AATCC Review

18 October 2024: Received
21 December 2024: Revised
18 January 2025: Accepted
24 January 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Effect of induced Defoliation on Apple Nursery plants grown under protected conditions in Northwestern Himalayan region

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ABSTRACT

The present investigation was carried out at SKUAST-K, The grafted apple plants cv. Gala Redlum /M9 T339 raised under polyhouse conditions and subsequent growth performance of plants in the following spring season after field transplanting. Treatments consisted of urea @ 4, 6 or 8 %, and Cu EDTA @ 0.5, 1, 1.5 or 2 % either alone or in combination of urea @ 2 % (sprayed 15 days before Cu EDA application) thus comprising a total 12 treatments in the experiment including untreated control. The urea (2 %) was sprayed on 16th October 2021 and the defoliation treatments i.e., urea @ 4, 6 and 8 % and Cu EDTA @ 0.5, 1, 1.5 and 2% were sprayed on 1st November 2022. The results revealed that Cu-EDTA either alone or in combination of two percent 8 urea induced early defoliation compared to untreated control and 4, 6 or 8 percent urea sprays. At 24 days after the defoliant's treatment, Cu- EDTA @ 1, 1.5 or 2 per cent either alone or in combination of 2 percent urea caused more than 90 per cent leaf defoliation. Cu EDTA @ 2 per cent resulted the highest leaf defoliation but was statistically at par with urea @ 2 % + Cu-EDTA @ 2 %, urea @ 2 % + Cu EDTA @ 1.5 % and urea @ 2 % + Cu EDTA @ 1 %. Urea spray as defoliant (4, 6 and 8%) delayed leaf defoliation but increased plant nitrogen content (in shoot and roots) and subsequent growth performance of plant in the following season after field transplanting. Compared to control. Adding 2 % urea with Cu-EDTA (sprayed 15 days before Cu). The combination of foliar sprays defoliants with urea can be used to obtain efficient early defoliation and promote nitrogen storage without reducing plant growth performance the following season. Because the tree growth during the first couple weeks after bud break is almost completely dependent on reserve nitrogen, it is hypothesized that no need to apply nitrogen fertilizer until two to three weeks after bud break for newly planted trees.

Keywords: *Defoliation, Cu-EDTA, Plant growth, Urea, Apple nursery*

INTRODUCTION

Modern-day cultivated apple in the Family Rosaceae, sub-fa mily Maloideae, botanically designated as *Malus* x *domestica* (Borkh.) is probably the result of inter-specific hybridization [1]. Nevertheless, the origin and ancestry of the *M*. x *domestica* hybrid complex remains debatable, the *Malus sieversii* (Ledeb.) Apple is widely cultivated in temperate latitudes or at high elevations in the tropics of all continents except Antarctica[2]however, commercial apple production is limited to temperate latitudes ranging from 25° to 52° [3]. According to FAOSTAT [4], China is the largest producer of apple followed by the European Union and India is the 5th largest apple-producing country in the world. In India, Union Territory of Jammu and Kashmir is leading producer followed by Himachal Pradesh and Uttarakhand. Area under apple cultivation in Jammu and Kashmir has been estimated about 1.64 thousand ha with annual production of 20.26 thousand MT and is mainly concentrated In Kashmir valley, apple farming has an important role in economy of the Union territory as the apple cultivation is highly profitable agricultural activity and the produce is of best quality in the country [5].

The success of an orchard is primarily determined by the use of high-quality planting materials. In Kashmir valley there is an increasing demand for high quality grafted plant materials of apple on dwarfing/semi-dwarfing clonal rootstocks such as M-9 and MM-106 for establishinghigh-density orchards. Production business of quality planting material is also one of the prime aspects in getting the good returns; therefore, adequate nursery management is a pre-requisite for satisfying the production of quality saplings [6].Good nursery management aims to provide quality planting material for plantation in the new development areas and replanting [7]. In India, nursery production of fruit crops generally applies the traditional system under open field conditions. Raising fruit nurseries in open field conditions has several limitations. Nursery saplings in open field's conditions are subjected to volatile climatic circumstances as well as high risk of insect and pest attacks that ultimately cause adverse effects on the growth and development of nursery plants. One of the most important aspects is the slow growth of plants in open flied that limits to achievement the desired plant height suitable

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DOI: https://doi.org/10.21276/AATCCReview.2025.13.01.77

for filed planting within a year as the larger proportion of nursery plants normally took two years for adequate plant size. Under polyhouse conditions a more stable environment is provided to favor adequate plant growth and development and the combination of new rootstocks and cultivars required by orchardists for commercial cultivation can be accomplished in a year or within a shorter period. The alleviated temperature inside polyhouse and protection from direct frost to the plants favours the plant growth to be continued for an extended period upto January hampers the natural leaf fall and plant still laden with green foliage. Digging trees that are still in leaf is impractical because leaf transpiration might result in water loss from plant and that may ultimately be able to cause considerable damage of the grafted plants. Early lifting of plant along with leaves can restrict air circulation in storage, promote fungus decay; create cleaning problems in the grading facilities and difficulty in handling after uprooting of plants. Such plants may also suffer from severe winter injury, branch dieback and death during over-wintering storage.

