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Effect of Foliar Application of Gibberellic Acid (GA_3) and 2,4-Dichlorophenoxyacetic Acid (2,4-D) on Yield and Fruit Quality of Low Seeded Kinnow Mandarin (*Citrus reticulata* Blanco)

Ehsan Ullah Khan*, Liaqat Ali
Nuclear Institute for Agriculture & Biology (NIAB), P.O. Box # 128, Faisalabad, Pakistan
Email: ehsanmarwat22@yahoo.com (E.U.K)

Abstract

Citrus particularly Kinnow mandarin occupies a prominent position in fruit industry all over the world. Despite a significant increase in Kinnow growing area in Punjab, improvement in fruit quality and yield is still negligible. In order to improve productivity and fruit quality, an experiment was conducted during two successive growing seasons (2012-13 and 2013-14) to investigate the effect of foliar application of the growth regulators (GA_3, 2,4-D) at pea-sized fruit stage of low seeded Kinnow mandarin plants. The efficacy of GA_3 and 2,4-D were evaluated either in single application or in combinations. The experiment was laid out in Randomized Complete Block Design having eleven treatments and a control, and each treatment was replicated three times. The results revealed that both the growth regulators significantly decreased preharvest fruit drop, leading to improvement in yield and fruit quality in both the seasons. Foliar spray containing 50 mg/L GA_3 + 10 mg/L 2,4-D led to marked increase in fruit weight, diameter, height, volume, shape index, juice percentage, TSS (°Brix), total sugars, and Vitamin C contents compared to control. In addition, significant decrease was observed in pre-mature and mature fruit drop in the treated plants compared to control. These growth regulators in the current concentration can be applied to enhance production and improve citrus fruit quality without compromising on the food safety standards.

INTRODUCTION

Citrus is one of the most important fruit crops grown in the tropical and subtropical regions of world. In Pakistan, it is the leading fruit crop with an estimated production of 2.17 million metric tons in a total area of 0.20 million hectares (Ministry of Food and Agric., 2014). Cultural, socio-economic, dietary, nutraceutical and medicinal importance of citrus fruits are well documented (Dugo and Di-Giacomo, 2002; Mabberley, 2004). Various cultivars and varieties are being cultivated in country but Kinnow cultivar is of key importance making Pakistan the largest Kinnow producer in the world**.** Besides local consumption, Kinnow has high export value due to its eye catching exterior look, excellent internal qualities in terms of taste and flavor, high TSS, juice contents and nutritional value. Pakistan exported 0.393 million metric tons of Kinnow fruits of worth $ 165.71 million during 2014-15 (Directorate of Agriculture, Punjab, 2015). Currently the share of Pakistan in world citrus fruit exports is about 0.1% which is very low as compared to other exporting countries. In addition, per hectare production of citrus is 9.5 tons which is lower than the potential of 18-20 tons/ha (Ashraf *et al.*, 2015). Among the major causes accounting for low quality and productivity are self-incompatibility, inadequate pollination, nutritional deficiency, water stress, insect-pest and disease infestations and hormonal imbalances (Davies and Albrigo, 1994; Agusti *et al.*, 2006; Alva *et al.*, 2006; Din *et al.*, 2012; Ashraf *et al.*, 2012, 2013).

Citrus fruit plants often produce profuse flowers and consequently a substantial number of flowers and fruits shed off as a way of reducing heavy fruit load (Modise *et al.*, 2009), followed by series of drops during the growth period. There are usually three periods of fruit abscission; the first is the period of fruit set, which usually lasts for a month following full bloom. The second period of intense fruit drop may occur at the onset of hot summer and is referred as 'June drop'. The third period of intense fruit abscission is called as 'preharvest drop' (Racsko *et al.*, 2006). It was reported by Saleem *et al.* (2005) that most of the fruitlets were dropped (80-91%) during the first month after final fruit set. The demand of Kinnow mandarin in local and international markets is increasing day by day. To fulfill this demand, good quality fruit production as well as high production per unit area is required. Improved fruit yield and quality could be obtained by reducing heavy fruit drop (Penter and Stassen, 1999).

