Pak. J. Bot., 40(3): 1013-1023, 2008.

SPRING APPLICATION OF GROWTH REGULATORS AFFECTS FRUIT QUALITY OF 'BLOOD RED' SWEET ORANGE

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Abstract

Spring applications of two plant growth regulators (GA_3 and 2, 4-D) alone and in combination, were tested on 'Blood Red' sweet orange trees at full bloom. Ultimate effects of these growth regulators were studied on external and internal fruit quality. Fruit weight, diameter, peel thickness and peel quantity were significantly decreased by the growth regulator treatments compared with control while juice contents (%), pulp (%), reducing sugars, non-reducing sugars and total sugars, seeds quantity and quality were significantly improved by GA_3 treatments compared with control. TSS (%), Vitamin C contents were increased by growth regulators treatments compared with non treated ones. In organoleptic tasting, taste, peel colour, pulp colour and appearance were also improved by growth regulator treatments compared with control. In conclusion mixture treatments performed best with regards to biochemical parameters compared with control.

Introduction

Fruit quality reflects numerous external and internal attributes, on the basis of which, minimum standards of palatability and commercial acceptability have been established over the years (Davies & Albrigo, 1994). In citrus, external features like fruit colour, size, and peel texture are the important parameters to estimate the quality of the fruit, while internal characters contributing to fruit quality include amount and quality of juice, seediness, vitamin C contents, total soluble solids (TSS), titratable acidity (TA) and TSS: TA ratio (Ahmed, 2006). The composition of citrus fruit varies with cultivar, climate, rootstock and cultural practices (Davies & Albrigo 1994; Sattar, 1999; Ahmed, 2006).

Today, Pakistan stands at 13th and 10th position among top citrus producing and exporting countries of the world respectively (Anon., 2005). The average yield of citrus in Pakistan is about 10 t ha^{-1} which is far less than world average citurs yield 30 t ha^{-1} (Anon., 1993). Annually, 1.7 MMT citrus is produced from a total area of 185 thousand hectares in Pakistan (Anon., 2005). The citrus industry in Pakistan has turned into monoculture comprising of 'Kinnow' mandarin although four decades ago among other species sweet orange was the major component of citrus plantation in the country (Malik *et al*., 1993). Low productivity and inferior fruit quality are the major reasons of depletion of sweet orange from our citrus industry. Oversized fruit with low juice contents having poor fruit quality discouraged the citrus growers and thus 'Kinnow' mandarin has replaced most of the sweet orange area in the Punjab province.

The application of plant growth regulator (PGR) can provide significant economic advantages to citrus growers when used in appropriate situations as these have proven effective in stimulating a number of desired responses such as increase in fruit size and delay in fruit maturity (Coggins Jr & Hield, 1968). Fruit development is thought to be triggered by hormones as it is evident from the report by Talon *et al*., (1990) that the endogenous gibberellin status of the developing citrus ovaries is the limiting factor for the initiation of fruit development. Application of Gibberellic acid (GA_3) before or at full

bloom increased fruit size and pedicel length of paclobutrazol (PP333) treated apple trees (Curry & Williams, 1983). 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 to clearly increase the fruit weight, peel thickness, juice content with improved taste of grapefruit (Berhow, 2000). The 'Baldy' mandarin fruit weight, diameter, volume, juice percentage, TSS, TA, TSS: TA ratio and ascorbic acid in juice were found to be affected by mid November spray treatments of GA_3 and $CaCl_2$ (El-Hammady *et al*., 2000).

A lot of work has been done on the use of PGR to improve fruit size, delay fruit maturity and over come rind staining in citrus. However, no studies have been conducted to evaluate the complete profile of fruit quality in response to growth regulators application to citrus during full bloom. Keeping in view the importance of fruit quality in citrus and the role of plant PGR in improving fruit size, juice contents and other quality issues, this study was designed to evaluate the effect of exogenous application of PGR at full bloom on the physico-chemical qualities of 'Blood Red' sweet orange. Overall objective of the experiment was to improve the quality of sweet oranges.

