



Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.173>

IMPACT OF PLANT GROWTH REGULATORS AND MICRONUTRIENTS ON GROWTH, YIELD AND FRUIT QUALITY OF KINNOW MANDARIN

Jyoti Yadav¹, Nidhika Thakur^{1*}, Bijendra Kumar Singh¹, Vishal Chugh², Kaushal Yadav¹,
Gaurav Patel¹ and Manoj Gaund¹

¹Department of Fruit Science, College of Horticulture, Banda University of Agriculture & Technology, Banda-210001, U.P., India.

²Department of Basic and Social Sciences, College of Horticulture, Banda University of Agriculture & Technology, Banda-210001, U.P., India.

*Corresponding author E-mail : nidhikathakur2025@gmail.com

(Date of Receiving-10-07-2026; Date of Revision-03-09-2026; Date of Acceptance-08-09-2026)

ABSTRACT

A field experiment was conducted during 2024-25 at Banda University of Agriculture and Technology, Banda to study the effect of plant growth regulators and micronutrients on growth, yield and fruit quality of kinnow mandarin. The experiment was laid out in a Randomized Block Design (RBD) comprising ten treatments with three replications. The foliar application of the plant growth regulators like NAA, 2,4-D and GA₃ @ 15ppm each and micronutrients i.e.; ZnSO₄ and FeSO₄ @ 0.4% concentrations was done in different combinations. Among the various treatments, T₉ [2,4-D (15 ppm) + ZnSO₄ (0.4%) + FeSO₄ (0.4%)] exhibited superior performance by recording the highest fruit yield (51.32 kg/plant), fruit width (7.99 cm), total soluble solids (13.89 °B), ascorbic acid content (48.40 mg/100g), juice content (49.73%), increase in plant height (61.70 cm), trunk girth (2.91 cm) and leaf area (35.86 cm²). This treatment also recorded the lowest rind thickness (3.06 mm), rind weight (50.52 g/fruit) and titratable acidity (0.56%). However, the maximum fruit length (6.53 cm), work to penetrate skin (1074.13 g.sec) and flesh firmness (476.65 g) were recorded with treatment T₁₀ [GA₃ (15 ppm) + ZnSO₄ (0.4%) + FeSO₄ (0.4%)]. Owing to this study, it can be concluded that the combined application of plant growth regulators and micronutrients significantly enhanced vegetative growth, yield potential and quality traits of Kinnow mandarin, with the foliar application of 2,4-D (15 ppm) + ZnSO₄ (0.4%) + FeSO₄ (0.4%) showing the most promising results under the agro-climatic conditions of Banda.

Key words : Plant growth regulators, Micronutrients, Kinnow, Yield and Firmness.

Introduction

In India, citrus fruits occupy a significant position among the most popular fruits and are widely cultivated across tropical and subtropical regions. It belongs to the family Rutaceae and sub-family Aurantoideae with chromosome number 2n = 18. Citrus is the third most important fruit crop in the world, following mango and banana, in terms of both cultivated area and production. Kinnow is a commercially important citrus fruit cultivated under irrigated conditions in the semi-arid and arid regions of the country. Kinnow mandarin is an interspecific citrus hybrid obtained by crossing King orange (*Citrus nobilis* Lour.) with Willow-leaf mandarin (*Citrus deliciosa* Tenore). It was developed by H. B. Frost in 1915 at the

University of California Citrus Experiment Station, USA and the hybrid was released for commercial cultivation in 1935. In India, Kinnow was introduced by Dr. J. C. Bakshi in 1954 at the Regional Research Station of Punjab Agricultural University, Abohar.

The major Kinnow growing states in India include Punjab, Madhya Pradesh, Haryana and Rajasthan. Kinnow is cultivated across 4.73 lakh hectares of area with 6.26 million metric tonnes of production in India (NHB, 2021). It has gained commercial importance due to its wide adaptability, prolific bearing, high consumer appeal, enhanced economic returns, attractive golden-orange fruits and superior juice quality with distinctive flavour. It is a sub-acidic fruit consumed fresh and used

in the production of commercial pectin, refreshing drinks and cosmetics (Bose and Mitra, 1996).

Plant growth regulators play a significant role in improving growth, fruit set, reducing fruit drop, regulating maturity, enhancing fruit quality and managing physiological and nutritional disorders in a wide range of tropical, subtropical and temperate fruit crops (Bhatia and Yadav, 2003 and Singh *et al.*, 2007). Foliar application of growth regulators such as GA₃, 2,4-D and NAA has shown significant effect in improving fruit size, regulating maturity, enhancing yield and improving quality attributes across various fruit crops (Divya and Prasad, 2006).

