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Impact of foliar application of growth regulators and micronutrients on fruit yield and quality of Kinnow

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Abstract
A research trial was carried out in a randomized block design with three replicates at Village Achariki, Abohar, District Fazilka, Punjab during 2017-2018 to study the effect of foliar application of growth regulators and micronutrients on yield and fruit quality of Kinnow. The experiment included nine treatments viz. Control (water spray), NAA@100 ppm, NAA@150 ppm, GA_3@75 ppm, GA_3@100 ppm, $ZnSO_4$@0.3%, $ZnSO_4$@0.5%, K_2SO_4@0.1% and K_2SO_4@0.2%. The application of GA_3@100 ppm recorded the highest plant growth (plant height, stem girth, canopy volume (E-W/N-S) and leaf area), number of fruits per tree (458) and fresh fruit yield (114.0 kg per tree). Thus, it can be concluded that the selection of a suitable plant growth regulator or nutrient (macro or micro) for foliar application to a citrus fruit crop is of great importance in order to achieve highest yield potential and quality through the optimal growth.

Keywords: Kinnow, plant growth regulators, micronutrients, quality, yield

Introduction
Citrus belonging to Rutaceae family is one of the major and economically important fruit crop grown worldwide mainly for its rich vitamin C content. The Kinnow is a high yield mandarin hybrid cultivated widely in Indian and Pakistan Punjab (Anon 2018) [1]. It is an anti-toxic fruit which is found good for skin, immunity and helps in lowering blood pressure. It is anti-inflammatory, boosts metabolism, controls acidity and constipation, and thereby balances the cholesterol content. Adequate nutrition of a plant helps to improve the optimum productivity and quality of the produce (Srivastava and Singh, 2002) [27]. However, in India, productivity of horticultural crops is static with a small per capita land holding in relation to differential nutrient application through plant root system. Thus, foliar application of nutrient and growth regulators may play an important role in improving the productivity and quality of the fruit. In North-West India, the cultivation of Kinnow has gained importance because of precocious bearing and high yield potential. However, the increased production has reported some of its intrinsic problems like excessive maiden cropping which leads to death of the trees, high proportion in variability of fruit size and tendency to suicidal bearing. The smaller fruit size with higher percentage deserves special attention as entire produce is consumed as fresh and the large fruit size fetches premium price in the market. There are many reasons for smaller fruit size and the inadequacy of potassium is the most striking factor that regulates the size of fruit (Gill *et al*. 2005; Rattanpal *et al*. 2005) [15, 22].

Auxins and gibberellins can be used to control the fruit drop and improve the fruit quality in citrus (Almeida *et al.* 2004) [2]. The foliar application of GA_3 may help in increase yield by reducing the percent fruit drop (Ullah *et al.* 2014) [30]. Foliar application of NAA (Naphthalene acetic acid) may help in reducing crop load, reducing alternate bearing and improving fruit size as well as quality in various species or cultivars (Guardiola *et al.* 2000; Ortola *et al.* 1991; Van *et al.* 1996) [16, 21, 31]. Researchers have suggested that application of suitable plant growth regulators and nutrients (macro and micro) for the control of excessive fruit drop and improvement of the yield plus quality of citrus fruits (Doberman and Fairhurst, 2000; Saleem *et al.* 2005) [9, 24]. Excessive drop of premature fruit may also be caused by high temperature and irrigation facility, attack of insect-pest and high wind velocity of the area(Ibrahim *et al*. 2007, Ashraf *et al*. 2012, Razi *et al.* 2011) [17, 3, 23].

Thus, adequate application of nutrients and growth regulators is strongly recommended for reducing premature drop of fruits (Modise *et al*. 2009 and Ashraf *et al*. 2012) [19, 3].

