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Effect of foliar application of different sources of nutrients on growth of Jambheri seedlings in primary nursery

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Abstract
The field experiment was conducted at the Center of Excellence for Citrus, College of Agriculture, Nagpur, during the academic year 2022–23. The experiment was laid out in a randomized block design with nine treatments, replicated three times. The data in respect of growth parameters of Jambheri rootstock, that is seedling length (48.68 cm), seedling diameter (0.73 cm), root length (14.56 cm), root diameter (0.87 cm), root volume (15.53 cm^3), root dry weight (1.89 g), leaf area (19.88 cm^2), number of leaves per seedling (60.44), fresh weight of seedling (36.43 g), and dry weight of seedling (12.14 g), were recorded significantly highest in treatment T_6-Nano DAP (200 ppm), while significantly maximum root-to-shoot ratio (0.301) was found in treatment T_5-Nano DAP (150 ppm) and T_9 treatment shows the minimum result across all treatments. Foliar application of Nano DAP 200 ppm shows promises for healthy growth and optimal cell sap condition in Jambheri rootstock during primary nursery stage.

Keywords: Jambheri, rootstock, nutrients, foliar, growth, primary nursery

Introduction
The citrus genus (Citrus), belonging to the Rutaceae family, is a commercially significant fruit crop cultivated in tropical and subtropical regions worldwide. It comprises 162 species within the sub-tribe Citrineae of the Aurantioideae sub-family. Major citrus species include mandarin, sweet orange, lime, lemon, grapefruit, pummelo, and citron. Citrus fruits possess numerous beneficial health and nutritive properties (Dubey *et al*., 2014) [8].

Most citrus species originated in tropical and subtropical Southeast Asia, mainly India, China, and the areas between them. Citrus species are predominantly diploid with a chromosome number of 2n=18. The Nagpur mandarin, grown in the Vidarbha region for over 150 years, is recognized as one of the finest due to its appealing color, flavor, balanced acidity, and numerous nutritional and medicinal benefits.

Major citrus-growing states in India include Maharashtra, Andhra Pradesh, Punjab, Karnataka, Odisha, Bihar, Assam, Tamil Nadu, and Gujarat. In 2019-20, India's citrus area was 1054 thousand hectares with a production of 13976 thousand MT, while mandarin occupied 480 thousand hectares producing 6368 MT (Anon., 2021, 2022).

Rootstocks play a pivotal role in growth, development, production quality and quantity of citrus. Commonly used rootstocks are Jambheri (*Citrus jambhiri*) and Rangpur lime (Citrus × limonia). Rootstock selection factors include grafting compatibility, drought, frost and disease resistance, mineral and water provision, and tolerance to abiotic stresses - impacting yield and fruit quality. Important drivers are tolerance to Citrus Tristeza Virus, Phytophthora, nematodes, salinity, water-use efficiency and drought (Sharma *et al.*, 2013) [18].

Nitrogen is the most widely used nutrient, essential for shoot growth, fruiting, fruit size and colour. Deficiencies can stunt growth, discolour leaves and cause dieback. Phosphorus plays key roles in photosynthesis, energy transfer, cell division, root growth and drought resistance. Potassium maintains turgor, reduces wilting, aids photosynthesis, food formation, respiration efficiency, disease resistance, sugar/starch translocation, protein content and cellulose formation (Marathe *et al*., 2021) [12].

Nano-fertilizers (30-40 nm) have high nutrient loading capacity, slow-release matching crop demand, increasing nutrient use efficiency, photosynthesis via expanded leaf area, while reducing toxicity from over-application and need for split fertilization (Naderi and Danesh-Shahraki, 2013) [15].

In nurseries, using appropriate fertilizers and micronutrients is crucial for improving seed germination and vigorous seedling growth for healthy plant establishment. Hence, this study was conducted on Jambheri rootstock seedlings to find the best source of nutrients against the growth and development of seedlings at the primary nursery stage.

Materials and Methods

The experiment was conducted in shade net during the years 2022–23 in the research field at the Centre of Excellence for Citrus, Bharatnagar, Nagpur. The treatment consisted of different sources of nutrients in water-soluble form. The nine treatments were comprised of T_1- Nano urea (100 ppm), T_2 - Nano urea (150 ppm), T_3- Nano urea (200 ppm), T_4- Nano DAP (100 ppm), T_5 - Nano DAP (150 ppm), T_6 - Nano DAP (200 ppm), T_7 -19:19:19 (1%), T_8- Urea (1%), and T_9-Control (water spray) and replicated thrice. The observations were recorded on the 240th day after seed sowing day (November 22, 2022). Growth quality parameters like seedling length (cm), seedling diameter (cm), root length (cm), root diameter (cm), root volume (cm^3), root dry weight (g), leaf area (cm^2), number of leaves in seedling^{-1}, fresh weight of seedling (g), dry weight of seedling (g), and root-to-shoot ratio were recorded.

