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The effect of spraying with Optimus plus nano-fertilizer and chelated iron on the root growth characteristics of apple seedlings, Ibrahimi variety

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Abstract

study was conducted on apple saplings, variety Ibrahimi, in a lath house at the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Karbala. from mid-March to the end of June 2023. It was designed to explore the main and interactive effects of two factors. The tested factors are labeled (A and B), and the levels of the evaluation factors are labeled (C). A: Factor 1 – the nano-fertilizer used: Optimus Plus, concentrations: 0, 1, and 2 mg L^{-1} [1]. Factor 2 – three levels of chelated iron (Fe-EDDHA) (three concentrations) (0, 75, and 150 mg L^{-1}). The research was conducted as a factorial experiment using a randomized complete block design (RCBD) with three replicates. The total number of seedlings per replicate was 18, which were randomly assigned to two experimental units. The results of the experiment indicated a significant effect of Optimus Plus fungicide at a concentration of 2 ml L^{-1} on all studied traits (root length, root diameter, root volume, moisture content, and root dry weight). yielding the highest values (32.56 cm,37.56cm^3, 6.92cm,60.16%,21.90 sapling^{-1}) respectively. Similarly, chelated iron at a concentration of 150 mg L^{-1} had a similar significant effect on the studied traits (root length, root diameter, root volume, moisture content, and root dry weight). yielding the highest values (37.22 cm,44.22 cm^3,6.89 cm,60.80%,24.48 sapling^{-1}) respectively. Significant differences were shown compared to the control treatment of spraying seedlings with distilled water only. Furthermore, the dual interaction between Optimus Plus fungicide at a concentration of 2 ml L^{-1} and chelated iron at a concentration of 150 mg L^{-1} had a significant effect on most of the studied traits (root diameter, root volume, moisture content, and root dry weight). which reached (47.00 cm^3, 65.85%, 27.75g sapling^{-1}) respectively.

Keywords: foliar feeding, sustainable agriculture, alternatives to chemical fertilizers, fruit trees

Introduction

Agricultural systems are under severe pressure in many nations by rising pollution, declining soil health, and dwindling crop yields resulting in economic losses. It goes without saying that soil fertility is low with poor productivity. Thus, exploring different approaches to increase production efficiency and improve food security is needed [1, 2, 3, 4]. Focus on reducing losses and pollution rates to achieve higher organic fruit yields, especially Apples (Malus domestica) in well-defined cultivation areas and high yielding plantations, at better orchard stages [5]. Apples are an essential crop in some countries, and for many exporting nations, apple is also an important source of funds, because of their durability and ability to transport. In addition, they contain high levels of protection, vitamins, proteins and carbohydrates [6,7].

It is essential to find alternatives to chemical fertilizers to minimize their negative impact on soil health. For instance, nano-fertilizers are one potential choice available that has been brought into commerce over the last few years to address the problems and harm caused by conventional chemical fertilizers [8,9]. Due to their high efficiency, effectiveness, and solubility, as well as their use in very small quantities, they achieve positive results without the need for repeated application. This makes them highly efficient compared to traditional fertilizers in foliar absorption [10,11,12].

There have been several studies on the advantages of using different nano-fertilizers to stimulate plant growth, including Optimus Plus, these nanofertilizers are good for the environment and thus represent an essential step toward sustainable agricultural development. as they can increase nutrient use efficiency and reduce environmental protection costs [13]. Studies suggest that nanofertilizers enhance nutritional efficiency, reduce their toxicity to soil organisms, mitigate the stress associated with excessive fertilizer use, and lower the overall fertilizer requirements [14,15] reported that adding the nanofertilizer Optimus Plus significantly improved growth traits, particularly in the variety Sharabi. [16] also indicated that all plant growth parameters of orange saplings were affected considerably when treated with the nano-fertilizer Optimus plus at a concentration of 1.5 ml L^{-1}, exhibiting the highest rates of sapling height, number of branches, stem diameter, number of leaves, leaf area, leaf content of total chlorophyll, and soluble carbohydrates. In addition to nano-fertilizers which have advanced agricultural practices, chelated fertilizers have also proven effective in terms of cost and efficiency, particularly through foliar spraying. This method allows plants to absorb a high percentage of essential nutrients, both macronutrients and micronutrients. Foliar feeding with chelated fertilizers, such as chelated iron, represents a promising strategy to alleviate the adverse effects of drought stress [17].