The process of defoliation which precedes extraction, classification and heeling-in of nursery stocks at the end of the growing season of temperate fruit tree nursery plants is important because it enhances leaf senescence, and facilitates autumnal mobilization of leaf nutrients into perennial woody tissues; and improves handling and storage processes of plants. Generally, natural defoliation is the most common in open field conditions that implying environmental temperatures below zero and frost during the optimal period before the removal of nursery stocks from the nursery beds.Manual defoliation of leaves is a common practice in nurseries to allow for early lifting of nursery plants in some regions of the world; but it is time-consuming, labour intensive and may cause injuries to the bark and buds [8]. The use of some chemical compounds is yet another method of defoliation; however, some chemical defoliants are known to cause either physical damage to plant tissues [9], and/or physiological problems associated with storage or establishment [10]. Some of copper-based preparations are most frequently used as defoliation compounds, especially, which causes rapid defoliation that results in early abscission of leaves, usually while the leaves are still green. The chelated copper compounds (Cu-EDTA) has shown to be effective defoliants and also useful to advance the period of digging and to protect apple trees from freezing injury on apple nursery stocks in autumn[11]. Also, time of defoliation has been observed to modify patterns of vegetative and reproductive growth in spring for deciduous trees growing in temperate climates [12]. Some researchers have tested a variety of chemical defoliants on various species in various countries, with varying results on induced defoliation and their subsequent effect on plant growth performance [13], but no research has been done on induced defoliation of apple nursery plants in Kashmir conditions, specifically under protected conditions.

MATERIALS AND METHODS

The present study was conducted at the Experimental Farm, Division of Horticulture, Faculty of Agriculture (Wadura Campus, Sopore, Baramulla) and Post Graduate Laboratory, Division of Fruit Science, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Science & Technology of Kashmir (SKUAST-K), Shalimar Campus, Srinagar, Union Territory of Jammu and Kashmir (India) during the year 2021-22. The geographical location of the experiment site i.e., Wadura Campus of SKUAST-Kashmir is located in the Baramulla district of Union Territory of Jammu and Kashmir (India) at 34.1o North latitude and 74.9o East longitude and 1587 m above the mean sea level. The location is characterized by very cold temperatures during December to March, April and May are cold and mild, June to August are hot months while September is mild. October and November are cold and dry. Heavy rainfall is experienced during spring season while frequent snow fall is common in the whole valley region. Temperature ranges from a minimum of about -6 oC in winter to a maximum of 36 oC in summer. The Plant Material Apple cv. Redlum Gala/M-9 T339 was used as plant materials for the study. Redlum Gala apple have compact to medium tree vigour with excellent spur density, medium and large size fruits, red skin and mature in the middle of the season. Rootstock M-9 T339 is a dwarfing type introduced in Kashmir from Holland and being used for the production of grafted planting materials of apple for high-density planting. Morphologically, M9 T339 rootstock is of weak vigour with short internodes, reddish brown in color (sunny side), strong undulated leaf margin, weak prudence on the lower side of leaf, long petiole length with small stipule [14]. Cleft grafting of Gala Redlum was performed on M-9 T337 during first week of March, 2021 and the grafted stocks were planted in a naturally poly house immediately after grafting. Planting was carried out in a double-row system at 50 x 30 x 20 cm spacing. For growth performance evaluation of treated nursery plants in the following growth season, three plants of each treatment ware planted in open field conditions on 1st March 2022. The spacing was 1 x 1 m. Similar cultural practices were adopted for the nursery plants under all the treatments. The experiment was laid out in a Randomized Complete Block Design. There were twelve treatments and each treatment was replicated thrice. Treatment application of The nursery plants were grown with similar cultural practices to all the treatments and well irrigated till 1st November 2021. Urea @ 2 % was applied on 16th October, 2021 in T9, T10, T11 and T12. The defoliation treatments i.e., urea (4, 6 and 8 %) and Cu-EDTA (0.5, 1, 1.5 and 2%) were applied on 1st November 2021 according to the treatment code. A hand held baby sprayer (two liters capacity) was used for spraying of the chemicals.

The Observations recorded viz., Leaf defoliation, Plant Nitrogen content and Terminal bud injury, Growth performance of grafted treated saplings in following growing season in field conditions: 1. Terminal shoot growth 2. Number of shoots per plant 3 Total shoot length Average shoot length 4 Number of leaves per plant 4. Leaf area 5 Leaf chlorophyll content.

RESULTS

Leaf defoliation : Data recorded on leaf defoliation as affected by urea and Cu-EDTA treatments have been presented in Table 1. Leaf defoliation as a percentage of total leaves on the plants was recorded for one month at 2 days internal starting immediately after the imposition of the treatments. It is evident from data that Cu-EDTA alone or in combination of 2 % urea (15 days before Cu-EDTA spray) induced early defoliation compared to untreated control as well as urea treatments (4, 6 or 8%). At 12 days after Cu-EDTA application, 52.85 to 63.40 % leaf defoliation was observed with Cu-EDTA treatment @ 1, 1.5 or 2 % applied alone or in combination of urea @ 2% (15 days before Cu-EDTA application), while control plants showed only 7.43 % defoliation. At 24 days after treatments, Cu-EDTA @ 1, 1.5 or 2 % applied alone or in combination of urea @ 2 % (15 days before Cu-EDTA spray) caused more than 90% leaf defoliation, wherein the highest leaf defoliation (98.63 %) was noted with Cu-EDTA

@ 2%. However, it was statistically at par with urea @ 2 % + Cu-EDTA @ 2 % (93.84 %), Urea @ 2 % + Cu-EDTA @ 1.5% (93.45 %) and urea @ 2 % + Cu-EDTA @ 1 % (92.15 % %). The increased doses of urea treatments (4, 6 or 8%) exerted delayed leaf defoliation. The leaf defoliation at 12 days after @ 8 %, 6 % and 4% urea treatments was 11.35, 8.07 and 5.30 %, respectively. At 24 days after treatment, urea @ 8 %, 6 % and 4 % resulted from 52.17, 55.39 and 54.66 % defoliation, respectively. At 30 days after treatment, Cu-EDTA @ 1, 1.5 and 2 % sprayed with or without pre-treatment of urea (2 % 15 days before Cu-EDTA application) was statistically at par to each other (Table 1).

