhakher et al. (2023) recorded that the application of sulphur @ 40 kg ha⁻¹ along with nano urea 3 ml L⁻¹ resulted in highest plant dry weight in sunflower.

4.15 SHOOT: ROOT RATIO

The data on the effect of foliar application of urea and nano urea on shoot: root ratio of apple nursery cv. Red Velox are given in Table 4.15 and Figure 4.6.

Table 4.15: Effect of foliar application of urea and nano urea on shoot: root ratio of apple nursery cv. Red Velox

Treatment	Shoot : Root
T ₁ – Urea @ 0.3%	6.11
T ₂ – Urea @ 0.4%	6.25
T ₃ – Urea @ 0.5%	6.23
T ₄ – Nano urea @ 0.3%	5.73
T ₅ – Nano urea @ 0.4%	5.26
T ₆ – Nano urea @ 0.5%	6.18
T ₇ – Control	7.76
CD _{0.05}	1.37

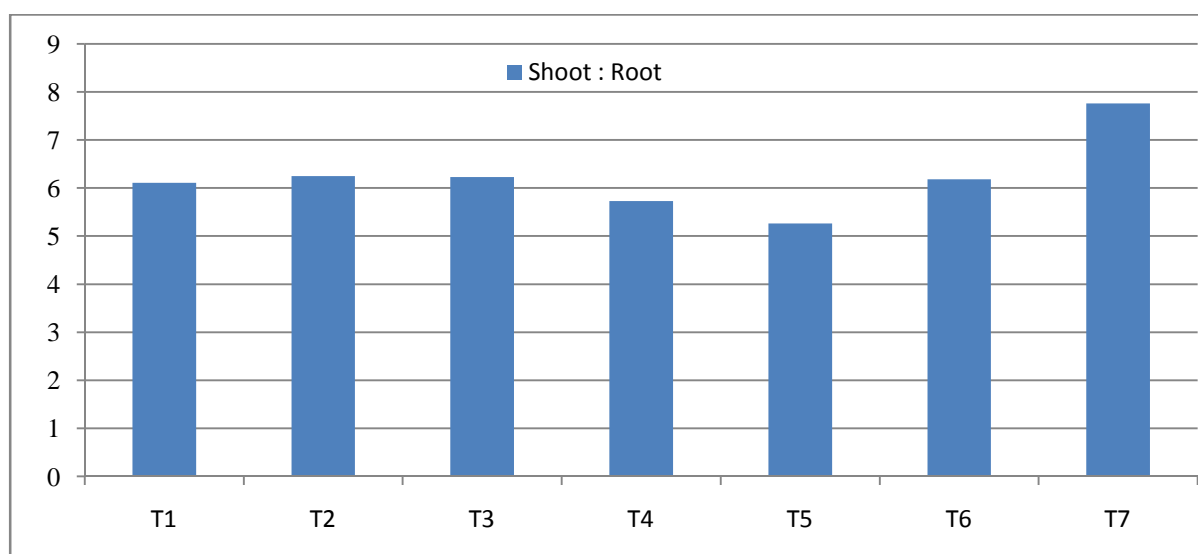


Figure 4.6: Effect of foliar application of urea and nano urea on of shoot: root of apple nursery cv. Red Velox

It is evident from the data (Table 4.15 and Figure 4.6) that shoot: root ratio of apple nursery was significantly affected by different treatments of urea and nano urea. The maximum shoot: root (7.76) was observed in treatment T₇ (Control) which was significantly higher over all the other treatments including control. Minimum shoot: root (5.26) was recorded in treatment T₅ (Nano urea @ 0.4%).

The shoot: root ratio is a common parameter used to assess the allocation of biomass between the above ground (shoot) and below ground (root) components of a plant. It is often used to understand the plant growth strategies and resource allocation patterns. Plants with more shoots absorb sunlight more efficiently, whereas plants with more roots compete more successfully for soil nutrients. Early-stage vegetation is characterised by large proportions of shoot output. For a plant to be able to absorb water and nutrients from the soil surrounding, its root system must be healthy and in good condition. Higher shoot: root ratio indicates the more vegetative growth of plants as compared to root growth. However, for proper plant stand the ideal requirement for the establishment of plant should be the moderate shoot and root ratio.

Chapter-5

SUMMARY AND CONCLUSION

The present investigations entitled “**Studies on the effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox**” were conducted during 2022-23 at the Pandah Farm of Department of Seed Science and Technology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The experiment was conducted in Randomised Complete Block Design with three levels of urea (0.3, 0.4, 0.5%), three levels of nano urea (0.3, 0.4, 0.5%) and control. Each treatment was replicated thrice. The results thus obtained under this experiment are summarized as below:

5.1 STUDIES ON THE EFFECT OF FOLIAR APPLICATION OF UREA AND NANO UREA ON GROWTH AND QUALITY OF APPLE NURSERY cv. RED VELOX

5.1.1 Plant height (cm) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum plant height (183.21 cm) was observed in nano urea @ 0.4% (T₅) and minimum plant height (167.22 cm) was recorded in control (T₇).