Research has shown that applying iron treatment can enhance plant growth, as iron is an essential nutrient that plays a crucial role in cellular functions such as photosynthesis and respiration [18,19,20,21]. This effect was confirmed by [22].in their study on the effects of foliar applications of chelated calcium and chelated iron. Their results demonstrated significant improvements in both vegetative and floral traits of the plant *Gazania splendens* L. [23] reported that foliar spraying with iron effectively enhanced vegetative growth traits and chlorophyll content in orange (Citrus medica) saplings. Likewise, [24] showed that the highest increase in all traits investigated was significant compared to the control treatment with nano-fertilizer Optimus Plus at 2 ml L^{-1} accompanied by chelated Iron (1000 mg L^{-1}). The interaction between the study factors (azotobacter + mycorrhizal fungi) + spraying nano-iron (3 g L^{-1}), biological fertilization (azotobacter + mycorrhizal fungi) + spraying chelated iron (6 g L^{-1}), and (spraying nano-iron (3 g L^{-1}) + spraying chelated iron (6 g L^{-1}) had the highest values [25] in the study of orange saplings.

The aims of this research to research were conducted to assess the impact of different concentrations of nano-fertilizer Optimus Plus and chelated iron on root system nutrient uptake capacity and how this effect is reflected in vegetative growth characteristics of apple saplings variety Ibrahimi. The aim was to encourage the vegetative and root growth of the Ibrahimi apple variety seedlings and to bring the seedling to a stage suitable for planting in the permanent location within a suitable time period.

Materials and Methods

This experiment was conducted in a lath house belonging to the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Karbala, for the spring season of March 2023. The objective was to study the effect of application of the nano-fertilizer Optimus Plus (organic fertilizer containing 30% organic matter, 5% total nitrogen, and 3% organic nitrogen)at three concentrations of (0, 1, and 2 ml L^{-1}) and chelated iron (Fe-EDDHA)) at three concentrations of (0, 75, and 100 ml L^{-1}) on the root growth traits of apple saplings of the Ibrahimi variety to produce saplings of suitable traits that have a marketable potential. Saplings of equal height {58} Saplings selected at one year. Saplings were planted in 1.25 kg black polyethylene bags, filled with a mixture of sandy and loamy soil (Table 1). Implementation for all the service practices like weeding, irrigation etc.

Table (1): Some physical and chemical properties of the soil used in the experiment

Soil texture	sandy mixture
Sand	956 gm kgm^{-1}
Silt	29 gm kgm^{-1}
Clay	15 gm kgm^{-1}
PH	7.6
EC	2.4 ds m^{-1}

The seedlings were sprayed using a 1L sprayer, and 1 cm^3 of bleach was added to each concentration as a substitute for the spreading agent (Tween-20). The seedlings were sprayed until completely wet with the nano-fertilizer plus Optimus in the early morning at three concentrations: 0 , 1, and 2 ml L^{-1}. The following morning, the seedlings were sprayed twice with chelated iron at concentrations of 0, 75, and 150 mg L^{-1}, with a one-week interval between sprays, starting on March 15, 2023. A control treatment was also used (sprayed with distilled water and bleach). Measurements were taken at the end of June 2023.

The experiment was designed as a factorial experiment in a R.C.B.D. with three replicates. There were 18 saplings per replicate, two per experimental unit. The following are the growth parameters which were recorded at the end of the experiment:

1. **The average longest root length (cm):** The length of the longest root in each sapling was measured using a measuring tape, starting from the crown area (the region

where the stem meets the roots at the soil surface) down to the root tip. The mean was then calculated from all measurements**.**

2. **Root volume average (cm^3)**: The root volume of the saplings was measured by immersing the roots in a graduated cylinder filled with a known volume of water and calculating the volume of the displaced water.

