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Effect of plant growth regulators and micronutrients on growth, yield and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco.)

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ABSTRACT

The investigation was carried out during 2023-24 and 24-25 at the Fruit orchard, Department of Fruit Science, Banda University of Agriculture and Technology, Banda to find out the effect of spray of plant growth regulators and micronutrients on growth, yield and fruit quality of Kinnow mandarin (*Citrus reticulata* Blanco.). The experimental design was set up in RBD having ten treatments and three replications. Among all the treatments, treatment T_9 - [2,4-D (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] recorded maximum increment in plant height (61.70 cm), increase in trunk girth (2.91 cm), increase in shoot diameter (1.36 cm), LAI (9.78), fruit set (69.54 %), fruit retention (75.28%), fruit yield (51.32 kg/plant), average fruit weight (191.45 g), fruit width (7.99 cm), TSS (13.89 °B), reducing sugars (5.59 %), non-reducing sugars (5.10 %), total sugars (10.95 %), ascorbic acid content (48.40 mg/100g), juice content (49.73%), and minimum fruit drop (24.51%), rind thickness (3.06 mm), rind weight (50.52 g/fruit) and titratable acidity (0.56%). However, the earliest time of bud break (2-10 February), time of fruit set (3-14 March) and maximum fruit length (6.53 cm) were observed with the treatment T_{10} - [GA_3 (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)]. Based on the findings, the combined application of 2,4-D (15 ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) can be recommended for improving overall productivity and fruit quality of kinnow mandarin under similar agro-climatic conditions.

Key words: Trunk girth, rind thickness, bud break, fruit drop, ascorbic acid.

INTRODUCTION

Citrus is one amongst the world's leading fruit crop. It is one of the most diversified and economically important fruit cultivated in tropical and subtropical regions. Being a member of the Rutaceae family, with most of the species indigenous to tropical and subtropical regions of South-East Asia (Bhatt *et al.*, 5). Kinnow is a citrus hybrid developed from the cross between cultivar 'King' (*Citrus nobilis*) and 'Willow Leaf' (*Citrus deliciosa*).

India ranks as the third leading country in citrus production, after China and Brazil. (Singh *et al.*, 19). Citrus is the third most widely grown and produced fruit in India after mango and banana. The major kinnow growing states are Punjab, Rajasthan, Haryana, Himanchal Pradesh, Jammu and Kashmir and Uttar Pradesh. The fruit contains high level of ascorbic acid, along with vitamin A and B, sugar, amino acids and other essential nutrients. It also contains 45-60% juice with TSS of 9.5-16 °Brix, minerals like sodium (0.01-0.03mg/g), potassium (1.6-2.5mg/g), calcium (0.14-0.47mg/g), copper (6-8mg/100g) and some volatile compounds. Kinnow tends to bear heavily in early years of production. The demand for the fruit is steadily rising in both national and international markets. To meet this growing demand, it is essential to boost the productivity while preserving fruit quality. One of the most effective strategies for achieving this is the foliar spray of plant growth regulators, which promote flowering, fruit set and overall fruit quality (Ashraf *et al.*, 4). PGRs and nutrient levels in citrus trees change with vegetative and reproductive growth, altering fruit set and quality. Hence, the application of plant growth regulators and nutrients have been demonstrated to boosting the yield and improving fruit quality.

MATERIALS AND METHODS

A field experiment was conducted at fruit orchard, College of Horticulture, Banda University of Agriculture and Technology, Banda during 2024 and 25. The experimental design was set up in RBD having ten treatments and three replications. The treatments were T_1 - (Control), T_2 - [NAA (15ppm)], T_3 - [2,4-D (15ppm)], T_4 - [GA_3 (15ppm)], T_5 - [$ZnSO_4$ (0.4%)], T_6 - [$FeSO_4$ (0.4%)], T_7 - [$ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)], T_8 - [NAA (15ppm) + $ZnSO_4$ (0.4 %) + $FeSO_4$ (0.4%)], T_9 - [2,4-D (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] and T_{10} - [GA_3 (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)]. These were applied twice a year i.e. during

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March and April and the parameters on growth, yield and fruit quality were recorded.

Increment in plant height was measured with the help of measuring tape, increase in trunk girth and shoot diameter with the help of vernier caliper however LAI was measured through leaf area meter. Ten shoots were selected in all direction of each selected plant and time of bud break and time of fruit set were noted. Four random branches growing in different directions were labeled and number of flowers per branch were counted. Later, number of fruits on each labeled branch were counted and the fruit set and fruit drop were measured by the formula given by Westwood (21).

For estimation of fruit retention percentage, the fruits retained in all the cultivars were recorded one week before harvesting of fruits, averaged and expressed in percentage as under given by Westwood (22).