Materials and Methods

The fruit for this study were taken from 15 years old sweet orange (*Citrus sinensis* Osbeck L cv. Blood Red) trees growing at Experimental Fruit Garden Sq No. 9, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Punjab, Pakistan. The trees were spaced at about 7 m x 7 m, grafted on rough lemon (*Citrus jambheri* Lush) rootstock, growing under similar agro-climatic conditions with similar cultural practices during the period of investigation (Saleem *et al*., 2004). Before start of the experiment, the trees were selected keeping in view uniformity of growth, fruit yield potential and possible disease incidence. Further soil analysis was done for evaluation of the soil fertility status of the soil, by collecting representative soil samples at different depths from four sites of the experimental orchard. The soil in the experimental site was sandy loam, alkaline in reaction (pH 8.13-8.5) having lower range of available nitrogen, phosphorus when analysed before start of the experiment Thirty nine uniform trees with no apparent disease incidence were selected for the experiment in the form of a block. A randomized complete block design was followed with 3 replications and a single tree was selected as a treatment unit.

Application of plant growth regulators: Efficacy of various concentrations of GA_3 and 2, 4-D alone and in combination was tested on 'Blood Red' sweet oranges to improve the fruit quaity during the years 2005-06. Aqueous solution of all the treatments was prepared and sprayed on whole trees to run off during full bloom according to method described earlier by Saleem *et al.,* (2007).

Treatments

T_0	Control	T_7	30 mg L^{-1} 2, 4-D
T_1	20 mg L^{-1} GA_3	T_8	45 mg L^{-1} 2, 4-D
T_2	25 mg L^{-1} GA_3	T_9	GA_3 + 2, 4-D (20 mg L^{-1} each)
T_3	30 mg L^{-1} GA_3	T_{10}	GA_3 + 2, 4-D (25 mg L^{-1} each)
T_4	45 mg L^{-1} GA_3	T_{11}	GA_3 + 2, 4-D (30 mg L^{-1} each)
T_5	20 mg L^{-1} 2, 4-D	T_{12}	GA_3 + 2, 4-D (45 mg L^{-1} each)
T_6	25 mg L^{-1} 2, 4-D		

(G = GA_3, G_1 = 10 mg L^{-1}, G_2 = 20 mg L^{-1}, G_3 = 30 mg L^{-1}, G_4 = 45 mg L^{-1}, D = 2, 4-D, D_1 = 10 mg L^{-1}, D_2 = 20 mg L^{-1}, D_3 = 30 mg L^{-1}, D_4 = 45 mg L^{-1})

Fruit sampling and physical analysis: Before start of fruit harvest, 30 fruit were sampled per replication uniformly from all the sides of the each tree and average fruit weight (g) was recorded. Sampled fruit were divided in two lots i.e., 20 for hedonic scale rating and 10 for physico-chemical analysis. The fruit diameter (mm) was measured using a manual vernier caliper. The fruits were washed under tap water, dried under shade, cut into two halves, and seeds of each 10 fruit was extracted separately to collect data on seed number and weight (g) while peel thickness (mm) was measured using a vernier caliper. After peeling, juice was extracted in a beaker to get average juice weight (g), while peel and pulp was also weighed (g) separately and the quantities of all these were expressed on percentage basis. A part of the juice was kept in sealed plastic container for biochemical analysis at the spot. Hedonic scale rating for pulp colour, taste, appearance and colour break of fruit was done by the method as described by Peryam & Pilgrim (1957).

Biochemical analysis of fruit: The fruit juice quality analyses including total soluble solids (TSS), acidity, TSS/acidity ratio, vitamin C, and sugars profile were done following standard procedures (Sattar, 1999) at the Pomology Laboratory, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.