Plant nitrogen content: Data recorded on nitrogen content in shoot and roots of grafted apple nursery plants as affected by urea and Cu-EDTA treatments have been presented in Table 2 and graphically depicted in Fig 1. It is evident from the data that urea treatments had a significant influence on shoot and root nitrogen content, wherein maximum shoot nitrogen (2.14%) was recorded with urea @ 8 % followed by urea @ 6% and 4 % (2.06 and 1.83 %, respectively). Cu-EDTA treatments exhibited comparatively lower values of shoot nitrogen compared to control, but when added with 2 % urea spray (15 days before Cu-EDTA application resulted in significantly higher nitrogen content in shoots compared to control. Similarly, nitrogen content in root was the highest (2.46 %) with urea @ 8 % followed by urea @ 6% and 4 % (2.37 and 2.13 %, respectively). Cu-EDTA combined with 2 % urea sprays (15 days before Cu-EDTA sprays) increased the nitrogen content in root compared to sole Cu-EDTA or control plants (Table 2). The lowest nitrogen content in shoot and root was recorded with Cu-EDTA @ 2 % (0.90 and 0.97 %, respectively).

Terminal bud injury: Data recorded on terminal bud injury in grafted apple nursery plants as affected by urea and Cu-EDTA treatments of have been presented in Table 3 and graphically depicted in Fig. 2. Data reveals that the increased levels of Cu-EDTA resulted in increased incidence of terminal bud injury. Also, the pre-treatment of urea @ 2 % (15 days before Cu-EDTA application) did not influence the effect of Cu-EDTA on terminal bud injury. The highest terminal bud injury (43.33 %) was recorded with 2 % Cu-EDTA sprayed alone or in combination with 2 % urea (15 days before Cu-EDTA application). Plants treated with Cu-EDTA @ 1.5 % alone or in combination with 2 % urea (15 days before Cu-EDTA application) showed 33.33 % terminal bud injury. There was 16.67 % terminal but injury in the plants treated with 1 % Cu-EDTA alone or in combination of urea @ 2 % applied 15 days before Cu-EDTA application. Control plants and plants treated with urea @ 4 %, 6 % or Cu-EDTA @ 0.5 % didn't have any terminal bud injury.

Growth performances of grafted treated saplings in the following growing season in field conditions

Terminal shoot growth: Terminal shoot growth of plants in the following growing season after transplanting of grafted plants in open field was significantly affected by urea and Cu-EDTA treatments (Table 4). The highest terminal shoot growth was measured in the plants sprayed with urea @ 8% (30.53 cm), followed by urea @ 6% and 4 % (26.93 and 23.30 cm, respectively). Cu-EDTA without pre-sprays of 2 % urea significantly reduced the terminal shoot growth, while Cu-EDTA treatments combined with 2 % urea (applied 15 days before Cu-EDTA application) significantly increased terminal shoot growth as compared to control (Table 4).

Plants treated with Cu-EDTA @ 0.5, 1, 1.5 and 2% and pre-sprayed with urea @ 2% resulted in terminal shoot growth of 25.60, 24.73, 23.80 and 22.50, respectively. The lowest terminal shoot growth was measured with Cu-EDTA @ 2% sprays

Number of shoots per plant: The number of shoots per plant in following growing season after transplanting of grafted plants in open field was significantly affected by urea and Cu-EDTA treatments (Table 4 and Fig. 2). Cu-EDTA alone or in combination of urea significantly influenced the number of shoots per plant. Urea (4, 6 and 8%) was not effective in increasing

he number of shoots per plant compared to control (Table 4). The highest number of shoots per plant was counted in plants sprayed with urea @ 2% + Cu-EDTA @ 2% (6.00), but it was at par with urea @ 2% + Cu-EDTA @ 1.5% (5.89), Cu-EDTA @ 2% (5.67) and urea @ 2% + Cu-EDTA @ 1% (5.56). Plants treated with 4, 6 and 8% urea produced 4.78, 4.89 and 5.00 shoots per plant, respectively (Table 4). The lowest terminal shoot growth was measured with Cu-EDTA @ 2% (4.67).

Average shoot length: Average shoot length in plants in the following season after planting in open field was significantly affected by urea and Cu-EDTA treatments (Table 5 and Fig. 3). Plants treated with urea @ 8 % resulted the highest average shoot length (23.37 cm), followed by urea @ 6 % (20.6 cm) and @ 4 % (22.23 cm). Plants treated with Cu-EDTA treatments alone or in the combination of 2 % urea (as pre-treatment 15 days before Cu-EDTA sprays) produced shorter shoots compared to control (Table 5). It was also evident from data that the increased levels of Cu-EDTA resulted in shorter shoots. The average shoot length with Cu-EDTA 0.5%, 1%, 1.5% and 2 % was 16.91, 16.73, 15.44 and 15.20 cm, respectively. The average shoot length with Cu-EDTA @ 0.5%, 1%, 1.5% and 2 % along with 2 % urea (applied 15 days before Cu-EDTA application) was 17.26, 17.12, 16.93 and 16.57 cm, respectively. Control plants resulted an average shoot length of 18.41 cm.