Similarly, micronutrients also have an essential role in plant metabolic activities. It is seen that iron is essential for improving photosynthetic efficiency and carbohydrate accumulation and developing the reproductive organs, particularly fruits, act as major sinks for translocated assimilates (Sohrab *et al.*, 2013). Zinc plays a vital role in the synthesis of tryptophan, which serves as a precursor for indole acetic acid (IAA) production and consequently improves tissue growth and development. It plays a significant role in starch metabolism and functions as a co-factor for several enzymes. It also influences photosynthetic processes, nucleic acid metabolism and protein biosynthesis (Alloway, 2008).

Keeping in view the economic importance, consumers demand and the scope of increasing the production of Kinnow in Bundelkhand region of Uttar Pradesh as well as the positive impact of application of plant growth regulators and micronutrients in improving the growth and yield of citrus fruits, the present investigation was undertaken.

Materials and Methods

The present investigation was carried out during 2024–25 at the fruit orchard, College of Horticulture, Banda University of Agriculture and Technology, Banda, Uttar Pradesh, India. The experiment was laid out in a Randomized Block Design (RBD) comprising ten treatments with three replications. The combinations of treatments were as T₁ - (Control), T₂ - [NAA (15ppm)], T₃ - [2,4-D (15ppm)], T₄ - [GA₃ (15ppm)], T₅ - [ZnSO₄ (0.4%)], T₆ - [FeSO₄ (0.4%)], T₇ - [ZnSO₄ (0.4%) + FeSO₄ (0.4%)], T₈ - [NAA (15ppm) + ZnSO₄ (0.4%) + FeSO₄ (0.4%)], T₉ - [2,4-D (15ppm) + ZnSO₄ (0.4%) + FeSO₄ (0.4%)] and T₁₀ - [GA₃ (15ppm) + ZnSO₄ (0.4%) + FeSO₄ (0.4%)]. The spray was done twice during March and April months and the parameters on growth, yield and fruit quality were recorded. Increment in plant height and trunk girth was measured by measuring tape, however leaf area was measured through digital leaf area

meter. Fruit length and fruit width were measured by digital vernier calliper. For estimation of volume, the fruits were carefully immersed in a graduated beaker filled with water. The fruit yield was estimated by multiplying the average weight of the fruit with the total number of fruits in each plant. The thickness of rind was measured with the help of digital vernier calliper and for rind weight, five fruits were selected and manually peel off its rind, after that weighed on digital electronic weighing balance, while pulp: peel ratio was estimated by dividing the weight of the fruit pulp with the weight of the fruit peel.

$$\text{Pulp : peel ratio} = \frac{\text{Weight of pulp}}{\text{Weight of peel}}$$

Hand refractometer was used to measure total soluble solids of fruits. The fruit juice was squeezed on the prism surface of the refractometer, the cover slip was placed back and the reading was observed through the eyepiece. The titratable acidity was analysed by titration method described by Rangana (2013). Vitamin A (carotenoid) of fruit pulp was analysed using spectrophotometer method described by Rangana (1997). Moisture content of fruit was determined by using electronic moisture analyser.

Moisture content (%)

$$= \frac{\text{Wt. of wet sample} - \text{Wt. of dry sample}}{\text{Weight of wet sample}} \times 100$$

The vitamin C content of the fruit juice was determined by the method described by Rangana (2013).

Vitamin C (mg/100g)

$$= \frac{\text{Dye factor} \times \text{Titre} \times \text{Volume make up}}{\text{Aliquot taken} \times \text{Weight of sample}} \times 100$$

For analysis of juice content, the fruits juice was extracted with the help of juice extractor. Fruit texture was measured with the help of Texture Analyzer.

Results and Discussion

The foliar application of plant growth regulators and micronutrients had significant effect on vegetative growth parameters of kinnow mandarin (*Citrus reticulata* Blanco.). The maximum increment in plant height (61.70 cm), trunk girth (2.91 cm) and leaf area (35.86 cm²) were observed with the treatment T₉ [2,4-D (15 ppm) + ZnSO₄ (0.4%) + FeSO₄ (0.4%)] as presented in Table 1. The enhancement in tree height and leaf size in treated plants may be attributed to the active role of Zn in tryptophan synthesis, which serves as a precursor for indole acetic acid (IAA) production, thereby promoting tissue growth

Table 1 : Effect of plant growth regulators and micronutrients on plant growth, fruit yield and quality of Kinnow mandarin.