5.1.2 Stem diameter (mm) of apple nursery of cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum stem diameter (15.70 mm) was found in nano urea @ 0.4% (T₅) and minimum stem diameter (11.99 mm) was recorded in control (T₇).

5.1.3 Number of branches per plant of apple nursery cv. Red Velox were significantly affected by different urea and nano urea treatments. The maximum number of branches (3.00) were recorded in nano urea @ 0.4% (T₅) and minimum number of branches (1.22) were recorded in control (T₇).

5.1.4 Number of leaves per plant of apple nursery cv. Red Velox were significantly affected by different urea and nano urea treatments. The maximum number of leaves (62.07) were observed in nano urea @ 0.4% (T₅) and minimum number of leaves (33.27) were recorded in control (T₇).

- 5.1.5** Leaf area (cm²) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum leaf area (33.51 cm²) was found in nano urea @ 0.4% (T₅) and minimum leaf area (23.01 cm²) was recorded in control (T₇).
- 5.1.6** Leaf chlorophyll content (mg g⁻¹) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum leaf chlorophyll content (2.76 mg g⁻¹) was associated with nano urea @ 0.4% (T₅) and minimum leaf chlorophyll content (2.21 mg g⁻¹) was found in control (T₇).
- 5.1.7** Leaf N and K (%) content of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. Leaf P (%) was not significantly influenced by different urea and nano urea treatments. The significantly higher leaf N content (2.43%) was measured in nano urea @ 0.4% (T₅) and minimum leaf N content (1.97%) was found in control (T₇). The significantly higher leaf K (1.63%) was observed in nano urea @ 0.4% (T₅) and minimum leaf K (1.38%) was recorded in control (T₇).
- 5.1.8** Fresh weight of shoots (g) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum fresh weight of shoots (246.30 g) was associated with in nano urea @ 0.4% (T₅) and minimum fresh weight of shoots (101.27 g) was found in control (T₇).
- 5.1.9** Dry weight of shoots (g) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum dry weight of shoots (116.56 g) was measured in nano urea @ 0.4% (T₅) and minimum dry weight of shoots (51.56 g) was recorded in control (T₇).
- 5.1.10** Number of roots per plant of apple nursery cv. Red Velox were significantly affected by different urea and nano urea treatments. The maximum number of roots (23.00) per plant were observed in nano urea @ 0.4% (T₅) and minimum number of roots (17.00) per plant were found in control (T₇).
- 5.1.11** Total root length (m) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum total root length (5.47 m) was measured in nano urea @ 0.4 % (T₅) and minimum total root length (2.50 m) was recorded in control (T₇).

5.1.12 Fresh weight of roots (g) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The fresh weight of roots (38.23 g) was observed in nano urea @ 0.4% (T₅) and minimum fresh weight of roots (14.17 g) was found in control (T₇).

5.1.13 Dry weight of roots (g) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum dry weight of roots (22.13 g) was found in nano urea @ 0.4% (T₅) and minimum dry weight of roots (6.80 g) was recorded in control (T₇).

5.1.14 Biomass of plant (dry weight basis) (g) of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum biomass of plant (138.69 g) was found in nano urea @ 0.4% (T₅) and minimum biomass of plant (58.36 g) was measured in control (T₇).

5.1.15 Shoot: Root ratio of apple nursery cv. Red Velox was significantly affected by different urea and nano urea treatments. The maximum shoot: root (7.76) was associated with control (T₇) and minimum shoot: root (5.26) was observed in nano urea @ 0.4 % (T₅).

5.2 CONCLUSION

On the basis of results obtained in present investigations, it may be inferred that three foliar applications of nano urea @ 4ml L⁻¹ at weekly interval in the month of July was found to be the best treatment for increasing plant height (183.21 cm), stem diameter (15.70 mm), number of branches (3.00) per plant, number of leaves (62.07) per plant, leaf area (33.51 cm²), leaf chlorophyll content (2.76 mg g⁻¹), leaf N (2.43%) and K (1.63%) content, fresh weight of shoots (246.30 g), dry weight of shoots (116.56 g), number of roots (23.00) per plant, total root length (5.47 m), fresh weight of roots (38.23 g), dry weight of roots (22.13 g), biomass of plant (138.69 g).

It is concluded that three foliar applications of nano urea @ 4ml L⁻¹ in July at weekly interval are beneficial for the growth and quality of apple nursery plants cv. Red Velox.