Total shoot length: Total shoot length per plant measured in the following season of field planting of grafted apple nursery plants was significantly affected by urea and Cu-EDTA treatments (Table 5 and Fig. 3). Plants treated with urea @ 8 % resulted the highest total shoot length (132.40 cm), followed by urea @ 6 % (108.68 cm) and urea @ 4 % (95.86 cm). Plants treated with Cu-EDTA alone or in combination of 2 % urea (15 days before Cu-EDTA sprays) produced lower total shoot length per plant compared to control (Table 5). Total shoot length per plant with Cu-EDTA @ 0.5%, 1%, 1.5% and 2 % was 88.38, 89.23, 84.05 and 86.11 cm, respectively. Total shoot length with 2 % urea (applied 15 days before Cu-EDTA application) + Cu-EDTA @ 0.5%, 1%, 1.5% and 2 % was 96.32, 95.11, 99.44 and 99.70 cm, respectively. Total shoot length per plant in control plants was 85.91 cm.

Number of leaves per plant: The number of leaves per plant counted in the following season after field planting of grafted apple nursery plants was significantly affected by urea and Cu-EDTA treatments (Table 6 and Fig. 4). Plants treated with urea @ 8 % resulted the maximum number of leaves per plant (111.33), followed by urea @ 6 % (107.33) and urea @ 4 % (104.33). Cu-EDTA (without 2 % urea) resulted in lower number of leaves per plant than control while adding 2% urea different concentration of Cu-EDTA (15 days before Cu-EDTA application) produced a statistically similar number of leaves per pant. Number of leaves

per plant with Cu-EDTA @ 0.5%, 1%, 1.5% and 2 % was 99.00, 97.67, 96.00 and 93.67, respectively. Total number of leaves per plant with Cu-EDTA 0.5%, 1%, 1.5% and 2 % along with 2 % urea spray (15 days before Cu-EDTA application) was 102.33, 101.67, 100.67 and 99.67, respectively. Control plants produced 100.33 leaves per plant.

Leaf area: Data recoded on leaf area measured in field planted grafted apple plants in the following season of nursery have been presented in Table 6 and graphically depicted in Fig. 4. Date reveals that leaf area was significantly affected by urea and Cu-EDTA treatments. Plants treated with urea @ 8 % resulted from the maximum leaf area (36.76 cm-2), followed by urea @ 6 % (36.67 cm-2) and urea @ 4 % (36.48 cm-2). Cu-EDTA (without 2 % urea) resulted in lower than the control, while adding 2% urea different concentration of Cu-EDTA (15 days before Cu-EDTA application) produced statistically similar leaf area in pants. Leaf area in plants treated with Cu-EDTA 0.5%, 1%, 1.5% and 2 % was 35.66, 35.43, 35.22 and 35.11 cm-2, respectively. Leaf area in plants treated with Cu-EDTA 0.5%, 1% and 1.5% along with 2 % urea spray (15 days before Cu-EDTA application) were 34.87, 34.66, 34.29 and 34.19 cm-2, respectively. Leaf area under control treatment was 34.74 cm-2.

DISCUSSION

Leaf defoliation: In present study, data on defoliation in grafted apple nursery plants recorded at 2-day interval indicated that urea and Cu-EDTA treatments significantly influenced the leaf defoliation pattern over time studies for 30 days after treatment application. Cu-EDTA alone or in combination of 2 % urea (15 days before Cu-EDTA spray) induced early defoliation compared to untreated control as well as urea (4, 6 or 8%) treatments. At 12 days after Cu-EDTA application @ 1, 1.5 or 2 % alone or in a combination of 2% urea (sprayed 15 days before Cu-EDTA application), 52.85 to 63.40 per cent leaf defoliation was achieved, while control plants showed only 7.43 % defoliation. And, at 24 days after treatments, Cu-EDTA @ 1, 1.5 or 2 % alone or in combination of 2 % urea (sprayed 15 days before Cu-EDTA application) caused more than 90% leaf defoliation, resulting the highest leaf defoliation (98.63 %) due to Cu-EDTA @ 2%, although it was statistically at par with urea @ 2 % + Cu-EDTA @ 2 % (93.84 %), Urea @ 2 % + Cu-EDTA @ 1.5% (93.45 %) and urea @ 2 % + Cu-EDTA @ 1 % (92.15 % %). In our study, increased doses of urea delayed leaf defoliation in apple nurseries. Earlier workers also reported defoliant in fruit nursery plants by using Cu-EDTA [15]. The possible reason for the highest leaf defoliation might be attributed that Cu-EDTA produces a larger amount of Ethylene synthesis enzymes like cellulose and pectinase which causes cell wall degradation. These Enzymes loosen the cell wall and cells which leads to leaf abscission. Delayed defoliation in higher doses of urea-treated plants might be due to the abundant availability of nitrogen for plant growth with suitable environmental conditions in polyhouse thereby delaying the leaf senescence. [16] also recorded early defoliation in apple, cherry and pear seedlings due to Cu-EDTA sprays at different concentrations and they found that leaf abscission usually increased with increasing concentration of Cu-EDTA.

Plant nitrogen content: Plant nitrogen content (in shoots and roots) of grafted apple nursery plants is greatly influenced by urea and Cu-EDTA treatments. Urea treatments significantly increased shoot and root nitrogen content with maximum shoot nitrogen (2.14%) and root nitrogen (2.46 %) due to urea @ 8 %. Shoot and root nitrogen content was lower in Cu-EDTA treated plants compared with control, while combining with 2 % urea spray (15 days before Cu-EDTA application) enhanced shoot and root nitrogen content to the level of control plants. The defoliants decreased nitrogen content in shoot and root-grafted apple plants, as a result of early defoliation and reduced mobilization of leaf nitrogen into tree storage, exiting low nitrogen content in Cu-EDTA treated plants while enhanced nitrogen content in plant receiving urea as a treatment. Previous works by [17] shown that the application of urea sprays on deciduous trees in the Autumn can increase tree nitrogen reserves.