Treatments	Increment in plant height (cm)	Increase in trunk girth (cm)	Leaf area (cm ²)	Fruit length (cm)	Fruit width (cm)	Fruit volume (cc)	Fruit yield (kg/plant)	Rind thickness (mm)	Rind wt (g/fruit)
T ₁	47.11	2.55	26.56	5.27	6.90	205.60	45.58	3.65	54.72
T ₂	49.82	2.62	29.73	5.97	7.68	231.61	46.35	3.56	54.60
T ₃	57.82	2.85	34.02	5.93	7.78	222.46	48.61	3.14	53.03
T ₄	55.83	2.76	31.71	5.87	7.67	232.54	46.24	3.45	54.53
T ₅	51.53	2.65	29.86	5.94	7.47	243.83	48.48	3.25	53.82
T ₆	53.31	2.68	32.77	5.84	7.29	223.55	49.57	3.26	52.93
T ₇	54.03	2.81	31.67	5.59	7.40	239.41	49.72	3.22	53.94
T ₈	56.84	2.82	33.43	6.47	7.91	241.01	50.46	3.08	52.79
T ₉	61.70	2.91	35.86	6.42	7.99	254.48	51.32	3.06	50.52
T ₁₀	59.16	2.73	34.35	6.53	7.83	251.44	49.95	3.29	53.89
S.E.m±	1.13	0.04	0.18	0.27	0.11	1.15	1.19	0.08	0.73
CD at 5%	3.35	0.13	0.52	NS	0.33	3.41	3.55	0.22	2.15

and development. The presence of optimum zinc levels in plants has been shown to positively influence photosynthetic processes, nucleic acid metabolism and protein biosynthetic activities (Hada *et al.*, 2014). Higher photosynthetic efficiency results in enhanced vegetative growth performance of plants. Iron serves as an essential element in the structure and functioning of several enzymes, such as flavoproteins, cytochrome oxidase, catalase, peroxidase and ferredoxin, participating in oxidation-reduction processes *i.e.*; NO_4^- , SO_4^{2-} and nitrogen fixation etc. These phenomena are responsible for rise in vegetative growth in kinnow (Pawar *et al.*, 2019) and similarly in Washington Navel orange El-Saida (2001).

The fruit quality of kinnow mandarin was also significantly influenced by foliar application of plant growth regulators and micronutrients as depicted in Tables 1 and 2. The highest fruit width (7.99 cm), fruit volume (254.48 cc), yield (51.32 kg/plant), TSS (13.89 °B), pulp: peel ratio (2.78), vitamin-C content (48.40 mg/100 g) and juice content (49.73 %), while lowest rind thickness (3.06 mm), rind weight (50.52g), titratable acidity (0.56%) and moisture content (71.43%) were observed with the treatment T₉ [2,4-D (15ppm) + ZnSO_4 (0.4%) + FeSO_4 (0.4%)]. The maximum fruit length (6.53 cm) was recorded with the treatment T₁₀ [GA_3 (15ppm) + ZnSO_4 (0.4%) + FeSO_4 (0.4%)] and maximum vitamin-A (carotenoid content) with treatment T₇ [ZnSO_4 (0.4%) + FeSO_4 (0.4%)].

The enhancement in fruit size with the foliar application of 2,4-D may be explained by its auxin-like activity, which promotes cell enlargement by modifying

cell wall permeability, increasing water uptake and stimulating cell expansion and elongation (Nirmaljeet *et al.*, 2000). The application of 2,4-D resulted in increased fruit weight, possibly due to enhanced auxin accumulation in the fruits, which facilitates developmental processes and contributes to improved fruit growth. It enhances cell expansion and elongation, leading to larger fruit cells and increased fruit volume. Adequate nutrient availability and hormonal regulation enhance water absorption, leading to increased cell turgidity, which supports fruit growth and development and ultimately results in greater fruit volume (Krishnamoorthy, 1981). Carotenoids are antioxidants bioactive pigment that protect chlorophyll from photodegradation and oxidation.

IAA plays a significant role in promoting Ca^{2+} transport within fruit tissues, contributing to higher sugar accumulation, increased total soluble solids and reduced acidity in fruits (Xie *et al.*, 1992). The increase in total soluble solids (TSS) content of fruits may be attributed to the role of iron in enhancing photosynthetic activity, which promotes carbohydrate accumulation and subsequently increases the TSS content of phalsa fruits (Jitendra *et al.*, 2017).

