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Effect of plant growth regulators on growth, flowering and fruit set of 4 year old Kinnow Mandarin (*Citrus reticulata* Blanco.) plant

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Abstract
The present experiment was carried out during December 2017 to May 2018 in Central Research Field of Department of Horticulture, SHUATS, Allahabad. The experiment was conducted in Randomized Block Design (RBD), with thirteen treatments, replicated thrice. the treatments were T_0 (Control), T_1 (NAA @ 25 ppm), T_2 (NAA @ 50 ppm), T_3 (NAA @ 75 ppm), T_4 (NAA @ 100 ppm), T_5 (NAA @ 125 ppm), T_6 (NAA @ 150 ppm), T_7 (GA_3 @ 25 ppm), T_8 (GA_3 @ 50 ppm), T_9 (GA_3 @ 75 ppm), T_{10} (GA_3 @ 100 ppm), T_{11} (GA_3 @ 125 ppm) and T_{12} (GA_3 @ 150 ppm).Based on the present investigation it is found that treatment T_{12} (GA_3 @ 150 ppm) found maximum (199.64, 205.477, 209.190, 214.51 and 216.887 cm) Plant height, (84.293, 86.983, 89.670, 94.233 and 100.450 cm) Spread of Canopy, (24.417, 24.760, 25.167, 25.590 and 26.150 cm^2) Leaf area, (28.487, 30.103, 31.670 33.100 and 33.770) Number of Branches, (4.663, 5.300, 5.657, 6.190 and 6.833 cm) Stem Diameter, (6.837, 7.013, 7.193, 7.410 and 7.783 cm) Length of Internodes at 30, 60, 90, 120 and 150 days respectively after spray of Plant growth regulators, the maximum Number of Flowers (199.510), Number of Fruits (48.643), minimum Number of Fruits drops (7.317), Average Fruit weight (43.693 g), Polar Length (4.293 cm) and minimum Pest incidence percent (1.590 %) was also found in treatment T_{12}, Followed by Treatment T_{11} in all the parameters, whereas minimum was recorded in Treatment Control.

Keywords: kinnow, plant growth regulators, NAA, GA_3

Introduction
Kinnow mandarin (*Citrus reticulata* Blanco), member of family Rutaceae, is a very popular fruit crop among various citrus species. The fruits are known for its good processing quality, excellent source of vitamin C, fresh consumption, aromatic flavor and low content of saturated fat, cholesterol and sodium. Kinnow mandarin is reported to be a hybrid between King tangor and Willow leaf mandarin. Among various citrus species, it has remarkable heat tolerance capability, a character inherited from its parent cultivar King and this helps it to survive in harsh hot summer with maximum temperatures around 48 °C (Shirgure, 2012) [8].
Kinnow is an economically important cash crop of India with great deal of production and export. Mandarin (*C. reticulata*) is the leading cultivated citrus crop in India (Srivastava and Singh, 2003) [9]. Fruits have loose skin with hollow central core and segments are easily separated from skin. Pulp is very fine and 10-14 segmented. The fruit juice is sweet, used for drinking and as table fruit. Squash, crush, syrup and concentrate are also prepared from mandarin (Obreza and Rouse, 2006) [5]. Kinnow is an important citrus fruit grown in South Indian states like Andhra Pradesh, Tamil Nadu and Karnataka.
Plant growth regulators have been used in citrus fruit production for influencing flowering, fruit set and fruit drop and play a major role in fruit growth and abscission. These regulators have also been used to influence fruit quality factors like peel quality and colour, fruit size, juice quality and to improve total soluble solids in different citrus species. This review may serve as a complete treatise on the possible roles of growth promoting substances on the physiological processes of citrus plant. (Harsimrat *et al.* 2015) [4].

Materials and Methods
The details of the various materials used and methods adopted in laid out the experiment are presented below:

Experimental site
The experiment was carried out using 4-year-old Kinnow plants at the Cenral Research field of Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, during the year 2017-2018.

Climatic condition of experimental area

The area of Allahabad district comes under subtropical belt in the South East of Utter Pradesh, which experience extremely hot summer and fairly cold winter. The maximum temperature of the location reaches up to 46 ºC – 48 ºC and seldom falls as low as 4 ºC – 5 ºC. The relative humidity ranged between 20 – 94 percent. The average rainfall in this area is around 1013.4mm annually. However, occasional precipitation is also not uncommon during winter months.