Fruit yield was estimated by multiplying the average weight of the fruit with the total number of fruits on each plant, average fruit weight and rind weight was measured by electronic weighing balance. However, fruit length and width were measured by vernier caliper. TSS of the fruits was measured with the help of hand refractometer. The titratable acidity and ascorbic acid was found out by the method as described by Rangana, (16). The reducing and total sugars were estimated by Lane and Eynon (13) method. The peel colour and juice colour were taken with the help of CIE color lab scale (Hunter LAB, CFEZ 3698). The results were expressed as 'L*' value, which shows lightness or darkness, having range between 0 to 100, where 100 for perfect white and 0 for black. The 'a*' value indicates redness when it is positive, greenness when negative and grey when it is zero. The 'b*' value, indicates yellowness of the sample fruit when positive, blueness when negative, and grey when zero.

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), shoot diameter (1.36 cm) and leaf area index (9.78) were observed with the treatment T_9 [2,4-D (15 ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] (Table 1). Increase in growth of tree was due to active involvement of zinc which plays a vital role in formation of tryptophan which is precursor of indole acetic acid which caused increased growth (Swietlik, 20). Similarly, Dawood *et al.* (6) noticed that adequate level of zinc in plants promote nucleic acid metabolism, photosynthesis and protein biosynthesis. They observed it on growth of orange cv. Washington Navel with foliar spray of zinc and similar finding were recorded by Rawat *et al.* (17). Ferrous is a crucial component of several flavoproteins, cytochrome oxidase enzymes, catalase, peroxidase and found in the ferredoxin which precipitates in oxidation-reduction reaction and nitrogen fixation etc. These phenomena are responsible for rise in vegetative growth in kinnow and Washington Navel orange (El-Saida, 7).

Table 1: Effect of PGRs and micronutrients on growth and fruit set in kinnow mandarin.

Treatment	Increment in plant height (cm)	Increase in trunk girth (cm)	Increase in shoot diameter (cm)	LAI	Time of bud break	Time of fruit set	Fruit set (%)
T_1	47.11	2.55	1.01	6.76	17-27 Feb	12 Mar-04 Apr	56.42
T_2	49.82	2.62	1.04	7.35	4-17 Feb	7-25 Mar	61.07
T_3	57.82	2.85	1.19	9.12	5-18 Feb	6-23 Mar	65.43
T_4	55.83	2.76	1.18	7.46	3-15 Feb	4-19 Mar	63.58
T_5	51.53	2.65	1.06	6.98	7-21 Feb	8-24 Mar	57.13
T_6	53.31	2.68	1.12	8.56	9-23 Feb	10-26 Mar	59.60
T_7	54.03	2.81	1.22	8.23	8-21 Feb	9-24 Mar	60.78
T_8	56.84	2.82	1.26	8.91	5-16 Feb	6-20 Mar	67.68
T_9	61.70	2.91	1.36	9.78	3- 13 Feb	5-18 Mar	69.54
T_{10}	59.16	2.73	1.16	9.34	2- 10 Feb	3-14 Mar	64.03
S.E.m±	1.13	0.04	1.02.	0.30	-	-	0.85
CD at 5%	3.35	0.13	0.05	0.89	-	-	2.52

The earliest bud break (2-10 February) and fruit set were recorded with the treatment T_{10} [GA_3 (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4 %)] as depicted in Table 1. GA_3 induces the early bud development, nucleic acid synthesis and protein metabolism in many perennial crops due to its antagonistic relationship with abscisic acid (Horvath *et al*., 9).

It is evident from Table 1 and 2, that the maximum percentage of fruit set (69.54 %), fruit retention (75.28%) and minimum fruit drop (24.51%) were recorded with the treatment T_9 [2,4-D (15 ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)]. The effect of 2,4-D on cell elongation and division enhances the structural integrity of the fruit, making it less vulnerable to premature detachment from the tree. Ram and Bose (15) observed that 2,4-D increased the level of auxin which might have prevented the formation of abscission layer resulting enhanced the retention of fruit. The greater number of flowers, fruit set and fruit retention were observed with the foliar application of $ZnSO_4$ due to the synthesis of more growth promoters and less abscisic acid, which led to the enhancement in absorption and translocation of more growth promoters (Kaur *et al*., 11).

