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Effect of plant growth regulators on growth and yield of nagpur mandarin (*Citrus reticulata* Blanco.)

■ **H.D. CHOUDHARY[1], M.C. JAIN, M.K. SHARMA[2]** AND **P. BHATNAGAR[1]**

Members of the Research Forum

Associated Authors:
[1]Department of Fruit Science, College of Horticulture and Forestry, JHALAWAR (RAJASTHAN) INDIA

[2]Department of Soil Science, College of Horticulture and Forestry, JHALAWAR (RAJASTHAN) INDIA

Author for correspondence :
M.C. JAIN
Department of Fruit Science, College of Horticulture and Forestry, JHALAWAR (RAJASTHAN) INDIA

ABSTRACT : An investigation was carried out at Fruit Research Farm, Department of Fruit Science at College of Horticulture and Forestry, Jhalawar during July, 2012 to April, 2013 to study the individual effect of plant growth regulators on growth and yield of Nagpur mandarin (*Citrus reticulata* Blanco.). The results revealed that application of GA_3 @ 100 ppm showed superior results with respect per cent increase in plant spread (20.59%) and crown volume (38.42%) over control on 150 days after treatment. The physical characters of fruit like maximum increase in diameter (horizontal and vertical), weight, volume and number of sacs per fruit, minimum days taken to first harvesting and complete harvesting was recorded with the spray of 100 ppm GA_3, which was closely followed by 30 ppm 2,4-D. The minimum peel thickness, number of seeds per fruit and average seeds weight per fruit was recorded with 30 ppm 2,4-D treatment. The maximum number of fruit per tree, fruit retention per cent and yield per plant and per hectare was recorded with the spray of 30 ppm 2,4-D which was significantly higher to control.

KEY WORDS : NAA, GA_3, 2,4-D, Triacontanol, Plant growth, Physical characteristics of fruits, Yield

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In India citrus fruits have a prominent place among popular and extensively grown tropical and subtropical fruits after mango and banana. Mandarin (*Citrus reticulata* Blanco) is considered to be one of the most important cultivated species among citrus and is being commercially grown in certain specific region of the country like Nagpur mandarin in Central India, Nagpur Santra is finest variety and very popular in India as well as in world for its good quality fruits. Fruit size big, subglobose, average weight 110-125 g, rind medium thick, fairly loosely adherent, surface is also relatively smooth but, segment found in 10-15 number and number of seeds 1-2 per segment, colour of peel pale orange yellow.

Fruit have mild flavor, excellent quality, juicy, TSS 10-120 brix, and acidity 0.50-0.70%. The total production of oranges in India is 3255.0 thousand MT from an area of 324.0 thousand hectares with the productivity of 10 MT/ha. In Rajasthan, mandarin covers 15.2 thousand hectares area and the productivity of 17.9 MT/ha (NHB, Database, 2011). In the state, In Jhalawar district mandarin where it is grown over 22,500 ha area, 13,000 ha of which are in the fruit bearing stage and the production is 2 lac tonnes (Anonymous, 2012).

The application of minute quantity of plant growth regulators can provide significant economic advantages to citrus growers by stimulating a number of desired responses such as increase in fruit size and delay in fruit maturity (Coggins Jr and Hield, 1968). Application of gibberellic acid (GA_3) before or at full bloom increased fruit size and pedicel length. Foliar application of different levels of GA_3 (5, 50, 100 and 500 mg L^{-1}) to young fruitlets just after fruit set have been reported for gain in fruit weight, reduction in peel thickness and better recovery percentage with improved taste of grapefruit (Berhow, 2000).