The reduction in acidity may be attributed to the rapid conversion of acids into sugars and their derivatives. The maximum availability of plant metabolites because of higher nucleic acid synthesis due to the involvement of zinc and ferrous resulted into increase in sugars, vitamin C and juice percentage in Kinnow mandarin. These findings are also in conformity with Kaur *et al.* (2015) and Heerendra *et al.* (2013) in kinnow. The spray of GA_3 (15 ppm) + ZnSO_4 (0.4%) + FeSO_4 (0.4%) recorded

Table 2 : Effect of plant growth regulators and micronutrients on fruit quality of Kinnow mandarin.

Treatments	Pulp: peel ratio	TSS (°B)	Titratable acidity (%)	Vitamin A content (IU)	Moisture content (%)	Vitamin C (mg/100g)	Juice content (%)	Work to penetrate skin (g.sec)	Flesh firmness (g)
T ₁	2.01	11.39	0.87	9.40	83.65	41.36	41.38	577.31	244.77
T ₂	2.10	12.29	0.83	8.04	77.63	43.41	45.64	635.96	260.60
T ₃	2.38	12.13	0.77	10.78	79.57	46.60	47.37	776.31	295.38
T ₄	2.05	12.38	0.85	9.35	75.73	46.44	48.66	818.96	356.66
T ₅	2.30	12.07	0.76	11.29	81.29	44.40	42.38	780.49	338.51
T ₆	2.52	12.34	0.82	10.60	76.30	45.63	44.25	827.77	396.97
T ₇	2.19	11.54	0.79	12.60	80.52	44.84	43.14	784.44	347.21
T ₈	2.58	13.43	0.63	10.50	79.70	47.41	45.76	927.22	412.37
T ₉	2.78	13.89	0.56	8.84	71.43	48.40	49.73	1035.10	428.02
T ₁₀	2.42	12.86	0.62	9.54	74.75	47.64	48.95	1074.13	476.65
S.E.m±	0.05	0.25	0.01	0.09	0.58	0.36	0.42	0.45	0.42
CD at 5%	0.15	0.74	0.02	0.28	1.72	1.06	1.25	1.35	1.25

the maximum texture profile *i.e.*; work to penetrate skin (1074.13 g.sec) and flesh firmness (476.65 g). Fruit firmness is among the most essential characteristics for a fresh market cultivar and is related to stage of harvest maturity and the variety. Weksler *et al.* (2009) explained that pretreatment of gibberellic acid increased the cellulose accumulation in cell wall and therefore increased texture firmness in the treated fruits. The firmness retaining effect of GA₃ could be explained by its role in inhibiting certain ripening related physiological activities (Kirmani *et al.*, 2013). The results are in conformity with those of Khandaker *et al.* (2015) in apple and Singh *et al.* (2020) in guava. Zinc is responsible for high pectin content which helps to retain fruit texture firmness.

Conclusion

The present investigation revealed that the foliar application of plant growth regulators and micronutrients significantly affected the growth, yield and fruit quality of Kinnow. Among the various treatments, T₉ [2,4-D (15 ppm) + ZnSO₄ (0.4%) + FeSO₄ (0.4%)] exhibited superior performance by enhancing vegetative growth such as increment in plant height, trunk girth and leaf area, along with improving fruit yield, fruit width, fruit volume, total soluble solids, juice content and ascorbic acid content, while reducing titratable acidity, rind thickness, rind weight and moisture content. Therefore, it was concluded that foliar application of plant growth regulators and micronutrients plays a significant role in improving the yield as well as fruit quality in Kinnow mandarin.