There was a significant influence of plant growth regulators and micronutrients on the fruit yield and quality of kinnow. The maximum fruit yield (51.32 kg/plant), average fruit weight (191.45g), fruit width (7.99 cm), TSS (13.89 ^{o}B), reducing sugars (5.59 %), non-reducing sugars (5.10 %), total sugars (10.95 %), ascorbic acid content (48.40 mg/100 g) and minimum rind weight (50.52g) and titratable acidity (0.56%) were observed with the treatment T_9 [2,4-D (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] while maximum fruit length (6.53cm) was recorded with the treatment T_{10} [GA_3 (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4 %)] (Table 3).

The enhancement in TSS of the fruits was due to the iron that played important part in photosynthesis and ultimately lead to the carbohydrates accumulation which increased TSS of phalsa (Ahamad *et al*., 1; Jitendra *et al.,* 10). Total soluble solids consist mainly of sugar (70-85%) along with a small proportion of other components, which supports the work of Salunkhe *et al.* (18) that the chemical increasing TSS also raises sugar contents in citrus fruits.

The reduction in acidity might 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. The above findings are also in conformity with Kaur *et al*. (12); Heerendra *et al*. (8) in kinnow and Ahamad *et al.* (2).

The peel colour of the fruits was as depicted in Fig 1. The L* value ranged from 0-100 and the highest value (64.01) with T_3 [2, 4 - D (15ppm)] while lowest (48.35) with the treatment [GA_3 (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)]. The treatment T_7 [$ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] showed the appealing combination of (a*=11.10; b*= 50.05) peel colour followed by treatment T_6 [$FeSO_4$ (0.4%)] (a*=12.12; b*=48.68).

The variation in peel colour among treatments may be due to the influence of plant growth regulators and micronutrients on pigment biosynthesis and fruit maturation processes. Higher L* values under 2,4-D

Table 2: Effect of PGRs and micronutrients on fruit yield and quality of kinnow mandarin.

Treatment	Fruit drop (%)	Fruit retention (%)	Fruit yield (kg/plant)	Average fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Rind weight (g/fruit)
T_1	29.52	70.15	45.58	164.77	5.27	6.90	54.72
T_2	27.11	72.88	46.35	169.44	5.97	7.68	54.60
T_3	25.84	74.14	48.61	179.59	5.93	7.78	53.03
T_4	28.39	71.61	46.24	166.81	5.87	7.67	54.53
T_5	28.27	71.72	48.48	177.60	5.94	7.47	53.82
T_6	28.83	71.16	49.57	186.83	5.84	7.29	52.93
T_7	27.89	72.12	49.72	172.37	5.59	7.40	53.94
T_8	26.06	73.93	50.46	189.14	6.47	7.91	52.79
T_9	24.51	75.28	51.32	191.45	6.42	7.99	50.52
T_{10}	27.56	72.43	49.95	184.58	6.53	7.83	53.89
S.E.m±	0.82	0.54	1.19	1.05	0.27	0.11	0.73
CD at 5%	2.43	1.61	3.55	3.11	NS	0.33	2.15

Table 3: Effect of PGRs and micronutrients on fruit quality of kinnow mandarin.

Treatments	TSS (°B)	Titratable acidity (%)	Reducing sugars (%)	Non-reducing sugars (%)	Total sugars (%)	Ascorbic acid content (mg/100g)
T_1	11.39	0.87	3.81	4.21	8.25	41.36
T_2	12.29	0.83	4.53	4.15	8.90	43.41
T3	12.13	0.77	4.57	3.89	8.66	46.60
T_4	12.38	0.85	5.50	4.46	10.20	46.44
T_5	12.07	0.76	4.63	4.96	9.85	44.40
T_6	12.34	0.82	4.33	4.69	9.27	45.63
T_7	11.54	0.79	4.47	4.94	9.66	44.84
T_8	13.43	0.63	5.53	4.78	10.57	47.41
T_9	13.89	0.56	5.59	5.10	10.95	48.40
T_{10}	12.86	0.62	5.55	4.87	10.68	47.64
S.E.m±	0.25	0.01	0.08	0.26	0.21	0.36
CD at 5%	0.74	0.02	0.25	0.77	0.63	1.06

*PGRs = Plant growth regulators, Mar = March, Apr = April, TSS = Total Soluble Solids, LAI = Leaf area index

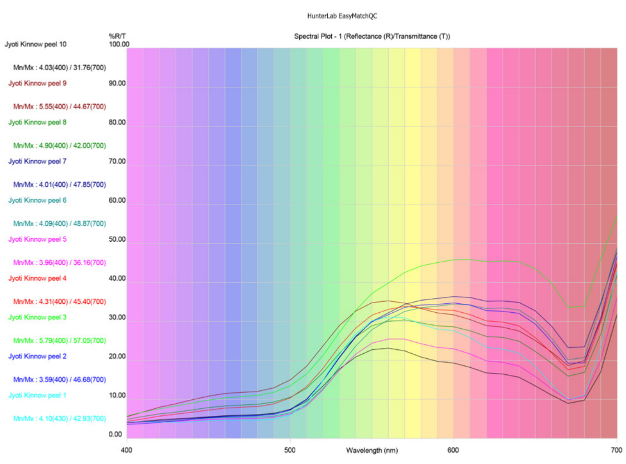

Fig. 1. Effect of PGRs and micronutrients on peel colour of kinnow mandarin.

indicate enhanced brightness, while the combined application of Zn and Fe (T_7 and T_6) improved a* and b* values, reflecting better development of attractive peel colour. These responses are likely associated with increased enzymatic activity and synthesis of carotenoids and related pigments.