Terminal bud injury: The increased doses of Cu-EDTA resulted in higher incidence of terminal bud injury even pre-treatment of urea @ 2 % (15 days before Cu-EDTA application) did not mitigate the effect of Cu-EDTA on terminal bud injury. The highest terminal bud injury (43.33 %) was recorded with 2 % Cu- EDTA either sprayed alone or in combination of 2 %. Plants treated with Cu- EDTA @ 1.5 % alone or in combination of 2 % urea showed 33.33 % terminal bud injury. There was 16.67 % terminal but injury in the plants treated with 1 % Cu-EDTA alone or in combination of urea @ 2 %. Higher incidence of terminal bud injury due to increased levels of Cu-EDTA might be attributed to the facts that the foliar spray of Cu-EDTA at high concentration leads to the formation of free radicle shat caused damage to cellular and sub-cellular structures of growing apical meristem, leading to denaturation of proteins, thereby destroying enzymes that are critical for cell functioning. [18] also observed that Cu-EDTA caused bud injury with high concentration. Terminal shoot growth and number of shoots per plant in the following growing season after field transplanting were affected by urea and Cu-EDTA treatment to the grafted plants in nursery. Increased doses of urea (4-8%) increased terminal shoot growth. Cu-EDTA treatments were detrimental to terminal shot growth, hence reduced terminal shoot growth was observed with increased levels of Cu-EDTA. Spraying of 2 % urea 15 days before Cu-EDTA application was fond effective in increasing the terminal shoot growth as compared to control plants. applying 2 % urea 15 days before Cu-EDTA sprays effectively increased the number of shoots per plant. In our study, the positive role of urea on terminal shoot growth were closely associated with the increased concentrations of plant nitrogen contend as observed in present study. According to [19], the application of urea sprays in the Autumn can increase tree nitrogen reserves as it gets stored in plant and utilized during next growing season for plants growth. Excessive copper can damage the plants cell membrane leading to reduced photosynthesis chlorosis and necrosis, furthermore, copper toxicity can cause oxidative stress in plants which can lead to the accumulation of reactive oxygen species and cell damage and reduced growth of plant. Similar results in deciduous plants were reported by, [20] and [21].

Average shoot length as well as total shoot length per plant measured in the following season of field planting was significantly affected by urea and Cu-EDTA treatment in grafted apple nursery plants. Plants treated with urea @ 8 % resulted from the highest average shoot length (23.37 cm) as well as total shoot length (132.40 cm), followed by Urea @ 6 % (20.6 and 108.68 cm) and urea @ 4 % (22.23 and 95.86 cm, respectively). Increased levels of Cu-EDTA resulted in shorter shoots and total shoot length per plant. Plants treated with Cu-EDTA alone or in combination of 2 % (15 days before Cu-EDTA application) produced shorter shoot length thereby lowered total shoot

length per plant compared to control and urea (4, 6 or 8%) treated plants. Number of leaves per plant was also significantly affected by urea and Cu-EDTA. Plants treated with urea @ 8 % resulted in the maximum number of leaves per plant (111.33), followed by Urea @ 6 % (107.33) and urea @ 4 % (104.33). Cu-EDTA (without 2 % urea) resulted in lower number of leaves per plant than control while adding 2% urea different concentration of Cu-EDTA (15 days before Cu-EDTA application) produced a statistically similar number of leaves per pant that of control plants. Leaf area was also influenced by urea and Cu-EDTA treatments. Plants treated with urea @ 8 % resulted the maximum leaf area (36.76 cm-2), followed by Urea @ 6 % (36.67 cm-2) and urea @ 4 % (36.48 cm-2). Cu-EDTA (without 2 % urea) resulted in lower leaf area than control, while adding 2% urea different concentration of Cu-EDTA (15 days before Cu-EDTA application) produced a statistically similar leaf area in pants. Nitrogen is key component of chlorophyll, which is responsible for green color of leaves and is essential for Photosynthesis. Adequate nitrogen helps plants produce more chlorophyll, which in turn increases the plant's ability to produce more leaves. Additionally, nitrogen is a key building block of proteins and protein is essential for plant growth and development including the production of new leaves. The decreases in the number of leaves per plant in Cu-EDTA treated plants might be due to damage of plant cell membranes leading to reduced photosynthesis chlorosis and necrosis when the leaves are damaged the plant may not be able to produce enough energy to support growth of new shoots. Similar results also agree with [22]that number of leaves increased significantly when sprayed with urea at high concentration.

CONCLUSION

Present investigation has led to the conclusion that foliar application Cu-EDTA effectively induced the early defoliation in grafted apple nursery plants raised under polyhouse conditions. More than 90% defoliation was achieved by 24 days after sprays with the application of Cu-EDTA @ 1%, 1.5% or 2 % however the higher doses of Cu-EDTA were detrimental in terms of terminal bud injury to the plants. Urea sprays (4, 6 and 8%) were not effective in early defoliation of grafted apple plants in polyhouse conditions. Cu-EDTA induced defoliation reduced plant nitrogen content and later affected growth performance (terminal shoot growth, number of shoots, leaves per plant, leaf area) in field conditions during the following growth season. Spaying of 2 % urea (15 days before Cu-EDTA application) improved plant nitrogen content and also favored the plant growth, leaf chlorophyll content and leaf nutrient status (nitrogen, phosphorus and potassium) during the following season in filed conditions. Therefore, 2 % urea (15 days before Cu-EDTA application) + 1% Cu-EDTA in first week of November proved to be best treatment for early defoliation of grafted apple nursery plants raised in polyhouse conditions and better growth of plant in following season under field conditions.