RESEARCH METHODS

The present investigation was carried out on six years old mandarin (*Citrus reticulata* Blanco.) cv. 'Nagpur' of uniform size and growth at the Fruit research farm,

Department of Fruit Science, College of Horticulture and Forestry, Jhalawar during July,2012 to April, 2013. The experiment consisted of 17 treatments having four levels of each NAA (50, 100, 150 and 200 ppm), GA_3 (25, 50, 75 and 100 ppm), 2,4-D (10, 20, 30 and 40 ppm) and triacontanol (5, 10, 15 and 20 ppm) along with water spray as control. The experiment was laid out in Randomized Block Design with three replications. The growth regulators, after weighing were dissolved in small quantity of 95 per cent absolute alcohol and 2,4-D was directly diluted in distilled water . Stock solution was first prepared for each growth regulator by diluting with distilled water. The solution of required concentration was then prepared by further dilutions of the measured volume of stock solution with distilled water.

Spray of growth regulators were done at first week of July 2012 under all treatments. Spraying was done as per treatment for each plant taking equal volume of the solution. Spraying was done in the evening with a compressed air hand sprayer. The control plant was sprayed with distilled water. The data generated during the experimentation were subjected to statistical analysis of variance. The significance of the treatments was tested through 'F' test at 5 per cent level of significance.

RESEARCH FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarised under following heads:

Plant growth characteristics:

It is evident from the results obtained, that the application of different plant growth regulator treatments at different concentrations had significantly influenced various vegetative growth characters as compared to control. In the present investigation, it was observed that amongst the various plant growth regulator treatments attempted, application of GA_3 and NAA resulted in higher rate on per cent increase in plant spread and crown volume as compared to other treatments. On 150 days after treatment application, the maximum per cent increase in plant spread and crown volume of 20.59 per cent and 38.42 per cent, respectively, were recorded due to 100 ppm GA_3 in (T_8) treatment which was closely followed by 75 ppm GA_3 in (T_7) treatment (Table 1). Similarly effect of GA_3 treatment on per cent increase in plant spread and crown volume was recorded significantly by Eelkim *et al.* (2003) in Satsuma mandarin, who observed that 25, 50 and 100ppm GA_3 concentrations increased the number of vegetative shoots in response to progressive increase in the doses of treatments. The application of GA_3 at 50, 100 and 150 ppm and showed that spray of 150 ppm GA_3 was effective for promoting earliness in sprouting of new shoot, increased shoot length and maximum number of

Table 1 : Effect of plant growth regulators on per cent increase in plant growth and yield of 'Nagpur' mandarin

Treatments	Plant spread (%)	Crown volume (%)	Weight of fruit (g)	No. of fruits/tree	Fruit retention (%)	Yield (kg/plant)	Estimated yield (tonnes/ha)
T_0	13.56 (5.50)	24.75 (17.56)	135.56	100.67	56.42 (69.43)	12.94	3.60
T_1	16.61 (8.20)	29.82 (24.86)	144.11	115.67	67.42 (85.27)	16.67	4.64
T_2	16.00 (7.62)	29.21 (23.94)	150.22	112.33	66.32 (83.89)	16.87	4.69
T_3	15.82 (7.50)	28.75 (23.22)	143.11	109.33	66.24 (83.78)	15.65	4.35
T_4	15.40 (7.10)	27.87 (21.88)	164.89	110.33	65.07 (82.17)	18.19	5.06
T_5	19.04 (10.66)	34.67 (32.40)	141.11	107.67	69.04 (87.08)	14.12	3.93
T_6	19.16 (10.80)	35.12 (33.12)	145.56	110.33	66.50 (84.11)	16.06	4.46
T_7	19.98 (11.72)	36.86 (36.03)	167.78	106.67	67.49 (85.36)	17.89	4.98
T_8	20.59 (12.39)	38.42 (38.65)	191.22	113.33	65.29 (82.53)	21.67	6.03
T_9	12.26 (4.51)	21.52 (13.48)	172.11	117.67	69.21 (87.34)	21.68	6.03
T_{10}	11.76 (4.17)	20.74 (12.55)	149.44	123.67	67.25 (85.06)	18.48	5.14
T_{11}	11.47 (3.98)	19.55 (11.31)	184.22	126.00	70.68 (89.05)	21.80	6.08
T_{12}	10.64 (3.43)	17.77 (9.37)	144.22	119.67	64.60 (81.61)	17.26	4.80
T_{13}	15.10 (6.80)	26.71 (20.22)	156.44	101.67	62.96 (79.32)	15.91	4.42
T_{14}	16.40 (7.98)	27.68 (21.60)	164.22	107.67	64.17 (81.03)	17.68	4.92
T_{15}	17.25 (8.81)	29.39 (24.12)	164.22	105.33	59.93 (74.88)	17.30	4.81
T_{16}	17.39 (8.96)	31.30 (27.07)	152.11	114.67	61.20 (76.79)	17.44	4.85
S.E.±	0.59	1.06	7.95	3.12	1.03	0.50	0.14
C.D. (P=0.01)	1.71	3.06	22.89	8.98	2.99	1.44	0.40