References

- Alloway, B.J. (2008). *Zinc in soils and crop nutrition*. International Zinc Association Brussels. 139 p.
- Bhati, B.S. and Yadav P.K. (2003). Effect of foliar application of urea and NAA on the yield parameters of ber (*Zizyphus mauritiana* Lamk.) cv. Gola. *Haryana J Hort. Sci.*, **3**(1-2), 148-149.
- Bose, T.K. and Mitra S.K. (1996). *Fruits in India*. Naya Prakash Publication., Kolkata, W.B. 705 p.
- Davarpanah, S., Akbari M., Askari M.A., Babalar M. and Naddaf M.E. (2013). Effect of iron foliar application (Fe-EDDHA) on quantitative and qualitative characteristics of pomegranate cv. "Malas-e-Saveh". *World of Sci. J.*, **4**, 179-187.
- Divya and Prasad (2006). Effect of plant growth substances on fruit bud dormancy fruit development and yield of aonla (*Embllica officinalis* Gaertn.) cv. Francis M.Sc. thesis submitted at NDUAT, Kumarganj-Faizabad (U.P.), India.
- El-Saida, S.A.G. (2001). Effect of some growth regulators and zinc sulphate treatments on yield and quality of Washington Navel orange. *Ann. Agric. Sci.*, **39**, 1199-1212.
- Heerendra, P., Dasharath P., Chander B., Bairwa S.K., Sudesh B. and Suresh P. (2013). Effect of foliar application of urea, zinc sulphate and 2,4-D on kinnow mandarin. *J. Progressive Agricult.*, **4**, 148-153.
- Hada, T.S., Singh B.K., Veer K. and Singh S.P. (2014). Effect of different levels of boron and zinc on flowering, fruiting and growth parameter of winter season guava (*Psidium guajava* L.) cv. L-49. *The Asian J. Hortic.*, **9**(1), 53-56.
- Jitendra, Saravanam S., Kasera Saurabh, Lall Deepak and Singh V.K. (2017). Effect of foliar spray of micro nutrients on plant growth, yield and fruit quality of phalsa (*Grewia asiatica* L.). *Environ. Ecol.*, **35**(4A), 2841-2845.
- Kaur, N., Monga P.K., Arora P.K. and Kumar K. (2015). Effect of micronutrients on leaf composition, fruit quality and yield of Kinnow mandarin. *J. Appl. Nat. Sci.*, **7**(2), 639-643.
- Kirmani, S.N., Wani G.M., Wani M.S., Ghani M.Y., Abid M.,

- Muzamil S., Hadin R. and Malik A.R. (2013). Effect of pre harvest application of calcium chloride, gibberellic acid and naphthalene acetic acid on storage of plum (*Prunus salicina* L.) cv. Santa Rosa under ambient storage conditions. *Afr. J. Agricult. Res.*, **8(9)**, 812-818.
- Krishnamoorthy, H.N. (1981). *Plant growth substances in agriculture*. Tata McGraw Hill Publishing Co. Ltd., New Delhi, 3-87.
- National Horticulture Board (2021). [Http://Nhb.Gov.In/](http://nhb.gov.in/statistics/Publication/Horticulture%20Statistics%20at%20a%20Glance-2018.pdf). Retrieved March 25, 2022, from <http://nhb.gov.in/statistics/Publication/Horticulture%20Statistics%20at%20a%20Glance-2018.pdf>.
- Nirmaljeet, K., Monga P.K., Thind S.K. and Thatai V.K. (2000). Effect of growth regulators on periodical fruit drop in Kinnow mandarin. *Haryana J. Horticult. Sci.*, **29**, 39-41.
- Panwar, P.A., Kohale V.S., Gawli K.A., Khadse A., Ashish Sarda, Nagmote and Amol (2019). Effect of foliar application of manganese and ferrous on vegetative growth, fruit yield and quality of mandarin (*Citrus reticulata* Blanco) cv. Kinnow. *J. Pharmacog. Phytochem.*, **8(6)**, 434-437.
- Rangana, S. (2013). *Manual for analysis of fruit and vegetable products*. Tata McGraw Co. Pvt. Ltd. New Delhi.
- Rangana, S. (1997). *Handbook of analysis and quality control of fruit and vegetable products*. 2nd edition. Tata McGraw Hill Publ. Co. Ltd., New Delhi, India.
- Singh, J. and Bal J.S. (2020). Impact of pre-harvest treatments on guava fruits under ambient storage conditions. *Science Archives*, **1(3)**, 150-154.
- Singh, J.K., Prasad J. and Singh H.K. (2007). Effect of micro-nutrient and plant growth regulators on fruit yield and physicochemical characteristics of aonla fruits cv. Narendra aonla 10. *Indian J Hort.*, **64(2)**, 216-218.
- Weksler, A., Dagar A., Friedman H. and Lurie S. (2009). The effect of gibberellin on firmness and storage potential of peaches and nutrients. In: *VII International Peach Symposium*, **962**, 591-595.
- Xie, Y.H., Cao Z.C and Fa Q. (1992). Effects of pre-harvest applications of calcium and IAA on the fruit quality, of Jincheng (*Citrus sinensis*). *J. Southwest Agric. Univ.*, **14(6)**, 543-545.