Statistical analysis: The response of experimental trees to different treatments for fruit quality was evaluated by statistical analysis of the data using software MSTAT-C (Freed & Scott, 1986), while DMR test was used to compare the differences among the treatment means at 5% probability level.

Results and Discussion

Physical analysis of fruit: All the experimental treatments significantly decreased fruit weight (111.5 g) compared with control (151.8 g). Maximum fruit weight (151.8 g) was achieved from control trees, statistically similar to 30 and 45 mg L^{-1} 2, 4-D treatments followed by 25 mg L^{-1} GA_3, 45 and 20 mg L^{-1} mixture (GA_3 + 2, 4-D) treatments. Minimum fruit weight was observed in 20 mg L^{-1} 2, 4-D treatment, which was at par with 20 mg L^{-1} GA_3, 25 and 30 mg L^{-1} mixture and 30 mg L^{-1} GA_3 (Table 1).

Fruit diameter was also significantly affected by different treatments compared with control. The treatments decreased the diameter (60.3 mm) as a whole compared with control (65.5 mm). Maximum fruit diameter (65.5 mm) was recorded from control trees, statistically similar fruit diameter in 30, 45 mg L^{-1} 2, 4-D, 20 mg L^{-1} mixture and 45 mg L^{-1} GA_3. Fruit of minimum diameter (54.9 mm) were found in trees treated with 25 mg L^{-1} mixture, statistically similar to 20 mg L^{-1} 2, 4-D, 25 mg L^{-1} 2, 4-D and 20 mg L^{-1} GA_3 treatments (Table 1). Growth regulator treatments had significant differences in fruit peel thickness compared with control. The maximum peel thickness (4.80 mm) was observed with application of 20 mg L^{-1} 2, 4-D, which was statistically similar to 25 mg L^{-1} 2, 4-D (4.73 mm), 20 mg L^{-1} GA3 (4.57 mm) treated trees and control (4.63 mm), while minimum peel thickness (2.70 mm) was recorded in fruit treated with 25 mg L^{-1} GA_3 + 2, 4-D mixture (6.55 mm). The application of 45 mg L^{-1} GA_3 (4.1 mm) and 45 mg L^{-1} 2, 4-D (4.1 mm) significantly decreased the peel thickness compared with control. Many of the treatments e.g., 45 mg L^{-1} GA_3 (4.07 mm) and 45 mg L^{-1} 2, 4-D (4.10 mm) significantly decreased thickness of peel compared with control. Internal physical characters recorded were peel, pulp and juice percentage in fruit harvested after application of different treatments (Table 1). The results regarding fruit peel percentage

Table 1. Effect of spring application of plant growth regulators on physical and biochemical characters of 'Blood Red' sweet Orange Fruit.