3- **The average root diameter (cm^3):** The average root diameter was calculated by assuming the root is cylindrical, using the following equation [27]:

$$D = 2\sqrt{\frac{V}{L} * \pi}$$

Where:

D = diameter of the root (cm) , V = volume of the root (cm^3) , π = constant ratio 22/7

4- **Moisture content percentage (%)**: It was calculated according to the following equation:

$$Moisture\ content = \frac{\text{fresh leaf weight} - dry\ leaf\ weight}{\text{dry leaf weight}} x100$$

5- **Root System Dry Weight Average (g)**: After rooting out the saplings the shoot system was carefully separated from the root system at the crown area. The roots were then rinsed with water and placed in perforated paper bags a electric oven set to 70°C until the roots reached a stable weight. Finally, the roots were weighed using a sensitive electric balance [28]

At the end of the experiment, the data were analyzed according to the factorial design (3×3) for the nano-fertilizer Optimus Plus and chelated iron. The means were compared based on the least significant difference (LSD) test at a probability level of 0.05.[29]

Results and Discussion

The average longest root length (cm)

Based on the means in Table 2, it was found that foliar spraying of the nano fertilizer Optimus Plus has a practical impact on the average length of the longest root of saplings. The treatment with a concentration of 2ml L^{-1} resulted in the highest average of 32.56cm, the saplings in the control treatment presented the lowest average 29.44cm. In the average of this trait, the effect of applying chelated iron was significantly superior. Saplings treated with 150 mg L^{-1} of chelated iron for saplings showed the maximum average, 37.22 cm while the control treatment had the lowest (21.00 cm). Similarly, application of nano fertilizer Optimus Plus with chelated iron (Table 2) did not affect the length of the longest root significantly.

Table (2): Effect of foliar application of the nano-enriched Optimus Plus and chelated iron and their interaction on the average longest root length (cm)of apple saplings, variety Ibrahimi

Concentrations of Nano fertilizer, Optimus Plus (ml^{-1})	Iron chelated concentrations (mg L^{-1})			Means of concentrations of Nano fertilizer, Optimus Plus
	0	75	150	
0	19.67	33.67	35.00	29.44
1	21.00	34.67	37.00	30.89
2	22.33	35.67	39.67	32.56
Means of iron chelated concentrations	21.00	34.67	37.22	
L.S.D. 0.05	Nano fertilizer, Optimus Plus	Iron chelated	Interaction	
	0.371	0.371	N.S	

Root volume average (cm^3)

The average root volume results (Table 3) show a considerable effect of the nano fertilizer, Optimus Plus. The 2 ml L^{-1} dose yielded the highest mean for root volume, equal to 37.56 cm³. At the same time, the control treatment had the lowest average root volume of 32.22 cm³. Moreover, chelated iron at 150 mg L^{-1} had a significant impact on root volume, with a maximum average of 44.22 cm³ per plant. Conversely, the lowest average was noted by the control treatment (23.11 cm³). Within the same table, the binary interaction was also found to be significant for root length. Optimus Plus nano-fertilizer (2 ml L$^{-1)}$ + chelated Fe (150 mg L^{-1}) also resulted in the highest average root length (47.00cm^3) in saplings. The lowest root length of 21.00 cm was recorded with the treatment of control.

Table (3): Effect of foliar application of the nano-fertilizer Optimus Plus and chelated iron, and the interaction between them on Root volume average (cm^3) of apple saplings, variety Ibrahimi**.**

Concentrations of Nano fertilizer, Optimus Plus (ml^{-1})	Iron chelated concentrations (mg L^{-1})			Means of concentrations of Nano fertilizer, Optimus Plus
	0	75	150	
0	21.00	35.33	40.33	32.22
1	23.00	37.67	45.33	35.33
2	25.33	40.33	47.00	37.56
Means of iron chelated concentrations	23.11	37.78	44.22	

L.S.D. 0.05	Nano fertilizer, Optimus Plus	Iron chelated	Interaction
	0.673	0.673	1.166

The average root diameter (cm3):

A highly significant effect of treatments on the root diameter is given in Table 4. Optimus Plus nano-fertilizer at the concentration of 2 ml L^{-1} provided the highest average of this attribute with 6.92 cm³, On the other hand, the control treatment presented the lowest average for this characteristic, of 6.39 cm³. There was also a significant effect of chelated iron on root diameter (Table 4). The maximum average diameter of the sapling root, which was 6.89 cm³, was obtained by treating with 150 mg L^{-1} chelated iron. Saplings had the lowest mean (6.47 cm³) for this trait in the control treatment. There was no significant effect on this trait from the binary interaction of the Ag-nano-fertilizer Optimus Plus and chelated iron.