Future scope: The future scope of current study in grafted apple nursery plants grown in polyhouse conditions can be used to induce early defoliation triggered by foliar spray of Cu-EDTA.

Acknowledgement: It is a great pleasure for me to express my deep sense of gratitude and indebtedness to my noble, able and sincere Advisor, Dr. Angrej .Ali Associate Professor, FOH Wadura Fruit Science, SKUAST-Kashmir who guided me with his perfect knowledge and experience, which paved the way for me in the completion of this heracleum task.

Conflict of interest: No

Table 1: Leaf defoliation in grafted apple nursery plants as affected by urea and Cu-EDTAtreatment

Treatment	Defoliation (%)*														
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
T_1 (control)	0.00	0.00	0.00 (1.00)	0.52 (1.23)	3.61 (2.14)	7.34 (2.88)	11.28 (3.50)	17.96 (4.35)	24.90 (5.08)	34.15 (5.92)	46.47 (6.88)	54.07 (7.42)	61.08 (7.87)	66.98 (8.24)	70.7 (8.46)
T_2 (urea@ 4%)	0.00	0.00	0.00 (1.00)	0.52 (1.23)	2.75 (1.93)	5.30 (2.51)	9.75 (3.27)	15.64 (4.07)	23.04 (4.90)	33.90 (5.90)	45.42 (6.81)	53.27 (7.37)	57.99 (7.68)	64.40 (8.08)	68.19 (8.31)
T_3 (urea@ 6%)	0.00	0.00	0.00 (1.00)	0.66 (1.28)	4.07 (2.25)	8.07 (3.01)	13.12 (3.75)	21.72 (4.76)	30.84 (5.64)	38.72 (6.30)	47.44 (6.96)	54.66 (7.46)	57.29 (7.63)	61.95 (7.93)	65.88 (8.17)
T_4 (urea@ 8%)	0.00	0.00	0.00 (1.00)	1.18 (1.47)	6.17 (2.67)	11.35 (3.51)	18.51 (4.41)	28.29 (5.40)	37.86 (6.23)	46.20 (6.87)	52.17 (7.29)	55.39 (7.50)	56.77 (7.60)	59.06 (7.75)	61.94 (7.93)
T_5 (Cu-EDTA @ 0.5%)	0.00	0.00	2.95 (1.98)	6.17 (2.67)	15.16 (4.01)	25.86 (5.18)	36.03 (6.08)	43.90 (6.70)	52.17 (7.29)	58.93 (7.74)	63.38 (8.02)	67.91 (8.30)	71.85 (8.53)	75.27 (8.73)	78.81 (8.93)
T_6 (Cu-EDTA @ 1%)	0.00	0.00	5.06 (2.46)	16.63 (4.19)	36.36 (6.11)	56.61 (7.59)	65.36 (8.14)	74.10 (8.66)	81.46 (9.08)	85.46 (9.25)	89.80 (9.48)	93.69 (9.73)	96.78 (9.88)	97.63 (9.93)	98.23 (9.96)
T_7 (Cu-EDTA @ 1.5%)	0.00	0.00	6.11 (2.66)	20.56 (4.64)	40.26 (6.42)	63.40 (8.02)	71.97 (8.54)	78.27 (8.90)	82.94 (9.16)	87.92 (9.43)	91.99 (9.64)	94.70 (9.78)	97.05 (9.90)	97.58 (9.92)	98.10 (9.95)
T_8 (Cu-EDTA @ 2%)	0.00	0.00	7.86 (2.97)	23.72 (4.97)	43.38 (6.66)	67.90 (8.30)	75.96 (8.77)	82.50 (9.13)	84.18 (9.23)	86.65 (9.42)	89.93 (9.58)	94.15 (9.74)	97.65 (9.92)	97.98 (9.94)	98.63 (9.92)
T_9 (urea@2% + Cu- EDTA @ 0.5%)	0.00	0.00	2.75 (1.93)	5.31 (2.51)	13.35 (3.78)	23.98 (4.99)	32,16 (5.75)	40.60 (6.45)	48.59 (7.04)	55.53 (7.51)	60.38 (7.83)	64.44 (8.09)	69.01 (8.41)	72.70 (8.58)	75.64 (8.75)
T_{10} (urea@2% + Cu- EDTA @ 1%)	0.00	0.00	4.85 (2.42)	14.36 (3.91)	31.68 (5.71)	52.85 (7.33)	63.54 (8.03)	72.66 (8.58)	78.96 (8.94)	84.40 (9.24)	88.27 (9.44)	92.15 (9.61)	94.75 (9.79)	95.82 (9.80)	97.49 (9.82)