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APPENDIX-I

Mean monthly meteorological data during crop growth period from February 2022 to December 2022

Months	Temperature (°C)			Relative Humidity (%)	Rainfall (mm)
	Minimum	Maximum	Mean		
February	2.7	18.7	10.7	54	82.7
March	9.4	28.6	19	44	0
April	13.3	33.2	23.25	37	1.0
May	16.1	32	24.05	52	84.8
June	17	32.1	24.9	49	85.6
July	20.5	28.5	24.5	51	195.4
August	19.9	29	24.45	78	219.5
September	17.8	27.8	22.8	77	233.5
October	11.4	26.3	18.85	64	79.7
November	6.4	24.1	15.25	55	2.4
December	2.5	21.7	12.1	51	0

Source: Meteorological Observatory, Department of Environmental Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP)

APPENDIX-II

Effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox

ANOVA for plant height

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.081		
Treatment	6	719.316	119.886	78.895
Error	12	18.235	1.520	
Total	20	737.632		

ANOVA for stem diameter

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.489		
Treatment	6	27.979	4.663	6.014
Error	12	9.305	0.775	
Total	20	38.773		

ANOVA for number of branches per plant

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.032		
Treatment	6	5.943	0.990	6.528
Error	12	1.821	0.152	
Total	20	7.796		

ANOVA for number of leaves per plant

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	3.212		
Treatment	6	1,864.91	310.818	669.849
Error	12	5.568	0.464	
Total	20	1,873.79		

ANOVA for leaf area

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	4.453		
Treatment	6	178.540	29.757	26.238
Error	12	13.610	1.134	
Total	20	196.602		

ANOVA for leaf chlorophyll content

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.007		
Treatment	6	0.556	0.093	100.227
Error	12	0.011	0.001	
Total	20	0.574		

ANOVA for leaf N

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.033		
Treatment	6	0.423	0.070	15.437
Error	12	0.055	0.005	
Total	20	0.511		

ANOVA for leaf P

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	-0.000		
Treatment	6	0.004	0.001	73,349.221
Error	12	0.000	0.000	
Total	20	0.004		

ANOVA for leaf K

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.000		
Treatment	6	0.146	0.024	28.157
Error	12	0.010	0.001	
Total	20	0.156		

ANOVA for fresh weight of shoots

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	8.233		
Treatment	6	37,979.480	6,329.913	579.679
Error	12	131.036	10.920	
Total	20	38,118.750		

ANOVA for dry weight of shoots

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	10.431		
Treatment	6	9,008.451	1,501.409	196.590
Error	12	91.647	7.637	
Total	20	9,110.529		

ANOVA for number of roots per plant

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.993		
Treatment	6	77.022	12.837	50.998
Error	12	3.021	0.252	
Total	20	81.035		

ANOVA for total root length

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.074		
Treatment	6	23.380	3.897	827.258
Error	12	0.057	0.005	
Total	20	23.511		

ANOVA for fresh weight of roots

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.253		
Treatment	6	1,171.797	195.299	52.009
Error	12	45.061	3.755	
Total	20	1,218.110		

ANOVA for dry weight of roots

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.409		
Treatment	6	459.840	76.640	49.004
Error	12	18.767	1.564	
Total	20	480.016		

ANOVA for biomass of plant

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	22.528		
Treatment	6	13,514.275	2,252.379	227.586
Error	12	118.762	9.897	
Total	20	13,655.565		

ANOVA for shoot: root ratio

Source of Variation	DF	Sum of Square	Mean Square	F-Calculated
Replication	2	5.208		
Treatment	6	10.644	1.774	3.028
Error	12	7.029	0.586	
Total	20	22.881		

**Department of Seed Science and Technology
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Title of the Thesis : “Studies on the effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox”

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Admission Number : H-2021-53-M

Major Discipline : Seed Science and Technology

Minor Discipline : Fruit Science

Date of Thesis Submission :

Total Pages of the Thesis : 64+iv

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ABSTRACT

The present investigation entitled, “Studies on the effect of foliar application of urea and nano urea on growth and quality of apple nursery cv. Red Velox” was carried in the Pandah Farm, Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan HP during 2022-23. The experiment was laid in Randomised Complete Block Design (RCBD), comprising 7 treatments viz, T₁: Urea @ 0.3%, T₂: Urea @ 0.4%, T₃: Urea @ 0.5%, T₄: Nano urea @ 0.3%, T₅: Nano urea @ 0.4%, T₆: Nano urea @ 0.5%, T₇: Control. Each treatment was replicated thrice. Three foliar applications of urea and nano urea were given at weekly interval in the month of July. Nano urea @ 0.4 % (T₅) significantly resulted in maximum plant height (183.21 cm), stem diameter (15.70 mm), number of branches (3.00) per plant, number of leaves (62.07) per plant, leaf area (33.51 cm²), leaf chlorophyll content (2.76 mg g⁻¹), leaf N (2.43%) and K (1.63%) content, fresh weight of shoots (246.30 g), dry weight of shoots (116.56 g), number of roots (23.00) per plant, total root length (5.47 m), fresh weight of roots (38.23 g), dry weight of roots (22.13 g), biomass of plant (138.69 g). From the present studies, it can be concluded that Nano urea @ 0.4 % (T₅) significantly enhanced the growth and quality of apple nursery cv. Red Velox.

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