Plant growth regulators (PGRs) as foliar applications are the most powerful tools used for manipulating tree growth, flowering, yield and fruit quality traits (Ashraf *et al.*, 2013). In addition, by hastening or delaying fruit maturation, the growers can utilize peak demands, avoid unfavorable environmental conditions and extend the market period (Hegazi, 1980). The application of plant growth regulators can re-enforce hormone balance in the peel, reducing or retarding this precocious fall and the losses at harvest (Almeida *et al.*, 2004). The use of 2,4-dichlorophenoxyacetic acid (2,4-D) and Gibberellic acid (GA_3) has become a wide spread practice in the citrus producing countries of the world to improve fruit quality and control fruit drop at various stages of fruit growth and development. Exogenous applications of the growth regulators have been tested on different citrus species alone or in combinations (Nawaz *et al.*, 2008; Saleem *et al.*, 2008) either at full bloom or at preharvest stage. The plant growth regulator 2,4-D is playing a vital role in checking pre-harvest fruit drop and ultimately increasing yield without adversely affecting the fruit quality. GA_3 is used widely in various horticultural crops to increase fruit height, diameter, weight and ultimately the yield in mango (Shinde *et al.*, 2008) to stimulate fruit set in peach (Stutte and Gage, 1990) and Clementine mandarin (Talon *et al.*, 1992), and to control cracking of pomegranate fruit (Sepahi, 1986). Moreover, GA_3 has increased the yield of fruit in Balady mandarin (El-Sese, 2005) and soluble solids as well as fruit weight in sweet cherry (Basak *et al.*, 1998). The world health organization (WHO) does not regard 2,4-D and its salts and esters as either genotoxic/carcinogenic and established an acceptable daily intake (ADI) for 2,4-D of 0-0.01 mg/Kg/day (USDA, 2006) which is far less from the concentration applied when it is sprayed as synthetic auxin on fruit trees. The aim of this experiment was to identify foliar sprays of GA_3 and 2,4-D at fruit pea sized stage to increase yield by reducing fruit drop and to improve fruit quality in Low seeded Kinnow under Faisalabad conditions.

MATERIALS AND METHODS

The present investigation was carried out during two fruiting seasons (2012-13 and 2013-14) on six years old low seeded Kinnow mandarin (*Citrus reticulata* Blanco) plants grafted on rough lemon (*Citrus jambheri* Lush) rootstock at citrus orchard, NIAB, Faisalabad, Pakistan. The plants were planted at 21 feet distance under square system, and had similar agro-climatic conditions. Only healthy plants, with uniformity in size, were studied. Before start of the experiment, soil analysis was carried out for confirmation of soil fertility status of the experimental site. The soil was sandy loam, alkaline in reaction (pH 8.1-8.7) with moderate range of available nitrogen and phosphorus. All the treatments were applied in low seeded Kinnow orchard under standard production practices. Aqueous solution of all the treatments was sprayed with a compressed air hand sprayer on whole plants to run off at fruit pea sized stage (5 mm in diameter). The control plants were sprayed with distilled water. The experiment was laid out in randomized complete block design (RCBD) with three replicates for each treatment. The foliar treatments employed were T_0 – Control (sprayed with distilled water only), T_1 – 10 mg L^{-1} GA_3, T_2 – 20 mg L^{-1} GA_3, T_3 – 30 mg L^{-1} GA_3, T_4 – 40 mg L^{-1} GA_3, T_5 – 10 mg L^{-1} 2,4-D, T_6 – 20 mg L^{-1} 2,4-D, T_7 – 30 mg L^{-1} 2,4-D, T_8 – 40 mg L^{-1} 2,4-D, T_9 – 10 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{10} – 20 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{11} – 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{12} – 40 mg L^{-1} GA_3 + 10 mg L^{-1}2,4-D

Data Collection and Evaluations

At commercial harvest (January), twelve fruits were sampled from all sectors of each replicate to evaluate the treatment effect on fruit quality and yield parameters viz., fruit weight (g), fruit diameter (mm), fruit length (mm), fruit volume (ml), fruit shape index, juice percentage, pH, acidity, TA%, TSS (°Brix), TSS/TA, total sugars, vitamin C contents, number of fruits per plant, fruit weight/plant (Kg), June drop and preharvest fruit drop. Physical and biochemical analysis of fruit were done according to Kassem *et al.* (2011) at the Citrus Laboratory, NIAB, Faisalabad. Fruit weight was recorded by weighing immediately after harvest. Fruit diameter (mm) and length (mm) were measured with the help of digital caliper. The juice was weighed and expressed as a percentage of the total fruit weight. The TSS (°Brix) of the juice was determined by using hand refractometer (ATAGO, USA Inc). Titratable acidity (TA) expressed as citric acid equivalent was determined by titrating 10 ml of the extracted juice against 0.1 N Sodium hydroxide using phenolphthalein as an indicator. The TSS/TA ratio was determined by dividing TSS with TA value. The vitamin C contents (mg/100 ml juice) were determined by titration with 2, 6 dichlorophenol-indophenol dyes. Total sugars (%) were determined according to Maqbool and Malik (2008). The total number of fruit per plant and weight of fruits/plant (Kg) were determined by harvesting fruits at mid-January in the two experimental seasons.