Results and Discussion

The data in respect to the effect of foliar application of different sources of nutrients on growth of jambheri seedlings in primary nursery were presented in Table.1. and depicted through Fig. 1. (shoot parameter) And Fig. 2. (root parameter).

Seedling length (cm)

The data regarding to seedling length was shows that, the treatment with T_6- Nano DAP 200 ppm recorded the maximum length seedling (48.68 cm), followed by T_5- Nano DAP 150 ppm (47.48 cm) on the other hand the treatment with T_9- Control recorded the lowest length seedling (35.63 cm).

Nutrients enhance shoot length in seedlings via improved photosynthesis & membrane permeability. Disparity observed in treatments; all showed increased length compared to control. Findings align with Maust *et al*. (1994) [13] & Arora *et al.* (1970) [6].

Seedling diameter (cm)

The treatment T_6- Nano DAP 200 ppm recorded the maximum seedling diameter (0.73 cm), which was found at par with T_4- Nano DAP 100 ppm and T_5- Nano DAP 150 ppm treatments with seedling diameter of (0.67 cm of both treatments) and on the other side minimum seedling diameter of (0.43 cm) was recorded in T_9- Control.

Nutrient application boosts seedling diameter through cell wall loosening, increased extensibility, and IAA synthesis. Findings align with Salama *et al.* (2020) [16] and Sebastian *et al.* (2020) [17].

Root length (cm)

The treatment T_6, with Nano DAP 200 ppm, displayed a considerably longer root (14.56 cm), at par with the treatment T_5, which contained Nano DAP 150 ppm (14.27 cm). On the other hand, the control treatment (T_9) recorded the smallest length of the root (8.81 cm).

Nano DAP 200 ppm boosts root length via elevated auxin levels, stimulating root growth. Similarly, results line with Kumar *et al.* (2012) [10], Bhusari *et al.* (2023) [7] and Al-Jilihawi & Merza (2020) [2].

Root diameter (cm)

The data showed that, significantly maximum root diameter (0.87 cm) was recorded in the treatment Nano DAP 200 ppm conc. i.e. T_6, which was found at par with the treatment Nano DAP 150 ppm (0.83 cm) i.e. T_5 and the treatment Nano DAP 100 ppm conc. i.e. T_4 (0.77 cm). Whereas, the minimum root diameter (0.47 cm) was recorded in control treatment (T_9).

Phosphorus in Nano DAP enhances root diameter, supporting stem and cell elongation. Benefits include stem fortification and nutrient acquisition. Supported by Kumar *et al.* (2012) [10].

Root volume (cm^3)

Significantly the maximum volume of root (15.53 cm^3) was observed in Nano DAP 200 ppm (T_6) treatment which was followed by the treatment Nano DAP 150 ppm (T_5) i.e. (15.22 cm^3) and minimum volume of root was observed in control (T_9) i.e. (10.47 cm^3).

Nano DAP 200 ppm enhances root volume by stimulating root initiation and nutrient acquisition, supporting superior root growth. These findings are congruent with those reported by Al-Jilihawi and Merza (2020) [2].

Root dry weight (g)

The dry root weight of Jambheri seedlings was significantly influenced due to different foliar sprays of nutrients. The treatment Nano DAP 200 ppm (T_6) recorded the highest dry root weight (1.89 g) which was found at par with Nano DAP 150 ppm (T_5) and Nano DAP 100 ppm (T_4)- 1.84 and 1.77 g respectively. On the other side minimum dry root weight were observed in control (T_9) i.e. water spray (1.22 g).

Nano DAP 200 ppm increases root dry weight via elevated auxin levels, enhancing root initiation and nutrient absorption, leading to elongated root cells and greater tap root length. These observations align with prior studies conducted by Al-Jilihawi and Merza (2020) [2] on lemon saplings and Mustafa *et al*. (2022) [14] on mandarin seedlings.

Leaf area (cm^2)

The maximum leaf area per seedling (19.88 cm^2) was recorded in Nano DAP 200 ppm (T_6) treatment which followed by the treatment Nano urea 200 ppm (T_3) (19.47 cm^2). Whereas, the lowest leaf area per seedling (14.24 cm^2) was noticed in the control (T_9).

Nano-DAP enhances plant physiology, increasing water, nutrient supply, and biocompounds, promoting leaf area. These findings are congruent with those reported by Al-Jilihawi and Merza (2020) [2], and corroborate the results obtained by Soliman *et al.* (2016) [19].

Number of leaves seedling^{-1}: Highest number of leaves per plant was recorded in T_6- Nano DAP 200 ppm treatment (60.44), which was found at par with T_3- Nano urea 200 ppm treatment with number of leaves per plant of (57.89 cm) and on the other hand minimum was noticed in T_9- Control that was (38.56 cm).

Leaf count increases in T_6 (Nano DAP 200 ppm) due to nitrogen and phosphorus synergy, promoting vigorous growth with enhanced branching. This architecture improves solar radiation interception, boosting leaf production. Furthermore, these findings corroborate the results reported by Kumar *et al.* (2012) [10] and Arora *et al.* (1970) [6].