Treatments	Fruit weight (g)	Fruit diameter (mm)	Peel thickness (mm)	Peel (%)	Pulp (%)	Juice (%)	TSS (%)	Acidity (%)	Vit. C (mg/100ml)	TSS/ Acidity
Control	151.80a	65.5a	4.63abc	36.06abc	23.00cde	40.77cd	9.22c	0.82fg	48.10bc	10.92def
G_1	90.25fg	58.4defg	4.57abcd	42.42a	17.57f	40.01d	11.48a	0.96ab	51.97ab	12.03bc
G_2	124.80bc	63.0abc	3.67ef	20.63e	27.97b	51.40a	8.83d	0.88de	45.33cd	10.04fgh
G_3	96.80defg	59.6cdef	4.27bcd	31.41bcd	22.81cde	45.78abcd	8.00e	0.91bcd	48.47bc	8.80i
G_4	119.80bcde	62.3abcd	4.07de	25.72de	31.88a	42.42bcd	10.60b	0.99a	47.78bc	10.7efg
D_1	86.90g	56.3fg	4.80a	40.76ab	17.41f	41.83cd	8.60d	0.78gh	54.25a	11.05de
D_2	108.80cdefg	58.3efg	4.73ab	31.17bcd	26.55bc	41.16cd	7.93e	0.71i	48.17bc	11.23cde
D_3	142.90ab	6.45ab	4.53abcd	35.70abc	22.78cde	39.15d	8.20e	0.74hi	46.45e	11.08de
D_4	129.20abc	63.9ab	4.10de	38.07abc	22.22de	39.19d	8.09e	0.85ef	45.75bcd	9.55hi
G_{1+} D_1	115.90bcdef	63.0abc	3.50f	33.47abcd	19.38ef	49.93ab	9.37c	0.95abc	40.98de	9.89gh
G_{2+} D_2	94.17efg	54.9g	2.70g	34.01abcd	19.47ef	44.88abcd	10.55b	0.89cde	47.32dc	11.76cd
G_{3+} D_3	105.50cdefg	59.4cdef	4.13cde	29.84cd	24.97bcd	48.81abc	11.57a	0.85ef	44.23cd	14.03a
G_{4+} D_4	122.90bcd	60.5bcde	4.30abcd	34.66abcd	20.08ef	44.79abcd	11.69a	0.92bcd	44.42cd	12.79b
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N.S = Non -significant, * = Figures sharing the same letters in the same column differ significantly at $P \leq 0.05$

G = GA_3.G_1= 10 mg L^{-1}. G_2 = 20 mg L^{-1}. G_3 = 30 mg L^{-1}. G_4 = 45 mg L^{-1}. D = 2, 4-D. D_1 = 10 mg L^{-1}. D_2 = 20 mg L^{-1}. D_3 = 30 mg L^{-1}. D_4 = 45 mg L^{-1}

showed significant differences among the treatments compared with control. Maximum peel (42.4%) was recorded in fruit harvested from 20 mg L^{-1} GA_3 treated trees, and found in descending order: 20 mg L^{-1} mg L^{-1} 2, 4-D (40.8%), 45 mg L^{-1} 2, 4-D (38.1%), control (36.01%), 30 mg L^{-1} 2, 4-D (35.7%), 45, 25, and 20 mg L^{-1} mixtures (34.7%, 34% and 33.47%) respectively. Minimum peel percentage (20.6%) was found in fruit treated with 25 mg L^{-1} GA_3. Remaining treatments were found statistically similar regarding the peel thickness of fruit.

The quantity of pulp in fruit was also significantly different among different treatments with maximum fruit pulp (31.7%) recorded in 45 mg L^{-1} GA_3 treated trees, while minimum fruit pulp (17.4%) was found from trees treated with 20 mg L^{-1} 2, 4-D compared with control (23%). Maximum fruit juice (51.4%) was found in fruit harvested from 25 mg L^{-1} GA_3 treated trees, statistically similar to 30 mg L^{-1} (44.9%), 25 mg L^{-1} (49.9%) and 45 mg L^{-1} (44.8%) mixture treatments. Minimum fruit juice (39.2%) was achieved from fruit harvested from trees treated with 30 mg L^{-1} 2, 4-D, statistically similar to all remaining treatments including control.