Results and Discussion

The present investigation entitled "Effect of Plant growth regulators on growth, flowering and fruit set of 4 year old Kinnow Mandarin Plant (*Citrus reticulata.*)." was carried out during December 2017 to May 2018 in Central Research Field of Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad (U.P.) India. The results of the present investigation, regarding the effect of Plant growth regulators on growth, Flowering and Fruit set of Kinnow, have been discussed and interpreted in the light of previous research work done in India and abroad. The experiment was conducted in Randomized block design with 13 treatments, and three replications.

The results of the experiment are summarized below.

Growth Parameters

Plant height was recorded maximum in treatment T_{12} (GA_3 @ 150 ppm) with (199.64, 205.477, 209.190, 214.51 and 216.887 cm) plant height at 30, 60, 90, 120 and 150 days respectively after spray of Plant growth regulators followed by T_6 (NAA @ 150 ppm) (191.267, 195.773, 201.787, 204.213 and 207.187 cm) at 30, 60, 90, 120 and 150 days respectively, where as minimum Plant height (153.793, 175.577, 161.080, 162.773 and 163.547 cm) was found with treatment T_0 (Control) at 30, 60, 90, 120 and 150 days respectively. Similar findings were also reported by Hifny *et al.,* (2017) [3] in Washington Novel Orange.

Spread of Canopy was recorded maximum in treatment T_{12} (GA_3 @ 150 ppm) with (84.293, 86.983, 89.670, 94.233 and 100.450 cm) Spread of Canopy at 30, 60, 90, 120 and 150 days respectively after spray of Plant growth regulators followed by T_8 (GA_3 @ 50 ppm) (76.338, 79.150, 81.563, 83.817 and 86.370 cm) at 30, 60, 90, 120 and 150 days respectively, where as minimum Spread of Canopy (57.300, 60.147, 61.537, 62.827 and 64.833 cm) was found with treatment T_0 (Control) at 30, 60, 90, 120 and 150 days respectively. Similar findings were also reported by Hifny *et al.,* (2017) [3] in Washington Novel Orange.

In terms of Leaf Area it is found that the treatment T_{12} (GA_3 @ 150 ppm) found maximum (24.417, 24.760, 25.167, 25.590 and 26.150 cm^2) Leaf area at 30, 60, 90, 120 and 150 days respectively after spray of Plant growth regulators followed by T_7 (GA_3 @ 25 ppm) (24.073, 24.507, 24.823, 25.140 and 25.697 cm^2) at 30, 60, 90, 120 and 150 days respectively, where as minimum Leaf Area (20.193, 20.357, 20.670, 20.970 and 21.383 cm^2) was found with treatment T_0 (Control) at 30, 60, 90, 120 and 150 days respectively. Similar findings were also reported by Hifny *et al.,* (2017) [3] in Washington Novel Orange.

Number of Branches was recorded maximum in treatment T_{12} (GA_3 @ 150 ppm) with (28.487, 30.103, 31.670 33.100 and 33.770) Number of Branches at 30, 60, 90, 120 and 150 days respectively after spray of Plant growth regulators followed by T_{11} (GA_3 @ 125 ppm) (24.767, 26.127, 27.540, 29.807 and 31.903) Number of Branches at 30, 60, 90, 120 and 150 days respectively, where as minimum Number of Branches (15.347, 16.200, 17.030,17.760 and 19.150) was found with treatment T_0 (Control) at 30, 60, 90, 120 and 150 days respectively.

Stem Diameter was recorded maximum in treatment T_{12} (GA_3 @ 150 ppm) found maximum (4.663, 5.300, 5.657, 6.190 and 6.833 cm) Stem Diameter at 30, 60, 90, 120 and 150 days respectively after spray of Plant growth regulators followed by T_{11} (GA_3 @ 125 ppm) (4.583, 5.070, 5.590, 6.137 and 6.590 cm) Stem Diameter at 30, 60, 90, 120 and 150 days respectively, where as minimum Stem Diameter (2.180, 2.430, 2.677, 3.077 and 3.413 cm) was found with treatment T_0 (Control) at 30, 60, 90, 120 and 150 days respectively. Similar findings were also reported by Hifny *et al.,* (2017) [3] in Washington Novel Orange.