Among nutrients, potassium is one of the most important macro-nutrients which highly mobile in plants from individual cell to xylem and phloem transport. Potassium (K) improves fruit quality by enhancing fruit size, juice content, color, size and juice flavor (Tiwari, 2005; Ashraf *et al.* 2010) [28, 4]. In other terms, K application improves mineral content, yield (El-Safty *et al*. 1998) [12] and fruit quality of citrus (Wei *et al*. 2002) [32]. Thus, optimum supply of K may positively affect the yield, quality and fruit drop of citrus crops. Similarly, deficiency of micronutrients (Zn, Cu, Fe and Mn) in the soil may affect the yield, quality and fruit dropping of citrus crops (Ibrahim *et al.*, 2007; Ashraf *et al*. 2012) [17, 3]. Application of $ZnSO_4$ (0.5%) significantly improves physical and chemical properties of fruits and thereby the yield (Dawood *et al*. 2000 and El-Baz, 2003) [8, 11]. Calcium is another essential element in plant nutrition to improve yield and fruit quality (EL-Shobaky and Mohamed 2000) [14]. The present study was thus undertaken to study the effect of foliar application of growth regulators and micronutrients on yield and fruit quality of Kinnow

Materials and Methods

A field experiment was carried out in a randomized block design with three replicates at Village Achariki, Abohar, District Fazilka, Punjab during 2017-2018 to study the effect of foliar application of growth regulators and micronutrients on yield and fruit quality of Kinnow (Fig. 1). The soil of the experimental field was sandy clay loam in texture with a pH value of 8.01. It was moderately fertile, with available nitrogen of 356.68 kg ha^{-1}, phosphorus of 14.90 kg ha^{-1}, potassium of 115.50 kg ha^{-1}, calcium of 14.28 kg ha^{-1}, magnesium of 25.60 kg ha^{-1}, sulphur of 38.94 kg ha^{-1} and electrical conductivity value of 1.68 dS m^{-1} at 25°C.

The experiment included nine treatments viz. Control (water spray), NAA@100 ppm, NAA@150 ppm, GA_3 @75 ppm, GA_3@100 ppm, $ZnSO_4$ @0.3%, $ZnSO_4$ @0.5%, K_2SO_4 @0.1%, K_2SO_4 @0.2%. Twenty seven trees of uniform size and vigour with a spacing of 4.5 x 4.5 m were selected and the cultural practices were performed as per the package of practices recommended by Punjab Agricultural University, Ludhiana. The nutrients and growth regulators were applied through foliar spray at two different times (first spray in first week of April and second spray in first week of May).

Result and Discussion

Growth parameters

The results indicated that the growth of plants (plant height, stem girth, canopy volume E-W/N-S and leaf area significantly was significantly affected by application of individual growth regulators and micronutrients respectively (Table 1). Among the various plant growth regulators and micronutrients, the foliar application of GA_3@100 ppm reported the maximum increase in plant height, stem girth, canopy volume E-W/N-S and leaf area which was at par with GA_3@75 ppm. While, the lowest increase in plant height, stem girth, canopy volume E-W/N-S and leaf area was recorded in control (T_1). The improved growth was recorded mainly 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 enhanced development of plants resulting in greater height and number of branches per plant and ultimately the greater plant spread and canopy volume. The results were in a good agreement with Choudhary *et al.* (2013) [7]. Positive impact of GA_3 application on plant spread and crown volume was recorded by Eelkim *et al.* (2003) [10] in Satsuma mandarin, where they reported increased number the vegetative shoots in response to progressive increase in the doses of treatments (25, 50 and 100 ppm concentrations of GA_3).

Yield attributes and fruit yield

The yield attributes *viz.* number of fruits per tree, fruit weight (g), fruit yield (kg/tree) were significantly influenced by application of individual plant growth regulators and micronutrients. The results revealed that application of GA_3@100 ppm recorded the highest number of fruits (458 fruits/tree) followed by GA_3@75 ppm (453.33 fruits/tree) (Table 2). Whereas, the minimum number of fruits (399 fruits/tree) were recorded in control. The highest fruit weight was observed in GA_3@75 ppm followed by GA_3@100 ppm (189.67 g) and NAA@150 ppm (185.53 g). While, the minimum fruit weight was recorded in the control. According to Chao *et al*. (2011) [6], an increase in fruit yield/tree might be due to more availability of gibberellic acid. Gibberellic acid promotes cell elongation, cell enlargement and increase in number of cells. The application of plant growth regulators and micronutrients significantly increased the fruit yield. Among the different treatments, GA_3@100 ppm recorded the maximum yield (114.00 kg/tree) followed by GA_3@75 ppm (113.33 kg/tree) and NAA@150 ppm (109.67 kg/tree) with minimum under control (96.00 kg/tree). These findings were found in close agreement with findings of Bhatt *et al.* (2016) [5] who obtained maximum fruit yield under GA_3@20 ppm) and the minimum under control.