Effect of growth regulator treatments on average number of seeds per fruit, their weight and percentage of healthy and aborted seeds was also recorded (Table 2). Number of seeds per fruit was significantly different in different treatments with maximum seeds per fruit (10.9) in trees sprayed with 30 mg L^{-1} mixture of GA_3 + 2, 4-D, which was also statistically similar to 25 mg L^{-1} GA_3. Minimum seeds per fruit (6.2) were extracted from 20 mg L^{-1} 2, 4-D treated trees, statistically similar to 45 mg L^{-1} 2, 4-D, control, 25 mg L^{-1} 2, 4-D, 45 mg L^{-1} mixture and 30 mg L^{-1} GA_3 treatment. Likewise, seed weight per fruit was also found significantly different among treatments with maximum seed weight per fruit in 30 mg L^{-1} mixture of GA_3 + 2, 4-D treated fruit, statistically similar to 25 mg L^{-1} GA_3 and mixture treatments (45 mg L^{-1} GA_3 and 25 mg L^{-1} 2, 4-D). Minimum mean seed weight in fruit was recorded in trees sprayed with 30 mg L^{-1} GA_3, statistically similar to 20 mg L^{-1} 2, 4-D and 20 mg L^{-1} GA_3. Rest of the treatments remained statistically similar. All the treatments had decreasing trend towards production of healthy seeds compared with control, except 20 mg L^{-1} mixture treatment which had maximum healthy seeds (88.1%) per fruit, statistically similar to control (86.9%), 45 mg L^{-1} GA_3 (86.1%), 25 mg L^{-1} 2, 4-D (85.3%) and 45, 30 mg L^{-1} mixture (83.1%, 80.6% respectively). Minimum healthy seeds (37.1%) were observed in 20 mg L^{-1} 2, 4-D, which was at par with 20 mg L^{-1} GA_3 treatment. Significant differences among treatments were observed in seed abortion intensity which was maximum (62.9%) in 20 mg L^{-1} 2, 4-D treatment followed by 20 mg L^{-1} GA_3 (54.4%), while minimum (11.9%) in 20 mg L^{-1} mixture which was statistically similar to control (13.8%), 45 mg L^{-1} GA_3 (13.9%), 20 mg L^{-1} 2, 4-D (14.7%), 45 mg L^{-1} mixture (16.9%), 30 mg L^{-1} mixture (19.3%) and 30 mg L^{-1} 2, 4-D (22.7%).

To elucidate the precise impact of PGR treatments on physical characteristics of 'Blood Red' sweet orange, fruit weight, diameter and peel thickness etc., were recorded (Table 1). Fruit weight was reduced by growth regulators treatments which might be due to increase in the total number of fruit (yield) per tree with application of PGR which shared assimilates accordingly. Similarly, reduction in fruit weight has also been reported in 'Valencia Late' sweet orange due to decrease in the size with the application of 2, 4-D (Stewart *et al*., 1951). Similarly, fruit weight is very important with respect to fruit quality as it adds towards fruit yield. Fruit weight follows yield trends i.e., generally larger fruits during lower total fruit yield and *vice versa* (Alva *et al*., 2006). Fruit diameter was significantly reduced by all those treatments which increased the number of fruit per tree as in last years the general production per tree was half of this year (bench mark data). This result is contrary to the finding of Stewart *et al.*, (1965) who reported an

Table 2. Effect of spring application of plant growth regulators on physical and biochemical characters of 'Blood Red' sweet Orange Fruit.