Table (4): Effect of foliar application of the nano-fertilizer Optimus Plus and chelated iron, and their interaction on the average root diameter (cm^3) of apple saplings, Variety Ibrahimi.

Concentrations of Nano fertilizer, Optimus Plus (ml^{-1})	Iron chelated concentrations (mg L^{-1})			Means of concentrations of Nano fertilizer, Optimus Plus
	0	75	150	
0	6.23	6.35	6.61	6.39
1	6.54	6.48	6.92	6.65
2	6.63	7.15	7.13	6.92
Means of iron chelated concentrations	**6.47**	**6.66**	**6.89**	

L.S.D. 0.05	Nano fertilizer, Optimus Plus	Iron chelated	Interaction
	0.280	0.280	N.S

Moisture content percentage (%)

The results shown in Table 5 clearly show that the applied nano-fertilizer Optimus Plus significantly affects the root moisture content of the roots of apple saplings. In particular, the average moisture content was found to be greater (60.16%) on the other hand the moisture content (54.89%) was lower than that of control treatment with Optimus Plus at a 2 ml L^{-1}. Additionally, this table depicts response to chelated iron for this trait. The part of apple saplings stems showed the highest moisture content

60.80% in the chelated iron treatment, and the control average moisture content was 54.80%. The binary interaction effect of chelated iron and Optimus Plus, as shown in Table 4 was also significant. The highest average (65.85%) was obtained with a concentration of 2 ml L^{-1} of the nutrient solution Optimus Plus and 150 mg L^{-1} of chelated iron, and the control treatment had the lowest rate (53.23%).

Table (5): Effect of spraying the nano-fertilizer Optimus Plus, chelated iron, and their interaction on the percentage of moisture content (%) in the roots of apple saplings, variety Ibrahimi.

Concentrations of Nano fertilizer, Optimus Plus (ml^{-1})	Iron chelated concentrations (mg L^{-1})			Means of concentrations of Nano fertilizer, Optimus Plus
	0	75	150	
0	53.23	55.12	56.33	54.89
1	54.60	57.44	60.24	57.43
2	56.57	58.08	65.85	60.16
Means of iron chelated concentrations	54.80	56.88	60.80	
$L.S.D._{0.05}$	Nano fertilizer, Optimus Plus	Iron chelated		Interaction
	0.653	0.653		1.132

Root system dry weight (g $sapling^{-1}$)

The root dry weight of saplings was markedly different as a function of application of the nano fertilizer Optimus Plus (Table 6). Spray application at 2 ml L^{-1} resulted in the highest average root dry mass of 21.90 g $sapling^{-1}$. In contrast, the control treatment only had an average of 17.74 g $sapling^{-1}$. In addition, the table shows that chelated iron also had a significant effect on this characteristic. The root dry weight of saplings averaged 24.48 g sapling-1 for the 150 mg L^{-1} (g L^{-1}) treatment, which was high relative to the control treatment, which averaged 16.45 g $sapling^{-1}$. Table 6 also reported the significant influential of the interaction between two factors on the mean dry weight of apple sapling root systems. More specifically, the highest average sapling dry weight of 27.75 g $sapling^{-1}$was obtained at a concentration of 2 ml L^{-1} of the Optimus Plus nutrient solution combined with 150 mg L^{-1} of chelated iron. Compared to the control treatment, which gave the lowest average yield of 15.26 g $seedling^{-1}$

Table (6): Effect of foliar application of the nano-fertilizer Optimus Plus and chelated iron, and their interaction on the dry weight of the root system (g saplings^{-1}) of the apple saplings, variety.