In terms of Length of Internodes it is found that the treatment T_{12} (GA_3 @ 150 ppm) found maximum (6.837, 7.013, 7.193, 7.410 and 7.783 cm) Length of Internodes at 30, 60, 90, 120 and 150 days respectively after spray of Plant growth regulators followed by T_{11} (GA_3 @ 125 ppm) (6.490, 6.740, 7.060, 7.287 and 7.473 cm) Length of Internodes at 30, 60, 90, 120 and 150 days respectively, where as minimum Length of Internodes (4.340, 4.520, 4.750, 5.043 and 5.217 cm) was found with treatment T_0 (Control) at 30, 60, 90, 120 and 150 days respectively. Similar findings were also reported by Hifny *et al.,* (2017) [3] in Washington Novel Orange.

Flowering and fruiting parameters

The Number of Flowers/plant is found maximum in treatment T_{12} (GA_3 @ 150 ppm) with (199.510) Number of Flowers after spray of Plant growth regulators followed by T_{11} (GA_3 @ 125 ppm) (198.310) Number of Flowers where as minimum Number of Flowers (115.210) was found with treatment T_0 (Control). Similar findings were also reported by Ullah *et al.,* (2014) [10] in Sweet orange.

Number of Fruits/plant was recorded maximum in treatment T_{12} (GA_3 @ 150 ppm) with (48.643) Number of Fruits/plant after spray of Plant growth regulators followed by T_{11} (GA_3 @ 125 ppm) (44.187) Number of Fruits where as minimum Number of Fruits (15.800) was found with treatment T_0 (Control). Similar findings were also reported by Ullah *et al.,* (2014) [10] in Sweet orange.

Number of Fruits drops is found minimum in treatment T_{12} (GA_3 @ 150 ppm) with (7.317) Number of Fruits drops after spray of Plant growth regulators closely followed by T_{11} (GA_3 @ 125 ppm) (7.887) Number of Fruits drops where as maximum Number of Fruits drops (21.147) was found with treatment T_0 (Control). Similar findings were also reported by Ullah *et al.,* (2014) [10] in Sweet orange.

Average Fruit weight was recorded maximum in treatment T_{12} (GA_3 @ 150 ppm) found maximum (43.693 g) Fruit weight after spray of Plant growth regulators closely followed by T_{11} (GA_3 @ 125 ppm) (40.643 g) Fruits weight where as minimum Fruits weight (21.587 g) was found with treatment T_0 (Control). Similar findings were also reported by Ullah *et al.,* (2014) [10] in Sweet orange.

Polar Length (cm) of fruits was recorded maximum in treatment T_{12} (GA_3 @ 150 ppm) found maximum (4.293 cm) Polar Length after spray of Plant growth regulators closely followed by T_{11} (GA_3 @ 125 ppm) with (4.113 cm) Polar Length where as minimum (1.697 cm) Polar Length was recorded in treatment T_0 (Control).

In terms of Pest incidence percent it is found that the treatment T_{12} (GA_3 @ 150 ppm) found minimum (1.590 %)

Pest Incidence after spray of Plant growth regulators followed by T_{11} (GA_3 @ 125 ppm) with (3.093 %) Pest Incidence Percent where as maximum (10.523 %) Pest Incidence was recorded in treatment T_0 (Control).

Table 1: Effect of Plant growth regulators on Plant height (cm), Spread of Canopy (cm) and Leaf area (cm^2) of Kinnow.