The juice colour of the fruits was recorded as shown in the Fig. 2. The L* value ranged from 0-100 and the highest value (48.85) was recorded with the treatment T_{10} [GA_3 (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] while lowest (40.75) with the treatment T_2 [NAA (ppm)]. The treatment T_7 [$ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] recorded the appealing combination of (a*= 11.94; b*= 40.35) for juice colour which was statistically at par with the treatment T_5 [$ZnSO_4$ (0.4%)] recording of (a*= 11.74; b*= 40.96). The variation in juice colour parameters among treatments may be attributed to the role of plant growth regulators and micronutrients in enhancing pigment synthesis and metabolic activity. Higher L* values under GA_3 treatment indicate improved brightness, while Zn and Fe combinations (T_7 and T_5) enhanced a* and b* values, suggesting better development of desirable colour attributes. These effects could be linked to improved enzymatic activity and synthesis of carotenoids and other pigments (Ahamad *et al.,* 3).

It was observed in the present investigation that the various combinations of growth regulators and micronutrients significantly influenced the growth, yield and fruit quality of kinnow mandarin.

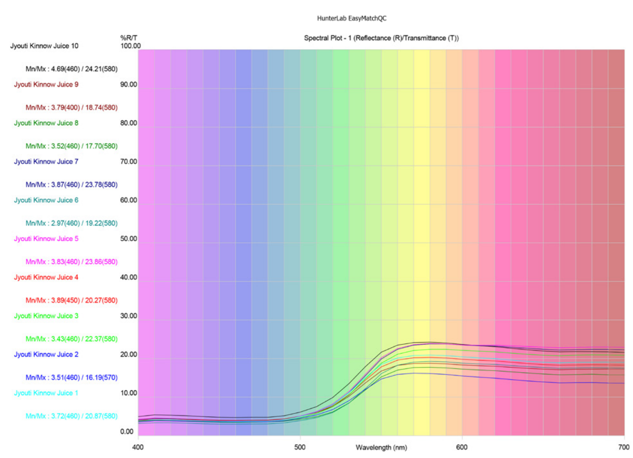

Fig. 2. Effect of PGRs and micronutrients on juice colour of kinnow mandarin.

The treatment T_9 [2,4-D (15ppm) + $ZnSO_4$ (0.4%) +$FeSO_4$ (0.4%)] showed the best performance with respect to increment in plant height, increase in trunk girth, increase in shoot diameter, LAI, fruit set, fruit retention, fruit yield, average fruit weight, fruit width, fruit volume, rind thickness, rind weight, total soluble solids, titratable acidity, reducing sugars, non-reducing sugars, total sugars, juice content, ascorbic acid content, and reduction in fruit drop, while treatment T_{10} [GA_3 (15ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] was found superior over other treatments for reducing the time of bud break, time of fruit set and maximum fruit length in Kinnow mandarin. However, the treatment T_7 [$ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] recorded the appealing peel and juice colour.

The present investigation clearly demonstrated that foliar application of plant growth regulators in combination with micronutrients significantly improved the growth, yield, and fruit quality of Kinnow mandarin. Among the treatments, 2,4-D (15 ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) proved most effective in enhancing vegetative growth, fruit set, yield, and biochemical quality attributes, along with reducing fruit drop. The GA_3-based treatment showed superiority in advancing phenological stages and increasing fruit length. Application of Zn and Fe also contributed to improved fruit quality parameters, particularly colour attributes. Therefore, it was concluded that the treatment T_9 [2,4-D (15 ppm) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)] was found to be the best for Kinnow mandarin under the agro-climatic conditions of the Bundelkhand region, as it significantly increased fruit yield and quality.

AUTHOR'S CONTRIBUTION

Conceptualization of research (N.T.); Designing of the experiment (N.T. and B.K.S.); Contribution of experimental materials (N.T., V.M. and V.C); Preparation of the manuscript (N.T., B.K.S., V.M. and V.C.).

DECLARATION

The authors have no conflict of interest.

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