Treatments	Sugars profile			Seed quantity and quality				Organoleptic evaluation			
	Total sugars (%)	R sugars (%)	NR sugars (%)	Total seed/ Fruit	Seed wt./ Fruit (g)	Healthy seeds (%)	Aborted seeds (%)	Appearance (Score)	Peel colour (score)	Pulp colour (score)	Taste (score)
Control	5.23efg	2.38f	2.85de	7.03cde	1.23de	86.18ab	13.75cd	2.42e	3.07c	3.20f	3.02h
G_1	9.06a	3.92a	5.14a	8.27c	1.03e	45.59d	54.44a	2.39e	2.17d	3.51ef	3.87bcde
G_2	7.46b	3.43b	4.03b	9.90ab	1.90ab	75.00bc	24.99bc	3.75bcd	3.09c	3.56def	3.64cdef
G_3	5.47ef	2.74de	2.73def	7.83cde	0.93e	64.49c	35.51b	3.21d	2.77cd	3.42ef	3.58def
G_4	5.03fg	2.99cd	2.04fg	8.23cd	1.33de	86.09ab	13.91cd	3.78bcd	3.13c	3.98bc	3.99bcd
D_1	4.57gh	2.53ef	2.04fg	6.20e	1.03e	37.13d	62.87a	3.19d	3.42bc	3.55def	3.48efg
D_2	3.88h	2.23f	1.65g	7.17cde	1.30de	85.34ab	14.69cd	3.94bc	3.84b	3.29f	3.39fgh
D_3	4.45gh	2.34f	2.11efg	8.03cd	1.40cde	77.32ab	22.67cd	3.54cd	3.79b	3.28f	3.11gh
D_4	4.13h	2.51ef	1.62g	6.53de	1.30de	75.17bc	24.83bc	3.50cd	3.42bc	3.79cde	3.30fgh
$G_{1+}D_1$	5.97de	2.86cde	3.11cd	8.57bc	1.57bcd	88.07a	11.93d	4.30ab	3.94ab	3.93bcd	4.07bc
$G_{2+}D_2$	6.94bc	3.12bc	3.82bc	8.13cd	1.67abcd	74.70bc	25.30bc	4.75a	4.53a	4.22ab	4.25ab
$G_{3+}D_3$	6.90bc	3.18bc	3.72bc	10.90a	2.07a	80.63ab	19.34cd	4.14bc	3.81b	4.30ab	4.52a
$G_{4+}D_4$	6.47cd	3.21bc	3.09cd	7.80cde	1.87abc	83.14ab	16.86cd	4.13bc	3.88b	4.50a	4.50a
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N.S = Non-significant, * = Figures sharing the same letters in the same column differ significantly at $P \leq 0.05$
R = reducing. NR = non-reducing. G = GA_3. G_1 = 10 mg L^{-1}. G_2 = 20 mg L^{-1}. G_3 = 30 mg L^{-1}. G_4 = 45 mg L^{-1}. D = 2, 4-D. D_1 = 10 mg L^{-1}. D_2 = 20 mg L^{-1}. D_3 = 30 mg L^{-1}. D_4 = 45 mg L^{-1}.

increase in fruit size of sweet orange with exogenous application of auxin just after bloom. However, it has also been reported that there was no effect of growth regulators spray on fruit development of 'Pera' sweet orange (Almeida *et al*., 2004). Similarly, 25 mg L^{-1} GA_3 application on flowers of 'Satsuma' mandarin increased the total fruit yield, while fruit size was decreased (Greenberg *et al*., 2000). 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 in Brazil (Schafer *et al*., 2000). Application of different growth regulators [GA, 2, 4-D and Naphthalene Acetic Acid (NAA) alone and in combination] on 'Pera' orange had no influence on the parameters of fruit development such as fruit length diameter and fresh mass (Almeida *et al*., 2004).

There were significant differences among treatments in peel thickness, but the effect of growth regulators was not uniform in different treatments. However, 20 mg L^{-1} 2, 4-D gave maximum peel thickness which is in accordance with reports by Stewart *et al*., (1951), who reported that 25 mg L^{-1} 2, 4-D application at full bloom increased the peel thickness of sweet orange fruit. However, with later application of 2, 4-D in summer, peel thickness was decreased (Coggins Jr & Hield, 1968) which is in contrary to Hield *et al*., (1965), who reported increased peel thickness by GA spray on 'Washington Navel' during June.