Treatment Symbol	Treatment Details	Plant height (cm)					Spread of Canopy (cm)					Leaf area (cm^2)				
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_0	Control (spray of water)	153.797	157.577	161.080	162.773	163.547	57.300	60.147	61.537	62.827	64.833	20.193	20.357	20.670	20.970	21.383
T_1	NAA @ 25 ppm	169.577	170.310	174.003	176.760	181.163	66.123	68.527	70.577	72.860	74.963	22.100	22.487	22.833	23.043	23.563
T_2	NAA @ 50 ppm	176.683	179.143	182.887	185.973	187.517	64.093	66.560	69.363	71.820	74.850	22.787	23.320	23.597	23.870	24.327
T_3	NAA @ 75 ppm	159.363	162.843	166.043	169.233	172.067	60.693	63.407	65.937	68.390	70.550	21.700	22.090	22.330	22.567	23.010
T_4	NAA @ 100 ppm	163.833	164.360	168.297	173.350	175.380	63.273	65.533	68.353	71.523	73.893	21.887	22.207	22.537	22.973	23.397
T_5	NAA @ 125 ppm	181.933	184.377	189.587	194.917	199.880	72.580	75.057	77.240	80.133	82.187	21.620	21.953	22.290	22.660	23.150
T_6	NAA @ 150 ppm	191.267	195.773	201.787	204.213	207.187	75.300	77.993	79.900	82.533	85.183	24.197	24.483	24.717	25.060	25.300
T_7	GA_3 @ 25 ppm	172.577	172.167	176.667	179.210	184.177	75.220	77.370	79.960	82.480	84.827	24.073	24.507	24.823	25.140	25.697
T_8	GA_3 @ 50 ppm	177.203	179.813	183.693	185.033	191.010	76.383	79.150	81.563	83.817	86.370	22.957	23.337	23.607	23.887	24.773
T_9	GA_3 @ 75 ppm	165.960	167.427	169.530	173.040	176.690	70.463	73.627	76.043	78.123	80.207	22.370	22.740	22.973	23.420	24.043
T_{10}	GA_3 @ 100 ppm	167.210	169.257	172.873	175.560	178.723	69.223	72.053	74.483	76.510	79.367	23.347	23.750	24.033	24.420	24.690
T_{11}	GA_3 @ 125 ppm	187.000	192.993	195.237	200.900	204.447	75.063	77.667	80.687	83.517	86.833	21.750	22.053	22.560	22.873	23.303
T_{12}	GA_3 @ 150 ppm	199.640	205.477	209.190	214.510	216.887	84.293	86.983	89.670	94.233	100.450	24.417	24.760	25.167	25.590	26.150
F-test		S	S	S	S	S	S	S	S	S	S	NS	NS	NS	NS	NS
SE(d)		5.342	3.699	2.792	5.465	4.712	3.458	3.406	3.289	3.408	3.643	1.265	1.253	1.296	1.272	1.268
C.D.		11.092	7.679	5.796	11.346	9.784	7.179	7.072	6.828	7.076	7.564	N/A	N/A	N/A	N/A	N/A

Table 2: Effect of Plant growth regulators on Number of Branches, Steam Diameter (cm) and Length of internodes (cm) of Kinnow.