Statistical Analysis

The current experiments were set up in Randomized Complete Block Design and the data were analyzed using STATISTICA (Version 5.5; Stats Soft). Analysis of variance (ANOVA) was used to test the statistical significance, and the significance of differences among means was carried out using Duncan Multiple Range (DMR) (Duncan, 1955) test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Effect on Fruit Weight of Low Seeded Kinnow Mandarin

Table 1 shows data regarding effect of 2,4-D and GA_3 either singly or in combination on fruit weight of low seeded Kinnow. Statistically significant effect of the growth regulators was observed on fruit weight of treated plants compared to untreated control in the current study. We noted that plants treated with 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D had the highest fruit weight (174.18 g and 183.33 g) compared to control in both the seasons. In the first experimental season (2012-13), maximum fruit weight (170.15 g) was obtained in 40 mg L^{-1} GA_3, treated plants and in the second year (2013-14), maximum fruit weight (182 g and 177.67 g) was recorded in plants treated with 10 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D and 20 mg L^{-1} 2,4-D, respectively. The current results indicate that an increase in the concentration of GA_3 increased the weight of retained fruits. Our results support the findings of Gosh *et al.* (2015) who reported that the fruit weight was significantly improved due to application of plant growth regulators. Similar enhancement in fruit weight obtained in the present study by the different sprayed substances specially fruit weight and size, and peel weight is also reported in previous experiments (Alberigo, 2002; El-Otmani *et al.*, 2002; Harty *et al.*, 2004). The current results were also in agreement with those of Saraswathi *et al.* (2003) who observed that 2,4-D and GA_3 and their combinations had beneficial effects on increasing fruit weight. Similarly, the findings of Daulta and Beniwal (1983) are in harmony with the current results who reported that foliar application of growth regulators significantly increased the fruit weight compared to control. Our results are in contrary to the previous report from Brazil which concluded that GA_3 application on 'Monti Parnaso'navel orange trees did not affect the fruit weight (Schafer *et al.*, 2000).

Effect on Number of Fruits/Plant and Weight of Fruits/Plant (kg)

Foliar applications of 2,4-D and GA_3 on low seeded Kinnow plants had significant effects on number of fruits and weight of fruits per plant compared to control (Table 1). It was noted that the number of fruits and weight of fruits per plant were higher in the second experimental year comparatively to first year results. In 2012-13, the highest number of fruits per plant (514.67) and weight of fruits per plant (89.72 Kg) were obtained from plants treated with 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, while in 2013-14 the highest number of fruits per plant (552) and weight of fruits per plant (93.76 Kg) were obtained from plants treated with 20 mg L^{-1} GA_3. The results were found to be in agreement with those of Thomas and Lovatt (2004) and Davies and Zalman (2006) who reported that preharvest application of growth regulators significantly increased number of fruits per plant and ultimately yield. The increase in yield by GA_3 treatments might be due to fact that it stimulates cell division and cell enlargement which reflects on increasing fruit weight and consequently fruit yield (Moore, 1979). Gibberellic acid creates sink strength in the fruit cells, thus attracts water and nutrients, hence increasing fruit weight.

Effect on The Physical Characteristics of Low Seeded Kinnow Fruits

It is well established that in citrus with excessive increase in fruit size, the quality is impaired, while on the other side small sized fruits are of low quality. In this study, low seeded Kinnow plants treated with 2,4-D and GA_3 had superior physical fruit characteristics viz. fruit diameter, height, volume, and shape index compared to control (Table 2). Maximum fruit diameter (72.30, 77.84 mm), height (69.96, 61.14 mm), volume (197.35, 202 ml), and shape index (1.01, 0.84) were obtained in treatment of 30 mg L^{-1} GA_3