Fresh weight of seedling (g)

Significant differences were found in all treatments the with respect to fresh weight of seedling. The maximum fresh weight of seedling (36.43 g) was noticed in the Nano DAP 200 ppm (T_6) treatment which followed by the treatment Nano DAP 150 ppm (T_5) i.e. (35.47g). On the other side the control T_9 water spray recorded minimum fresh weight of seedling (25.53 g).

Maximal fresh weight per plant in Nano DAP 200 ppm treatment due to enhanced water and nutrient mobilization. Accelerated rates promote photosynthetic assimilate production, leading to superior seedling growth and increased biomass accumulation. These findings are congruent with those reported by Salama *et al.* (2020) [16]. Furthermore, the study conducted by Abobatta *et al.* (2023) [1] corroborates with result of research.

Dry weight of seedling (g)

The maximum dry weight of seedling (12.14 g) was noticed in the Nano DAP 200 ppm (T_6) treatment which was found at par with the treatment Nano DAP 150 ppm (T_5) i.e. (11.82 g). Whereas the control (T_9) water spray recorded minimum dry weight of seedling (7.84 g).

Maximal dry weight per plant in Nano DAP 200 ppm treatment due to enhanced water and nutrient mobilization. Accelerated rates promote photosynthetic assimilate production, leading to superior seedling growth and increased dry biomass accumulation. Results align with Mahmoodi *et al.* (2017) [11] and corroborate Al-Juthery *et al.* (2019) [3].

Root-to-shoot ratio

There was a significant difference among the treatments with regard to root shoot ratio. The maximum root shoot ratio (0.301) recorded in Nano DAP 150 ppm (T_5) treatment which was found at par with the treatment T_6, T_1, T_4, and T_2 (0.299, 0.291, 0.290 and 0.290 respectively). Whereas, on the other side the lowest root shoot ratio (0.247) recorded in the control (T_9).

Nutrient applications enhance growth parameters, altering resource allocation dynamics, reflected in root-to-shoot ratio. All treatments show increased ratio compared to control, emphasizing nutrient management's impact on plant growth and productivity.

Fig 1: Effect of foliar application of different sources of nutrients on Jambheri shoots in primary nursery stage

Fig 2: Effect of foliar application of different sources of nutrients on jambheri roots in primary nursery stage

Table 1: Effect of foliar application of different sources of nutrients on seedling length, seedling diameter, root length, root diameter, root volume, root dry weight, leaf area, number of leaves seedling^{-1}, fresh weight of seedling, dry weight of seedling, and root-to-shoot of jambheri seedlings in primary nursery

Treatments	Seedling length (cm)	Seedling diameter (cm)	Root length (cm)	Root diameter (cm)	Root volume (cm^3)	Root dry weight (g)	Leaf area (cm^2)	Number of leaves seedling^{-1}	Fresh weight of seedling (g)	Dry weight of seedling (g)	Root-to-shoot ratio
T_1 - Nano Urea (100 ppm)	45.11	0.57	13.12	0.63	13.99	1.49	17.27	54.33	31.82	10.08	0.291
T_2 - Nano Urea (150 ppm)	46.13	0.6	13.39	0.7	14.28	1.58	18.32	56.44	32.69	10.31	0.29
T_3 - Nano Urea (200 ppm)	47.33	0.63	13.61	0.73	14.51	1.65	19.47	57.89	33.89	10.6	0.287
T_4 - Nano DAP (100ppm)	46.5	0.67	13.51	0.77	14.41	1.77	18.09	55.67	33.99	11.31	0.29
T_5 - Nano DAP (150 ppm)	47.48	0.67	14.27	0.83	15.22	1.84	18.95	56.56	35.47	11.82	0.301
T_6 - Nano DAP (200 ppm)	48.68	0.73	14.56	0.87	15.53	1.89	19.88	60.44	36.43	12.14	0.299
T_7 - 19:19:19 (1%)	37.63	0.53	10.08	0.63	11.91	1.61	17.23	43.44	30.84	10	0.268
T_8 - Urea (1%)	39.62	0.5	11.17	0.6	11.42	1.54	16.59	50.33	30.55	9.87	0.282
T_9 - Control (Water spray)	35.63	0.43	8.81	0.47	10.47	1.22	14.24	38.56	25.53	7.84	0.247
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. m (±)	0.281	0.031	0.13	0.035	0.089	0.063	0.105	1.194	0.123	0.121	0.004
C.D (0.05%)	0.843	0.093	0.389	0.103	0.272	0.19	0.315	3.578	0.37	0.365	0.011

Conclusion

From the results obtained it can be concluded that The seedling length, seedling diameter, root length, root diameter, root volume, root dry weight, leaf area, number of leaves per seedling, fresh weight of seedling and dry weight of seedling were recorded as significantly highest in treatment T_6 - Nano DAP (200 ppm) in primary nursery.

Significantly maximum root-to-shoot ratio was found in treatment T_5 - Nano DAP (150 ppm), which was at par with treatment T_6 in the primary nursery.

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