Fruit quality

The results obtained in the present study indicated a significant increase in fruit diameter (Table 3). The highest horizontal and vertical fruit diameters were recorded in GA_3@100 ppm with minimum under control. However, the maximum peel weight and thickness were recorded in control treatment. The application of gibberellic acid reduced the peel weight and thickness due to cell elongation and enlargement. Among the various plant growth regulators and micronutrients, the minimum number of seeds per fruit was recorded in GA_3@100 ppm. However, the maximum number of seeds per fruit was recorded in control. The reduction in number of seeds per fruit might be due to parthenocarpic effect of gibberellic acid. Similar results have been reported by Bhatt *et al*. (2016) [5] where minimum number of seeds per fruit were recorded in GA_3@10 ppm.

The juice content of Kinnow fruit was also significantly influenced by application of plant growth regulators and micronutrients. The maximum juice percent was recorded by application of GA_3@100 ppm with minimum under control. The increase in juice percentage may be explained by the fact that hormones play a regulating role in the mobilization of metabolites within a plant. It is a well-established fact that developing fruits are extremely active metabolic “sinks” which mobilize metabolites and direct their flow from vegetative structure. These results were in good agreement with that of Nawaz *at el.* (2008) [20] where they reported the maximum juice content with foliar application of GA_3@50 ppm.

The results obtained revealed that the total soluble solids in fruit juice were significantly affected by different treatments

(Table 3). Application of GA_3@100 ppm recorded maximum total soluble solids in fruit juice with minimum value under control. It might be due to quick metabolic transformation of starch and pectin into soluble sugars and rapid mobilization of photosynthetic metabolites and minerals from other parts of the plant. Similar results have been reported in Jagtap *et al*. (2013) [18]. The acidity percentage was reduced with foliar application of nutrients and growth regulators. The minimum value acidity was obtained with the application of GA_3@100 ppm with highest value under control. The decrease in the titrable acidity was mainly due to the increase in total soluble solids. These results are in accordance with the findings of Jagtap *et al.* (2013) [18] who reported the lowest value of titrable acidity in GA_3@50mg/l. The results were also in good agreement with Shinde *et al.* (2008) [26]. The different treatments significantly influenced the reducing, non-reducing and total sugars content of fruit juice. Among different treatments, application of GA_3@100 ppm recorded higher percentage of reducing, non-reducing and total sugars than all other treatments with minimum values under control. Increase in reducing sugars might be due to the effect of gibberellic acid (Tymowska-Lalanne and Kreis, 1998) [29] on the activity of invertase enzyme, which break down sucrose into fructose and glucose and hence results in increased reducing sugars. The results are being supported by the findings of Saleem *et al.* (2008) [25] who observed a similar increase in reducing, non- reducing and total sugar content in sweet orange with application of GA_3@20 mg.

Fig 1: Experimental trial of Kinnow at Village Achariki, Abohar, District Fazilka, Punjab

Table 1: Effect of foliar application of growth regulator and micronutrient on plant height, stem girth, canopy volume and leaf area.

Treatments	Plant height (m)	Stem girth (cm)	Canopy volume E-W (m)	Canopy volume N-S (m)	Leaf area (cm^2)
Control (water spray)	3.14	38.33	1.26	1.36	25.60
NAA (100ppm)	3.77	43.33	1.57	1.67	29.63
NAA (150ppm)	3.93	44.67	1.63	1.73	30.83
GA_3 (75ppm)	4.08	45.67	1.68	1.75	31.20
GA_3 (100ppm)	4.09	49.00	1.71	1.76	31.60
$ZnSO_4$ (0.3%)	3.28	39.00	1.32	1.39	26.10
$ZnSO_4$ (0.5%)	3.34	40.33	1.37	1.49	26.33
K_2SO_4 (0.1%)	3.47	40.67	1.43	1.61	27.63
K_2SO_4 (0.2%)	3.76	43.00	1.55	1.65	28.43
S.Em.±	0.04	1.54	0.01	0.01	0.21
CD at 5%	0.13	4.60	0.04	0.04	0.64

Table 2: Effect of foliar application of growth regulator and micronutrient on total number of fruit, fruit weight and yield per plant.