+ 10 mg L^{-1} 2,4-D in both the seasons, respectively. In 2012-13, the highest fruit diameter (72.51 mm) and fruit volume (195.73 ml) were obtained from plants treated with 40 mg L^{-1} GA_3 and in 2013-14, the highest fruit diameter (74.43 mm), volume (201 ml) and shape index (0.82) were recorded in 20 mg L^{-1} 2,4-D. The use of PGRs in improving citrus fruit quality had been well documented in previous reports (Fidelibus *et al.*, 2002; Saleem *et al.*, 2008, Kassem *et al.*, 2011, Asharf *et al.*, 2012, 2013). GA_3 is well known for its capacity to increase source activity and redistribute carbohydrate, resulting in increased sink strength of developing fruit, either through increased cell division or enhanced cell size (Iqbal *et al.*, 2011). Application of GA_3 and 2,4-D promotes fruit diameter and height as these growth regulators increase plasticity of the cell wall followed by the hydrolysis of starch into sugars. Thus, reduces the cell water potential, resulting in the entry of water into the cell and causing elongation (Tuan *et al.*, 2013). Therefore, spraying GA_3 and 2,4-D greatly accelerating fruit growth rate (height and diameter) in comparison with untreated control.

Effect on Chemical Characteristics of Low Seeded Kinnow Fruits

The growth regulators (2,4-D and GA_3) treatments at pea sized fruit stage had an increasing trend towards juice percentage, juice pH, juice acidity, TA%, TSS (°Brix), and total sugars (Table 3, 4). As the concentrations of these growth regulators increased, all these characteristics increased accordingly. Compared to control samples, the highest juice percentage (54.98, 57.3) and pH (3.88, 3.54) were recorded in fruits treated with 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D and 40 mg L^{-1} 2,4-D, respectively. The increase in juice volume by 2,4-D might be explained by their influence in enhancing cell expansion which increases vesicle capacity for juice accumulation (Agusti *et al.*, 2002). In control fruit samples, juice acidity (7.33 and 8.33%) and TA% (0.92 and 1.06%) were recorded the highest compared to all other treatments. The data on total soluble solids (TSS, °Brix), TSS/TA, vitamin C (mg/100 ml) and total sugars (%) as well as for control samples are presented in Table (4). Statistical analysis indicated that the results are highly significant for all of the above traits in both the seasons. In comparison to control, maximum TSS (11.77, 10.73°Brix), total sugars (10.08, 8.37%) and vitamin C contents (49.2, 44.2 mg/100 ml) were recorded in 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D in both the seasons. However, it was observed that these values were higher in the 1st experimental year (2012-13) compared to second year (2013-14). The TSS/TA ratio was marginally different among the treatments as well as in the experimental years i.e. it was the highest (15.82) in 40 mg L^{-1} GA_3 treated fruits (2012-13) followed by 2013-14 with 13.03. From the current results, we can infer that both 2,4-D and GA_3 had beneficial effect on chemical attributes studied. In case of juice percentage our results were found to be in harmony with Atawia and El-Desouky (1997) and Matthew *et al.* (2002) who reported that growth regulators sprays at flowering and preharvest stage significantly improved the juice percentage in various citrus species. Results regarding TSS percentage were found to be in pertinent with the report of Huang and Huang (2005) who investigated that application of growth regulators like Auxins and Gibberellins can significantly increase the total soluble solids (TSS) of in citrus fruit juices. The results related to acidity percentage and Vitamin C contents were found to be in close agreement with those of El-Otmani *et al.* (2004), and Xiao *et al.* (2005). They reported that 2,4-D, GA_3 and NAA significantly reduced acidity percentage, whereas increased the Vitamin C contents of the citrus fruits. The results regarding sugar contents clearly supports the findings of Ingle *et al.* (2001) and Wang *et al.* (2004) who reported that 2,4-D and GA_3 and some other growth regulators increased the total sugar contents in various mandarin and sweet orange cultivars. Increase in TSS might be due to conversion of carbohydrate into simple sugars (Rub *et al.*, 2010) and TSS:TA might be due to increase in TSS and decrease in TA (%) in comparison to control.