(T_0- Control, T_1- NAA 50ppm, T_2- NAA 100ppm, T_3- NAA 150ppm, T_4- NAA 200ppm, T_5- GA_3 25ppm, T_6- GA_3 50ppm, T_7- GA_3 75ppm, T_8- GA_3 100ppm, T_9- 2,4-D 10ppm, T_{10}- 2,4-D 20ppm, T_{11}- 2,4-D 30ppm, T_{12}- 2,4-D 40ppm, T_{13}- Triacontanol 5ppm, T_{14}- Triacontanol 10ppm, T_{15}- Triacontanol 15ppm, T_{16}- Triacontanol 20ppm

leaves per shoot in sapota (Bhujbal *et al*., 2012).

The maximum per cent increase in plant spread and crown volume with the spray of GA_3 might be due to beneficial effect of 100 ppm GA_3 in cell elongation and enlargement. The increased uptake of water and nutrients due to persuasive swelling forces leading the softening of cell wall and thereby favoured better development of plants resulting in greater height and number of branches per plant and ultimately the greater plant spread and canopy volume. These results are in close conformity with those reported by Saleem *et al*. (2007) in 'Blood Red' sweet orange, Kumar *et al.* (2012) in strawberry and Kacha *et al.* (2012) in phalsa.

Physical characteristics of fruits:

It is evident from the present results that application of various plant growth regulators at different concentrations significantly improved physical characteristics of fruits like horizontal diameter, vertical diameter, peel thickness, weight, volume of fruit, number of seeds per fruit, average seeds weight per fruit, number of sacs per fruit, number of fruits per tree, fruit retention, days taken to first harvesting and total days taken to complete harvesting as compared to control are presented.

The data recorded on horizontal and vertical diameter of fruit clearly indicate that application of GA_3 at 100 ppm exhibited maximum horizontal and vertical diameter of fruit (8.03 cm) and (8.23 cm) which was found to be at par with 30 ppm 2,4-D (7.64 cm) and (7.83 cm) treatment. The minimum horizontal diameter of fruit (6.12 cm.) and vertical diameter of fruit (5.64 cm.) was recorded at control (Table 2). The results obtained in present investigation are supported by the findings of Chao *et al.* (2011) in mandarin. Likewise Garner *et al.* (2011) working with 'Hass' avocado reported that foliar application of GA_3 at 25ppm increased yield and fruit size.

The influence of plant growth regulators on peel thickness of fruit in Table 2. Among the various plant growth regulator treatments, the minimum peel thickness of 3.41 mm was recorded at 30 ppm 2,4-D treatment. Whereas, the maximum peel thickness (5.33 mm) was observed under control. The present results are in close conformity with the finding of Davies *et al.* (1999) in 'Hamlin' sweet orange and Ingle *et al.* (2001) in nagpur mandarin.