Treatment Symbol	Treatment Details	Number of Branches					Stem Diameter (cm)					Length of Internodes (cm)				
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_0	Control (spray of water)	15.347	16.200	17.030	17.760	19.150	2.180	2.430	2.677	3.077	3.413	4.340	4.520	4.750	5.043	5.217
T_1	NAA @ 25 ppm	18.463	19.463	20.593	21.527	22.960	2.380	2.800	3.073	3.477	3.823	4.497	4.690	5.000	5.227	5.507
T_2	NAA @ 50 ppm	18.900	20.117	21.113	22.423	23.777	2.707	3.073	3.277	3.660	4.013	4.783	4.967	5.243	5.627	5.890
T_3	NAA @ 75 ppm	20.153	20.743	21.853	22.707	24.633	2.513	2.910	3.310	3.753	4.120	4.890	5.167	5.450	5.763	5.987
T_4	NAA @ 100 ppm	19.627	20.923	22.127	23.253	24.003	3.040	3.387	3.593	4.117	4.450	5.123	5.313	5.663	5.890	6.093
T_5	NAA @ 125 ppm	21.293	22.430	23.403	24.293	25.497	2.930	3.217	3.653	3.787	4.343	5.450	5.713	5.993	6.213	6.563
T_6	NAA @ 150 ppm	22.643	23.787	25.057	26.220	27.607	3.583	3.970	4.320	4.690	5.067	5.880	6.070	6.340	6.563	6.757
T_7	GA_3 @ 25 ppm	26.253	27.467	28.820	29.880	30.250	4.173	4.537	4.830	5.057	5.593	5.623	5.833	6.163	6.557	6.800
T_8	GA_3 @ 50 ppm	24.340	25.617	26.753	28.293	30.653	4.390	4.817	5.200	5.653	6.057	5.720	6.067	6.393	6.950	7.183
T_9	GA_3 @ 75 ppm	28.347	29.277	29.960	30.183	30.937	4.460	4.877	5.383	5.827	6.153	5.970	6.273	6.697	7.027	7.220
T_{10}	GA_3 @ 100 ppm	26.150	27.787	29.047	30.393	31.140	4.503	5.073	5.530	6.030	6.307	6.133	6.400	6.793	7.067	7.400
T_{11}	GA_3 @ 125 ppm	24.767	26.127	27.540	29.807	31.903	4.583	5.070	5.590	6.137	6.590	6.490	6.740	7.060	7.287	7.473
T_{12}	GA_3 @ 150 ppm	28.487	30.103	31.670	33.100	33.770	4.663	5.300	5.657	6.190	6.833	6.837	7.013	7.193	7.410	7.783
F-test		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
SE(d)		1.671	1.620	1.730	1.717	1.802	0.388	0.397	0.341	0.316	0.317	0.337	0.323	0.318	0.294	0.296
C.D.		3.469	3.364	3.592	3.564	3.741	0.805	0.825	0.707	0.657	0.659	0.701	0.671	0.661	0.610	0.615

Table 3: Effect of Plant growth regulators on Number of Flowers/Plant, Number of fruits/plant, Fruit drop (%), Avg. Fruit weight (g), Polar length (cm) and Pest incidence (%) of Kinnow.

Treatment Symbol	Treatment Details	Number of flowers/Plant	Number of fruits/plant	Fruit drop %/plant	Average fruit weight 30 Days	Polar length (cm)	Pest Incidence %
T_0	Control (spray of water)	115.210	15.800	21.147	21.587	1.697	10.523
T_1	NAA @ 25 ppm	145.287	29.263	15.670	25.567	2.040	6.490
T_2	NAA @ 50 ppm	163.250	30.493	13.593	29.533	2.567	5.807
T_3	NAA @ 75 ppm	167.870	31.317	11.887	28.770	3.033	3.847
T_4	NAA @ 100 ppm	170.383	32.337	11.803	29.340	2.863	6.370
T_5	NAA @ 125 ppm	172.810	34.890	12.240	29.213	3.140	4.683
T_6	NAA @ 150 ppm	176.720	36.380	11.293	32.490	3.177	4.917
T_7	GA_3 @ 25 ppm	179.393	32.397	12.123	31.453	3.230	4.537
T_8	GA_3 @ 50 ppm	186.553	35.113	10.340	32.840	3.493	3.310
T_9	GA_3 @ 75 ppm	189.960	39.177	11.150	36.557	3.617	3.607
T_{10}	GA_3 @ 100 ppm	194.140	42.327	10.640	38.047	4.077	3.160
T_{11}	GA_3 @ 125 ppm	198.310	44.187	7.887	40.643	4.113	3.093
T_{12}	GA_3 @ 150 ppm	199.510	48.643	7.317	43.693	4.293	1.590
F-test		S	S	S	S	S	S
SE(d)		8.706	2.082	1.610	3.059	0.345	1.569
C.D.		18.075	4.323	3.343	6.351	0.717	3.257

Conclusion

Based on the present investigation it is concluded that treatment T_{12} (GA_3 @ 150 ppm) is found to be best in terms of maximum Plant height (cm), Spread of Canopy (cm), Leaf area (cm^2), Number of Branches/plant, Stem Diameter (cm), Length of Internodes (cm) at 150 days respectively after spray of Plant growth regulators, the maximum Number of Flowers/plant, Number of Fruits/plant, minimum Number of

Fruits drops/plant, Average Fruit weight (g), Polar Length (cm) and minimum Pest incidence percent was also found in treatment T_{12} (GA_3 @ 150 ppm) Followed by Treatment T_{11} (GA_3 @ 125 ppm), whereas minimum was recorded in Treatment T_0 (Control).

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