Effect on Fruit Drop of Low Seeded Kinnow Plants

Foliar application of 2,4-D and GA_3 are regarded as one of the most effective growth regulators in preventing fruit drop in citrus (Michael *et al.*, 1999; Iqbal *et al.*, 2011). The perusal of the Table 5 shows that foliar application of GA_3, 2,4-D and their combinations at different concentrations significantly increased the yield by reducing June and preharvest fruit drop in both the seasons. Preharvest fruit drop is of commercial importance to farmers, as this drop occurs just before harvesting when fruit is physiologically mature. In the current study, the highest June fruit drops (61.01 and 68.58%) as well as preharvest fruit drops (73.26 and 77.67%) were recorded in control plants compared to growth regulator treated Low seeded Kinnow plants. In 2012-13, the lowest June drop and preharvest fruit drops (25.38 and 59.98%, respectively) were obtained in 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D treated plants. The current results are in close connection with the findings of Almedia *et al.* (2004) and Davies and Zalman (2006) who reported that 2,4-D, and GA_3 had significantly reduced fruit drop both in June and at preharvest stage in various citrus species. The results of the present study proved that foliar application of plant growth regulators and their combinations was effective in reducing fruit drop, which ultimately resulted into increase in Low seeded Kinnow fruit yield. The current results also confirm the findings of previous reports which concluded that foliar-applied plant growth regulators were effective in enhancing citrus yield (ElSaida, 2001; Saleem *et al.*, 2005; Omaima and Metwally, 2007; Ashraf *et al.*, 2012, 2013). It seems that GA_3 intensifies an organ ability to function as a nutrient sink and also increases the biosynthesis of IAA in plant tissues which delays the formation of the separation layer therefore enhancing fruit retention (Kassem *et al.*, 2011).

CONCLUSION

Foliar application of plant growth regulators (GA_3 and 2,4-D) has been a quite common practice in some parts of the world. Improvements in fruit quality and yield and reduction in June and preharvest fruit drop are mostly achieved through exogenous application of plant growth regulators. From current results, we can infer that exogenous application of GA_3 and 2,4-D at fruit pea sized stage markedly increased fruit growth, improved fruit quality and yield by reducing preharvest fruit drop in Low seeded Kinnow plants. Positive results can be achieved, by using the right time of spray and required quantity of both GA_3 and 2,4-D.

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Table 1: Effect of growth regulators, on fruit weight, number of fruits/plant and fruit weight/plant of low seeded Kinnow mandarin.

Treat.	**Fruit weight (g)**		**Number of fruits/plant**		**Fruit weight/plant (Kg)**	
	2012-13	**2013-14**	**2012-13**	**2013-14**	**2012-13**	**2013-14**
T_0	132.01h	141.67e	300.33f	364.33e	39.65 g	51.62i
T_1	159.06dc	161.67cd	321.33f	493.33c	51.07f	79.78fg
T_2	148.84efg	154.67d	467bc	552a	89.72a	93.76a
T_3	160.89bcd	168bc	510.33ab	480.67c	82.10b	80.77efg
T_4	170.15ab	145e	441cd	497.67c	75.11bcd	91.18ab
T_5	158.84cd	160cd	417de	491.33c	66.28e	78.63 g
T_6	157.08cde	177.67ab	459.33cd	527.67b	72.08cde	85.33cde
T_7	140.62 gh	170bc	398e	453d	55.88f	76.99 g
T_8	164.24bc	168.33bc	483.67abc	515.67b	79.54bc	86.77bcd
T_9	151.29def	182a	482abc	481.33c	72.91cde	87.62bc
T_{10}	142.12fg	164cd	480.67abc	518b	68.26de	84.9cdef
T_{11}	174.18a	183.33a	514.67a	495c	69.5de	71.78h
T_{12}	166.36abc	166.67c	452.33cd	491c	75.21bcd	81.84defg

Means in each column followed by the same letters are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test. Treatments: T_1 – 10 mg L^{-1} GA_3, T_2 – 20 mg L^{-1} GA_3, T_3 – 30 mg L^{-1} GA_3, T_4 – 40 mg L^{-1} GA_3, T_5 – 10 mg L^{-1} 2,4-D, T_6 – 20 mg L^{-1} 2,4-D, T_7 – 30 mg L^{-1} 2,4-D, T_8 – 40 mg L^{-1} 2,4-D, T_9 – 10 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{10} – 20 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{11} – 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{12} – 40 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D.

Table 2: Effect of growth regulators on physical characteristics of low seeded Kinnow mandarin.