Concentrations of Nano fertilizer, Optimus Plus (ml^{-1})	Iron chelated concentrations (mg L^{-1})			Means of concentrations of Nano fertilizer, Optimus Plus
	0	75	150	
0	15.26	17.49	20.48	17.74
1	15.97	18.33	25.20	19.83
2	18.14	19.80	27.75	21.90
Means of iron chelated concentrations	16.45	18.54	24.48	
L.S.D. $_{0.05}$	**Nano fertilizer, Optimus Plus**	**Iron chelated**		**Interaction**
	0.563	0.563		0.975

The improvement in the growth parameters under study (root growth parameters) may be attributed to the direct and indirect influence of the research factors. The nano-fertilizer Optimus Plus had a significant impact on the studied traits, possibly due to its contribution to increased protein and carbohydrate formation, which enhances chlorophyll synthesis and thus stimulates carbon assimilation, this is because the Optimus Plus nano-fertilizer contains amino acids that effectively support protein synthesis, especially since glycine and glutamine are among its main components. The presence of these amino acids enhances carbon assimilation efficiency and improves nutrition. These two amino acids also contribute to the construction and stimulation of many plant enzymes and coenzymes coenzymes [30, 31, 32]. This is direct evidence that amino acids are involved in protein formation and the regulation of plant metabolism processes, which in turn increase growth by inducing cell division and establishing homeostasis in plant tissues (Tables 1, 2, 3). This effect is consistent with the findings of multiple studies [33]. On citrus mandarins [34] on sweet lime, and [35] on native oranges. Furthermore, Optimus Plus nano-fertilizer contains nitrogen, which plays a vital role in increasing vegetative growth and is involved in the synthesis of porphyrin groups, which are part of chlorophyll synthesis. It also participates in the formation of tryptophan, the primary precursor to IAA, which stimulates cell elongation, positively impacting growth indicators [31]. IAA is a hormone that enhances cell elongation and positively affects traits [30]. The smaller the particle, the greater the surface area. So, the effectiveness of the nano fertilizer Optimus Plus could also be due to this. The increased surface area makes soluble in much more solvent, especially water. This allows nanoparticles to diffuse better into contact surfaces, like plant roots. Moreover, this could also enhance carbon assimilation by increasing the surface area for several metabolic reactions, leading to increased dry matter accumulation and plant growth [36].

This sapling response to micronutrient chelated iron treatment is attributed to the role of micronutrients in plant growth and development. They are crucial for many physiological processes indirectly and indirectly activate different enzymes. Therefore, apical gradients will tend to stimulate activity at the periphery of the plant and result in a general increase in productivity of the whole plant particularly regarding the protein and carbohydrate fractions whose effects are integrated in the whole plant [37]. This is due to the critical role of foliar nutrition in plant metabolism, especially if it contains chelated iron Chelated iron provides the building blocks necessary for the formation of root systems, increasing the efficiency of the root system in taking up water and nutrients from the soil. This action, in his turn, allows the transfer of these resources to the shoot system. It also promotes root elongation and diameter, as cytokinins are biosynthesized and transported to the leaves, where they promote cell division and differentiation, cell wall development, further root extension [38, 39, 20]. These results are consistent with [41, 42].

Moreover, these effects could also be due to the involvement of iron in cytochromes, that facilitate carbon assimilation and respiration [40]. The interaction of iron with vegetative growth is particularly complicated in fruit trees compared to most other nutrients [43, 44]. Foliar feeding with chelated iron was responsible for this effect and the marked increase in plant growth and growth parameters (Tables 1, 2, 3, 4, and 5). These results are consistent with those found in [45, 46, 47] When they studied peach seedlings, apple seedlings of the Anna variety, pear seedlings.

The results of the current study demonstrated that using the nano-fertilizer Optimus Plus and chelated iron, either separately or together, positively affected growth traits of the roots and their moisture content of apple saplings, variety Ibrahimi, which was reflected in plant growth and productivity. Overall, the results demonstrated the importance of the combined effect of nano-fertilizer and chelated iron in achieving sustainable agricultural practices. Therefore, the results suggest the future use of nano-fertilizers and foliar feeding with chelated fertilizers, such as chelated iron, in fruit tree nurseries. This approach aims to improve nutrient management and reduce the use of chemical fertilizers for fruit tree orchards and nurseries, contributing to the adoption of sustainable, environmentally friendly agricultural practices.

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