The citrus fruit is a hesperidium berry having a leathery peel surrounding the edible portion of the fruit. The edible portion comprises of segments containing juice vesicles and seeds. The presence of leathery rind protects the fruit from damage during handling and desiccation during storage (Davies & Albrigo, 1994). Peel weight may contribute about $1/3^{rd}$ of the total biomass of the citrus fruit (Ahmed, 2006). From the results in Table 1, it is evident that with increase in peel thickness especially due to application of GA_3 the peel weight was also increased. So, it is inferred from the above findings that growth regulator treatments had no consistent effect on peel quantity and the significant difference in treatments might be due to different peel thickness in different treatments. Most of the treatments produced equal quantity of pulp except some outliers (42.42 % in 10 mg L^{-1} GA_3) having 31.9%, 27.9% and 26.6% pulp in 45 mg L^{-1}, 25 mg L^{-1} GA_3 and 20 mg L^{-1} 2, 4-D treatments respectively. This behaviour in pulp production may be attributed to least effect of treatments on pulp quantity in fruit. Juice contents were higher in all the mixture treatments compared with control and higher doses of GA_3 (30 and 45 mg L^{-1}), being at par with each other, reflecting increase in juice contents by GA_3 application alone and in combination with 2, 4-D. These effects of plant growth regulators on fruit juice contents are contrary to the previous findings in which the spray applications of 2, 4-D, GA or their combination did not affect the juice contents of 'Washington Navel' sweet orange (Lima & Davies, 1984). Our results confirm the findings of Fidelibus *et al*., (2002) that GA application increases the juice contents of processing oranges. However the results reported by Fidelibus *et al*., (2002) are not consistent for all varieties as juice content of 'Hamlin' and 'Valencia' increased with the application of GA_3 but not that of 'Pineapple' at same application timings and harvest dates.

Generally the number of seeds in all the treatments did not exceed 10 per fruit in 'Blood Red' sweet orange, which must be attributed towards cultivar characteristics as in 'Kinnow' mandarins more than 20 seeds are common. Although there existed significant differences among treatments but the differences were not uniform according to the varying concentrations of different growth regulators. So, the difference might be due to other unknown reasons which has yet to be studied. Previously, it has been reported that sometimes in seedy citrus cultivars seed number is reduced by spray of GA_3, however it

is cultivar dependent (Lima & Davies, 1984). Variation in seed weight was due to different number of seeds and not due to seed health as it was not affected by treatments. Seed abortion was also similar in most of the treatments except two outliers having 54.4 % and 62.9 % aborted seeds in 20 mg L^{-1} GA_3 and 10 mg L^{-1} 2, 4-D respectively. Our results do not coincide with previous findings by Moreira *et al*., (1996) who reported that 200 mg L^{-1} GA_3 spray application one month after anthesis reduced the fruit size and seed number per fruit of 'Ponkan' mandarin. Overall seediness did not seem a major problem in 'Blood Red' cultivar. So, if the production of 'Blood Red' sweet orange is reasonable it may take a suitable place in our citrus industry due to this characteristic.

Hedonic scale rating: Peel colour, smoothness of fruit, TSS:TA ratio, taste and pulp colour were tested by hedonic scale rating (Table 2) which revealed that peel colour was significantly affected by different treatments compared with control. Maximum colour break (4.5) was observed in 25 mg L^{-1} mixture treatment, statistically similar to 20 mg L^{-1} mixture treatment (3.9), followed by 45 mg L^{-1} (3.9) and 30 mg L^{-1} (3.8) mixture treatment. Minimum peel colour break (2.2) was recorded in 20 mg L^{-1} GA_3 treatment, which was statistically similar to 30 mg L^{-1} GA_3 (2.8) followed by control (3.1), 25 mg L^{-1} GA_3 (3.1) and 45 mg L^{-1} GA_3 (3.1). The smoothness of fruit surface (appearance) was also significantly affected by all the treatments compared with control. The smoothest surface was found in fruit harvested from 25 mg L^{-1} mixture treatment, statistically similar to 20 mg L^{-1} mixture (4.3), followed by 30 mg L^{-1} mixture (4.1) and 45 mg L^{-1} mixture treatment (4.1). The most rough surface was found in fruit harvested from 20 mg L^{-1} GA_3 (2.38) followed by control (2.4). Pulp colour was significantly improved by different treatments of plant growth regulators compared with control. The best pulp colour (4.5) was judged in 45 mg L^{-1} mixture treatment fruit, statistically similar to 30 mg L^{-1} (4.3) and 25 mg L^{-1} (4.2) mixture treatments compared with the poorest pulp colour (3.2) observed in fruit from control tree, which was at par with 30 mg L^{-1} 2, 4-D (3.3) and 25 mg L^{-1} 2, 4-D (3.3) treatment. TSS: TA ratio was significantly different among different treatments compared with control, with highest value (14) in fruit harvested from 30 mg L^{-1} mixture treatment compared with control, followed by 45 mg L^{-1} mixture treatment (12.8), statistically similar to 20 mg L^{-1} mg L^{-1} GA_3 (12). Minimum TSS:TA ratio (8.8) was noted in 30 mg L^{-1} GA_3 treatment compared with control, statistically similar to 45 mg L^{-1} 2, 4-D (9.6). The taste of the fruit was significantly enhanced by all the treatments compared with control. The best fruit taste (4.5) was found in 30 mg L^{-1} mixture treatment, statistically similar to 45 mg L^{-1} mixture (4.5), 25 mg L^{-1} mixture (4.2) treatments followed by 20 mg L^{-1} mixture (4.1), 45 mg L^{-1} GA_3 (3.9) and 20 mg L^{-1} GA_3 (3.8). Minimum score (3.02) of fruit taste was recorded in control trees, statistically similar to 30 mg L^{-1}, 45 mg L^{-1}, 25 mg L^{-1} and 20 mg L^{-1} 2, 4-D with scores 3.1, 3.3, 3.4 and 3.5 respectively.