Treat.	**Fruit diameter (mm)**		**Fruit height (mm)**		**Fruit volume (ml)**		**Fruit shape index**	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
T_0	67.92abcd	67.07d	59.66ab	53.83f	140.89e	152.67e	0.88bcde	0.8abc
T_1	71.75a	73.48b	59.98ab	57.34de	181.05c	196abc	0.84de	0.78bc
T_2	69.24abc	72.36b	54.81b	56.74e	157.94d	178.33d	0.79e	0.78bc
T_3	72.25a	74.38b	69.35a	58.49cde	183.18bc	199.33ab	0.96abc	0.78bc
T_4	72.51a	69.25cd	67.94a	56.77e	195.73ab	155e	0.93abcd	0.76c
T_5	70.40ab	73.68b	69.35a	58.4cde	140.48c	187.67bcd	0.91abcde	0.79bc
T_6	67.44abcd	74.43b	61.43ab	62.41a	176.38c	201a	0.91abcd	0.82ab
T_7	64.44bcd	72.96b	54.71b	59.88bc	148.39de	192abc	0.85cde	0.82ab
T_8	68.7abc	73.07b	64.88ab	60.13bc	184.69abc	192.67abc	0.94abcd	0.82ab
T_9	64.17cd	74.25b	63.33ab	59.51bcd	171.08c	198.33abc	0.99ab	0.82ab
T_{10}	62.5d	71.58bc	63.36ab	58.55cde	153.62de	185cd	0.96abc	0.82ab
T_{11}	72.30a	77.84b	69.96a	61.14ab	197.35a	202a	1.01a	0.84a
T_{12}	67.15abcd	72.6b	64.75ab	59.39bcd	183.54abc	190abcd	0.96abc	0.81ab

Means in each column followed by the same letters are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test. Treatments: T_1 – 10 mg L^{-1} GA_3, T_2 –

20 mg L^{-1} GA_3, T_3 – 30 mg L^{-1} GA_3, T_4 – 40 mg L^{-1} GA_3, T_5 – 10 mg L^{-1} 2,4-D, T_6 – 20 mg L^{-1} 2,4-D, T_7 – 30 mg L^{-1} 2,4-D, T_8 – 40 mg L^{-1} 2,4-D, T_9 – 10 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{10} – 20 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{11} – 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{12} – 40 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D.

Table 3: Effect of different growth regulators on juice quality characteristics of low seeded Kinnow mandarin.

Treat.	Juice percentage		Juice pH		Juice Acidity (%)		Titratable acidity (TA) (%)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
T_0	50.23d[1]	52.93ab	3.58c	3.4a	7.33a	8.33b	0.92a	1.06ab
T_1	50.76cd	55.37ab	3.68bc	3.49a	5.77b	6.53c	0.74b	0.84cd
T_2	54.73a	54.3ab	3.73abc	3.73a	5.3b	7.17bc	0.68b	0.92bcd
T_3	52.26abcd	48.87b	3.63c	3.41a	5.77b	7.7bc	0.74b	0.98bc
T_4	50.9cd	53.77ab	3.72abc	3.5a	5.4b	9.87a	0.69b	1.23a
T_5	52.66abcd	55.43ab	3.71abc	3.44a	5.47b	6.5c	0.70b	0.83cd
T_6	51.24bcd	55.37ab	3.6c	3.48a	5.73b	6.07c	0.73b	0.78d
T_7	54.14abc	57.27a	3.72abc	3.47a	5.9b	6.3c	0.76b	0.81cd
T_8	54.15abc	54.8ab	3.88a	3.54a	5.10b	6.73c	0.65b	0.86cd
T_9	50.60d	53.57ab	3.71abc	3.54a	6.23ab	6.2c	0.80ab	0.79cd
T_{10}	46.61e	56.93ab	3.87a	3.44a	5.83b	6.93bc	0.75b	0.89bcd
T_{11}	54.98a	57.3a	3.77abc	3.42a	6.0ab	7.5bc	0.78ab	0.96bcd
T_{12}	54.59ab	55ab	3.86ab	3.42a	6.03ab	7.33bc	0.72b	0.94bcd

Means in each column followed by the same letters are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test. Treatments: T_1 – 10 mg L^{-1} GA_3, T_2 – 20 mg L^{-1} GA_3, T_3 – 30 mg L^{-1} GA_3, T_4 – 40 mg L^{-1} GA_3, T_5 – 10 mg L^{-1} 2,4-D, T_6 – 20 mg L^{-1} 2,4-D, T_7 – 30 mg L^{-1} 2,4-D, T_8 – 40 mg L^{-1} 2,4-D, T_9 – 10 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{10} – 20 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{11} – 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{12} – 40 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D.