Application of plant growth regulators had significantly increased the weight and volume of fruits over control. However, in the present study, the maximum fruit weight (191.22 g) was recorded by 100 ppm GA_3 treatment closely followed by 30 ppm 2,4-D (184.22 g) as compared to minimum at control (135.56 g) (Table 1). Similarly, the maximum volume of fruit (247.56 cc.) was recorded at 100 ppm GA_3 treatment that was followed by 30 ppm 2,4-D (211.89 cc) while the minimum volume (145.44 cc) was

Table 2 : Effect of plant growth regulators on physical characteristics of fruits of 'Nagpur' mandarin

Treatments	Diameter of fruit (cm)		Peel thickness (mm)	Volume of fruit (cc)	No. of seeds/ fruit	Avg. seeds weight/ fruit (g)	No. of sacs/fruit	Days taken to first harvesting	Total days taken to complete harvesting
	Horizontal	Vertical							
T_0	6.12	5.64	5.33	145.44	15.44	1.86	9.89	260.33	294.67
T_1	6.80	5.97	4.09	155.22	11.44	1.03	10.89	254.67	285.33
T_2	7.02	6.50	3.88	171.78	14.44	1.34	11.11	253.33	283.33
T_3	6.82	6.22	3.79	164.22	10.44	1.26	11.56	251.33	281.33
T_4	7.13	7.44	4.01	189.44	14.56	1.71	11.11	248.67	278.67
T_5	7.26	7.27	4.77	149.89	9.89	0.99	11.44	238.33	268.33
T_6	6.97	6.71	4.13	177.78	14.89	1.74	10.56	235.67	265.67
T_7	6.59	6.37	4.25	181.78	12.44	1.04	11.44	234.33	2264.33
T_8	8.03	8.23	3.97	247.56	14.56	1.67	12.56	231.67	261.67
T_9	6.43	6.38	4.96	190.22	14.78	0.98	11.11	240.67	270.67
T_{10}	7.46	7.39	5.11	164.22	13.67	1.55	11.78	239.33	269.33
T_{11}	7.64	7.83	3.41	211.89	9.44	0.97	12.11	233.67	263.67
T_{12}	6.97	6.75	3.48	173.78	9.56	1.41	10.89	236.67	266.67
T_{13}	6.90	6.26	3.98	160.56	14.44	1.48	11.44	253.33	283.33
T_{14}	7.40	7.34	4.41	181.56	14.56	1.01	10.89	251.67	281.67
T_{15}	7.08	6.37	3.66	186.78	11.56	1.42	10.44	249.67	279.67
T_{16}	6.65	6.28	3.94	172.78	10.44	1.04	10.56	248.33	278.33
S.E.±	0.20	0.25	0.23	10.66	1.07	0.12	0.42	5.30	5.35
C.D. (P=0.05)	0.59	0.72	0.67	30.69	3.09	0.36	1.21	15.27	15.42

(T_0- Control, T_1- NAA 50ppm, T_2- NAA 100ppm, T_3- NAA 150ppm, T_4- NAA 200ppm, T_5- GA_3 25ppm, T_6- GA_3 50ppm, T_7- GA_3 75ppm, T_8- GA_3 100ppm, T_9- 2,4-D 10ppm, T_{10}- 2,4-D 20ppm, T_{11}- 2,4-D 30ppm, T_{12}- 2,4-D 40ppm, T_{13}- Triacontanol 5ppm, T_{14}- Triacontanol 10ppm, T_{15}- Triacontanol 15ppm, T_{16}- Triacontanol 20ppm)

recorded in control (Table 2). The increase in weight and volume of fruit due to GA_3 treatment were also recorded by Reddy and Prasad (2012) in pomegranate and Chao *et al*. (2011) in mandarin. Similarly Nawaz *et al.* (2008) reported the increased fruit size (71.20 mm) by application with 10 ppm GA_3 treatment in Kinnow mandarin and likewise finding were also reported by Kacha *et al.* (2012) in phalsa fruits.