T_{11} (urea@2% + Cu- EDTA @ 1.5%)	0.00	0.00	5.64 (2.57)	17.89 (4.34)	36.24 (6.10)	59.38 (7.77)	67.75 (8.28)	75.23 (8.73)	79.95 (8.99)	85.20 (9.28)	89.07 (9.49)	93.45 (9.73)	96.01 (9.84)	97.60 (9.87)	98.22 (9.89)
T_{12} (urea@2% + Cu- EDTA @ 2%)	0.00	0.00	7.02 (2.83)	21.57 (4.75)	38.83 (6.31)	63.80 (8.05)	67.75 (8.52)	77.97 (8.88)	82.50 (9.13)	88.01 (9.43)	89.95 (9.50)	93.84 (9.76)	96.01 (9.85)	97.18 (9.90)	98.04 (9.95)
SE(m)			0.02	0.04	0.04	0.04	0.05	0.04	0.03	0.02	0.03	0.03	0.03	0.04	0.05
CD. (p <=0.05)			**0.07**	**0.13**	**0.13**	**0.13**	**0.16**	**0.12**	**0.09**	**0.08**	**0.09**	**0.12**	**0.13**	**0.12**	**0.15**

*Note: values in parenthesis are square root transformed values. *At 2 days interval after Cu-EDTA spray.*

Table 2: Plant nitrogen content in grafted apple nursery plants as affected by urea and Cu-EDTAtreatments

Treatment	Plant nitrogen content (%)	
	Shoot	Root
T_1: Control	1.33	1.35
T_2: Urea @ 4%	1.82	2.13
T_3:Urea @ 6%	2.06	2.37
T_4: Urea @ 8%	2.14	2.46
T_5:Cu-EDTA @ 0.5%	1.10	1.26
T_6: Cu-EDTA @ 1%	1.01	1.11
T_7:Cu-EDTA @ 1.5%	0.97	1.02
T_8: Cu-EDTA @ 2%	0.90	0.97
T_9: Urea@2% + Cu-EDTA @ 0.5%	1.76	2.25
T_{10}: Urea @ 2% + Cu-EDTA @ 1%	1.58	2.12
T_{11}: Urea@2% + Cu-EDTA @ 1.5%	1.52	2.05
T_{12}: Urea@2% + Cu-EDTA @ 2%	1.46	1.99
SE(m)	0.02	0.02
CD (p=0.05)	**0.05**	**2.23**

Table 3: Terminal bud injury in grafted apple nursery plants as affected by urea and Cu-EDTA sprays treatments

Treatment	Terminal Bud injury (%)
T_1: Control	0.00 (1.00)
T_2: Urea @ 4 %	0.00 (1.00)
T_3: Urea @ 6 %	0.00 (1.00)
T_4: Urea @ 8 %	23.33(4.16)
T_5: Cu-EDTA @ 0.5%	0.00 (1.00)
T_6: Cu-EDTA @ 1 %	16.67(4.16)
T_7: Cu-EDTA @ 1.5 %	33.33(4.91)
T_8: Cu-EDTA @ 2%	43.33(6.40)
T_9: Urea @ 2 % + Cu-EDTA @ 0.5 %	0.00 (1.00)
T_{10}: Urea @ 2 % + Cu-EDTA @ 1 %	16.67 (4.16)
T_{11}: Urea @ 2 % + Cu-EDTA @ 1.5 %	33.33 (4.91)
T_{12}: Urea @ 2 % + Cu-EDTA @ 2 %	43.33 (6.40)
SE(m)	0.25
CD (p=0.05)	**0.74**

Note: values in parenthesis are square root transformed values.

Table 4: Terminal shoot growth and number of shoots per plant in following growing season after transplanting in open field as affected by urea and Cu-EDTA sprays in grafted apple nursery plants

Treatment	Terminal shoot growth (cm)	Number of shoots per plant
T_1: Control	21.73	4.57
T_2: Urea @ 4 %	23.30	4.78
T_3: Urea @ 6 %	26.93	4.89
T_4: Urea @ 8 %	30.53	5.00
T_5: Cu-EDTA @ 0.5%	17.90	5.22
T_6: Cu-EDTA @ 1 %	16.40	5.33
T_7: Cu-EDTA @ 1.5 %	15.63	5.44
T_8: Cu-EDTA @ 2%	15.23	5.67
T_9: Urea @ 2 % + Cu-EDTA @ 0.5 %	25.60	5.00
T_{10}: Urea @ 2 % + Cu-EDTA @ 1 %	24.73	5.56
T_{11}: Urea @ 2 % + Cu-EDTA @ 1.5 %	23.80	5.89
T_{12}: Urea @ 2 % + Cu-EDTA @ 2 %	22.50	6.00
SE(m)	0.37	0.16
CD (p=0.05)	**1.10**	**0.48**

Table 5: Total shoot length per plant in following growing season after field transplanting as affected by urea and Cu-EDTAtreatment in grafted apple nursery plants

Treatment	Average shoot length (cm)	Total shoot length (cm)
T_1: Control	18.41	85.91
T_2: Urea @ 4 %	20.06	95.86
T_3: Urea @ 6 %	22.23	108.68
T_4: Urea @ 8 %	23.37	132.40
T_5: Cu-EDTA @ 0.5%	16.91	88.31
T_6: Cu-EDTA @ 1 %	16.73	89.23
T_7: Cu-EDTA @ 1.5 %	15.44	84.05
T_8: Cu-EDTA @ 2%	15.20	86.11
T_9: Urea @ 2 % + Cu-EDTA @ 0.5 %	17.26	96.32
T_{10}: Urea @ 2 % + Cu-EDTA @ 1 %	17.12	95.11
T_{11}: Urea @ 2 % + Cu-EDTA @ 1.5 %	16.93	99.70
T_{12}: Urea @ 2 % + Cu-EDTA @ 2 %	16.57	99.44
SE(m)	0.09	3.02
CD (p=0.05)	**0.28**	**8.92**