Table 4: Effect of growth regulators on chemical characteristics of low seeded Kinnow mandarin.

Treat.	Total soluble solids (TSS) (°Brix)		TSS/TA		Vitamin C (mg/100 ml)		Total sugars (%)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
T_0	11.0b[1]	10.03 b	13.52b	9.73bc	39.2cd	36.8ab	9.04abc	6.82b
T_1	11.33ab	10.07b	15.24ab	12.1ab	45.6ab	37.4ab	8.17bcd	8.57a
T_2	11.37ab	10.27ab	17.16a	11.23ab	41.8bc	37.7ab	9.15abc	7.29ab
T_3	11.23ab	10.47ab	14.50ab	11.07ab	34.67d	36.73ab	8.93abc	7.39ab
T_4	11.13ab	10.33ab	15.82ab	8.23c	41.6bc	34.67b	6.83d	8.24ab
T_5	10.90b	10.3ab	15.68ab	12.73a	35.8d	41.47ab	7.62cd	7.9ab
T_6	11.0b	10.03b	15.04ab	12.57a	39.23cd	37.47ab	9.47ab	8.27ab
T_7	11.30ab	10.5ab	15.10ab	13.03a	41.77bc	41.07ab	9.17abc	8ab

T_8	11.03b	10.43ab	16.97a	12.14ab	39.6cd	36.43ab	8.46abc	8.25ab
T_9	11.07ab	10.17ab	13.93b	12.81a	40.93bc	41.37ab	9.0abc	8.32ab
T_{10}	11.27ab	10.47ab	15.12ab	11.94ab	48.1a	37ab	8.76abc	7.64ab
T_{11}	11.77a	10.73a	14.29ab	11.11ab	49.2a	44.2a	10.08a	8.37ab
T_{12}	11.03b	10.27ab	15.37ab	10.95ab	47.43a	38.3ab	8.39abcd	7.77ab

Means in each column followed by the same letters are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test. Treatments: T_1 – 10 mg L^{-1} GA_3, T_2 – 20 mg L^{-1} GA_3, T_3 – 30 mg L^{-1} GA_3, T_4 – 40 mg L^{-1} GA_3, T_5 – 10 mg L^{-1} 2,4-D, T_6 – 20 mg L^{-1} 2,4-D, T_7 – 30 mg L^{-1} 2,4-D, T_8 – 40 mg L^{-1} 2,4-D, T_9 – 10 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{10} – 20 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{11} – 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{12} – 40 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D.

Table 5: Effect of growth regulators on June and pre-harvest fruit drop of Low seeded Kinnow mandarin.

Treatments	**June fruit drop (%)**		**Pre-harvest fruit drop (%)**	
	2012-13	2013-14	2012-13	2013-14
T_0	61.01a[1]	68.58a	73.26ab	77.67a
T_1	55.24a	59.33bcd	73.22ab	62.33de
T_2	53.79ab	65.67ab	72.27ab	72.33ab
T_3	37.01cd	53.83def	66.72bc	58.08ef
T_4	51.57ab	63.17abc	74.18ab	66.58bcd
T_5	42.10bc	59.08bcd	69.42abc	65.42cd
T_6	53.22ab	65.42ab	73.32ab	70.08bc
T_7	52.60ab	58.33bcde	74.12ab	66bcd
T_8	56.79a	48.42f	77.95a	52.75fg
T_9	29.11de	57.17bcde	61.52cd	63.17de
T_{10}	53.76ab	47.83f	71.23ab	48.67 g
T_{11}	25.38e	55.5cdef	59.98d	68.5bcd
T_{12}	54.76a	50.42ef	75.78ab	50.42 g

Means in each column followed by the same letters are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test. Treatments: T_1 – 10 mg L^{-1} GA_3, T_2 – 20 mg L^{-1} GA_3, T_3 – 30 mg L^{-1} GA_3, T_4 – 40 mg L^{-1} GA_3, T_5 – 10 mg L^{-1} 2,4-D, T_6 – 20 mg L^{-1} 2,4-D, T_7 – 30 mg L^{-1} 2,4-D, T_8 – 40 mg L^{-1} 2,4-D, T_9 – 10 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{10} – 20 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{11} – 30 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D, T_{12} – 40 mg L^{-1} GA_3 + 10 mg L^{-1} 2,4-D.