The influence of plant growth regulators on number of seeds per fruit and average seeds weight per fruit are presented in Table 2. The data reveal that the application of plant growth regulators had significantly increased the number of seeds per fruit and average seeds weight per fruit of Nagpur mandarin over control. Among the various plant growth regulator treatments, the minimum number of seeds per fruit of (9.44) and minimum average seeds weight per fruit of (0.97 g) were recorded at 30 ppm 2,4-D treatment (Table 2). However, the maximum number of seeds per fruit (15.44) and maximum average seeds weight per fruit (1.86 g) were observed at control. The present results are in consonance with the findings of Saleem *et al.* (2008) in 'Blood Red' sweet orange and Saleem *et al*. (2007) in sweet orange.

The number of sacs per fruit of Nagpur mandarin was significantly improved by application of different plant growth regulator treatments at various concentrations (Table 2). It is evident from the data obtained that application of GA_3 at 100 ppm concentration had exhibited highest number of sacs per fruit as compared to other treatments and control. The maximum number of sacs per fruit of 12.56 was recorded at 100 ppm GA_3 treatment closely followed by 30 ppm 2,4-D. However, the minimum number of sacs per fruit of 9.89 was recorded at control, respectively. The variation in the number of sacs per fruit due to different plant growth regulators might be attributed to difference in enzymetion alluding during cell division and cell differentiation phases of fruit developments.

The application of plant growth regulator treatments had significantly increased the number of fruits per tree and fruit retention per cent over control are presented in Table 1. The maximum number of fruits per tree (126.0) was recorded at 30 ppm 2,4-D treatment as compared to minimum (100.67) in control. Similarly the maximum fruit retention per cent (70.68%) was recorded at 30 ppm 2,4-D treatment closely followed by 10 ppm 2,4-D (69.21%) treatment. The minimum fruit retention of 56.42 per cent was recorded at control. The application of 2, 4-D at 40 ppm gave significantly maximum number of fruits (64.00). Reddy and Prasad (2012) also reported similar results. Similar beneficial effect of 2,4-D on number of fruit per tree and fruit retention was also recorded by Ashraf *at el.* (2013) in Kinnow mandarin.

It is evident form the data (Table 2) that, the minimum days taken to first harvesting (231.67 days) was recorded at 100 ppm GA_3 treatment which was closely followed by 30 ppm 2,4-D (233.67 days). The maximum days taken to first harvesting (260.33) was recorded at control. Similar results of minimum total days taken to complete harvesting (261.67 days) was recorded at 100 ppm GA_3 treatment which was closely followed by 30 ppm 2,4-D (263.67 days). The maximum days taken to first harvesting (294.67) was recorded under control. A similar result of earlier harvesting due to application of GA_3 was recorded by Duarte *et al.* (2006) in 'Clausellina' Satsuma mandarin, this might be attributed to harvesting of fruit maturity under different GA_3 concentration.

Yield attributing characteristics:

The effect of plant growth regulators on yield of Nagpur mandarin fruits are presented in Table 1. The data showed that the application of different plant growth regulators at various concentrations had significantly increased the yield of Nagpur mandarin fruits over control in the present investigation. Amongst the various plant growth regulator treatments attempted the maximum yield of 21.80 kg/plant and (6.08 tonnes/ha.) was recorded at 30 ppm 2,4-D treatment followed by 10 ppm 2.4-D treatment. The minimum yield of (12.94 kg/plant and 3.60 tonnes/ha.) was observed at control. The increase in yield of Nagpur mandarin fruits by application of 2,4-D and GA_3 treatments may be attributed to the fact that partitioning of assimilates by 2,4-D and GA_3 more towards the fruit development and better translocation of assimilates further leads to improvement in yield contributing characters like size and weight of fruits as evident by the present study which finally increased the yield (Khalid *et al*., 2012) in 'Kinnow' mandarin. Similar results were also observed by application of 2,4-D treatment, in pomegranate as reported by Reddy and Prasad (2012), in 'Nova' mandarin as reported by Greenberg *et al*. (2006) and in Nagpur mandarin as reported by Ingle *et al.* (2001).

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