Treatments	Total no. of fruit/plant	Fruit weight (g)	Yield/plant (kg/tree)
Control (water spray)	398.67	161.87	96.00
NAA (100ppm)	433.67	182.07	108.33
NAA (150ppm)	440.67	185.53	109.67
GA_3 (75ppm)	453.33	203.33	113.33
GA_3 (100ppm)	458.33	189.67	114.00
$ZnSO_4$ (0.3%)	404.67	169.93	100.00
$ZnSO_4$ (0.5%)	411.67	174.20	101.00
K_2SO_4 (0.1%)	422.67	178.73	105.33
K_2SO_4 (0.2%)	427.67	180.13	108.00
S.Em.±	2.16	7.08	1.63
CD at 5%	6.48	21.23	4.89

Table 3: Effect of foliar application of growth regulator and micronutrient on fruit diameter, peel weight, peel thickness, number of segments, number of seeds and juice content%, TSS%, total acidity, sugars and ascorbic acid.

Treatments	Fruit diameter horizontal (mm)	Fruit diameter vertical (mm)	Peel weight (g)	Peel thickness (mm)	Number of segments	Number of seeds (seeds/ fruit)	Juice content (%)	TSS (⁰Brix)	Total acidity (%)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100g)
Control (water spray)	69.07	54.77	56.50	3.29	9.67	25.33	33.17	15.33	0.94	7.38	5.13	2.26	35.10
NAA (100ppm)	74.59	61.06	47.17	2.53	10.67	17.00	50.27	15.57	0.84	8.39	5.55	2.84	41.60
NAA (150ppm)	75.03	62.29	46.33	2.52	10.33	16.67	51.30	15.87	0.83	8.50	5.63	2.86	42.90
GA3 (75ppm)	75.93	63.91	45.83	2.46	11.00	16.33	54.33	16.10	0.82	8.78	5.76	3.02	45.50
GA3 (100ppm)	78.79	65.53	37.40	2.41	11.33	14.33	55.57	16.17	0.80	9.02	5.83	3.19	52.00
ZnSO4 (0.3%)	72.68	55.36	53.33	3.07	10.33	24.33	37.60	15.40	0.93	7.83	5.27	2.56	36.40
ZnSO4 (0.5%)	72.90	57.90	50.33	2.95	10.67	22.33	43.73	15.43	0.87	7.89	5.32	2.57	37.70
K2SO4 (0.1%)	73.21	58.87	49.67	2.87	10.33	21.33	45.57	15.47	0.86	7.99	5.37	2.62	39.00

K2SO4 (0.2%)	73.59	60.67	49.00	2.62	10.33	18.00	49.60	15.51	0.85	8.19	5.46	2.73	40.30
S.Em.±	1.14	1.23	1.91	0.07	0.43	1.29	0.69	0.11	0.02	0.08	0.03	0.08	2.24
CD at 5%	3.41	3.68	5.73	0.22	NS	3.87	2.07	0.34	0.06	0.25	0.09	0.23	6.70

The data analysis revealed that there was a significant increase in the ascorbic acid content of fruit juice with application of nutrients and growth regulators (Table 3). Among different treatments, foliar application of GA_3@100 ppm recorded the highest ascorbic acid content compared to other treatments. The minimum ascorbic acid content was recorded in control. Similarly, an increase in ascorbic acid of guava fruit might be due to high synthesis of nucleic acid on account of maximum availability of fruit metabolism (El-Sherif *et al*. 2000) [13].

Conclusion

The results of the present study indicated a significant improvement in growth of tree, fruit yield and quality of Kinnow through independent foliar application of different growth regulators and nutrients. The application of GA_3@100 ppm resulted in maximum plant growth (plant height, stem girth, canopy volume (E-W/N-S) and leaf area), number of fruits per tree (458) and fresh fruit yield (114.0 kg per tree). Thus, selection of a suitable plant growth regulator or nutrient (macro or micro) for foliar application to a citrus fruit crop is of great importance in order to achieve highest yield potential and quality through the optimal growth.

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