Table 6: Number of leaves per plant and leaf area in following seasonafter planting as affected by urea and Cu-EDTA treatments in grafted apple planted in

Treatment	Number of leaves per plant	Leaf area (cm^2)
T_1: Control	100.33	34.74
T_2: Urea @ 4 %	104.00	36.48
T_3: Urea @ 6 %	107.33	36.67
T_4: Urea @ 8 %	111.33	36.76
T_5: Cu-EDTA @ 0.5%	99.00	35.66
T_6: Cu-EDTA @ 1 %	97.67	35.43
T_7: Cu-EDTA @ 1.5 %	96.00	35.22
T_8: Cu-EDTA @ 2%	93.67	35.12
T_9: Urea @ 2 % + Cu-EDTA @ 0.5 %	102.33	34.87
T_{10}: Urea @ 2 % + Cu-EDTA @ 1 %	101.67	34.66
T_{11}: Urea @ 2 % + Cu-EDTA @ 1.5 %	100.67	34.29
T_{12}: Urea @ 2 % + Cu-EDTA @ 2 %	99.67	34.19
SE(m)	0.90	0.19
CD (p=0.05)	**2.66**	**0.56**

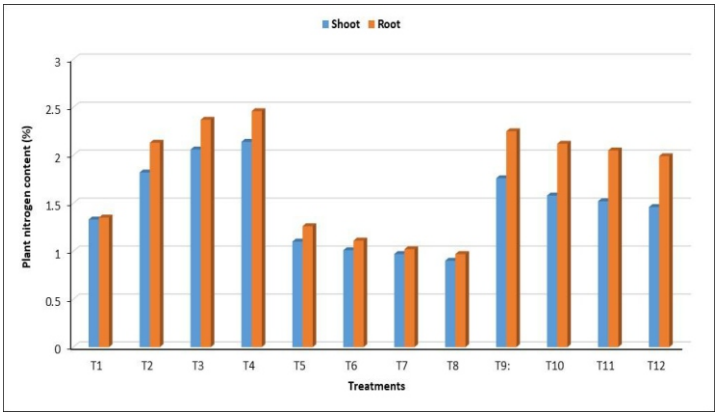

Fig. 1: Plant nitrogen content as affected by induced defoliation treatments of urea and Cu-EDTA sprays

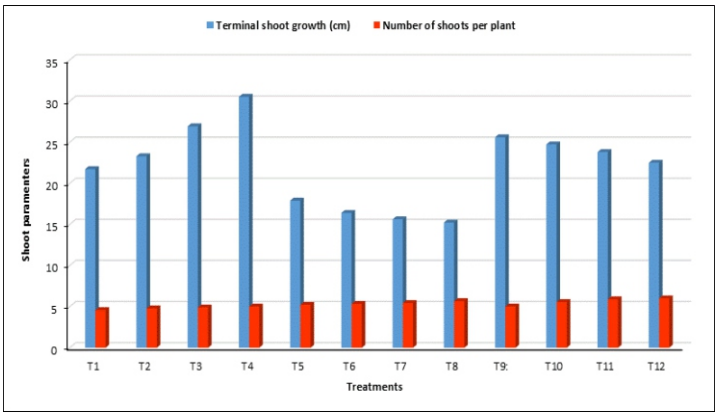

Fig. 2: Terminal shoot growth and number of shoots per plant in following growing season after transplanting in open field as affected by urea and Cu-EDTA sprays in grafted apple nursery plants

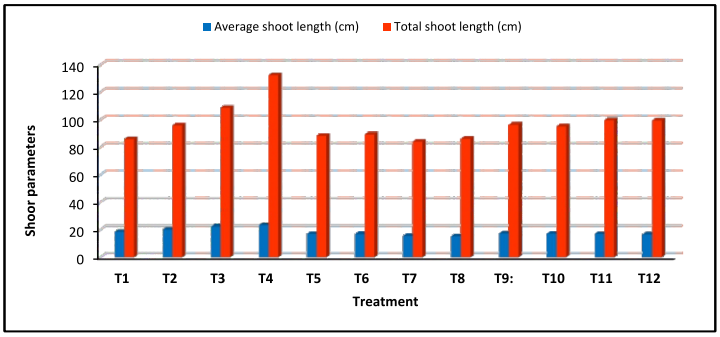

Fig. 3: Total shoot length per plant in following season of field planting as affected by urea and Cu-EDTA sprays in grafted apple nursery plants

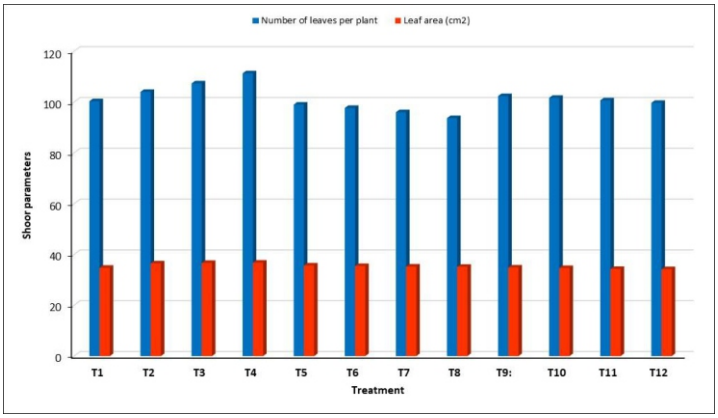

Fig. 4: Number of leaves per plant and leaf area in grafted apple planted in following growing season as affected by urea and Cu-EDTA treatments

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