Spring application of PGR significantly affected the smoothness of fruit surface, peel colour development, taste and pulp colour of 'Blood Red' sweet orange. Mixture treatments produced the tastiest fruit compared with control, which might be due to some synergistic effect of the both growth regulators as most of the individual treatments got similar score in organoleptic evaluation of fruit. Peel colour development was delayed in most of individual treatments of GA_3 like 10 and 25 mg L^{-1} concentration, however, other two concentrations behaved statistically similar to control in colour development. 2, 4-D treatments produced comparatively better colour compared to control as well as GA_3,

which is contrary to previous reports that 2, 4-D delays yellow colour development in lemons (Rajput & Haribabu, 1985). Similarly, GA_3 is also reported to delay colour development in lemons (Rajput & Haribabu, 1985) and is used to extend the growth period of crop which confirms our finding of low score in colour development in GA_3 individual treatments.

Biochemical analysis of fruit: Data regarding biochemical characteristics of fruit juice, including TSS, TA, Vitamin C, total sugars, reducing sugars and non-reducing sugars is presented in Table 1. There was no clear cut trend of TSS among treatments compared with control as some of the treatments gave higher TSS, while others had lower TSS than control. Maximum TSS (11.7%) was recorded in 45 mg L^{-1} mixture treatment, statistically similar to 30 mg L^{-1} mixture (11.6%) and 20 mg L^{-1} GA_3 (11.5%), while minimum TSS (7.9%) was recorded in 25 mg L^{-1} 2, 4-D, which was at par with 30 mg L^{-1} GA_3, 45 p mg L^{-1} 2, 4-D and 30 mg L^{-1} 2, 4-D. Most of the treatments produced higher TA compared with control, while some of the treatments produced lower acidity levels. Maximum acidity (0.99%) was recorded in 45 mg L^{-1} GA_3, statistically similar to 20 mg L^{-1} GA_3 (0.96%) and 20 mg L^{-1} mixture treatment (0.95%). Minimum acidity (0.71%) was found in 25 mg L^{-1} 2, 4-D, statistically similar to 30 mg L^{-1} 2, 4-D (0.74%). Regarding vitamin C, the data revealed that there were significant differences among the treatments with maximum vitamin C (54.3 mg/100 ml) in 20 mg L^{-1} 2, 4-D treatment, statistically similar to 20 mg L^{-1} GA_3 (51.9 mg/100 ml). Minimum vitamin C (36.5 mg/100 ml) was recorded in 30 mg L^{-1} 2, 4-D, statistically similar to 20 mg L^{-1} mixture (40.9 mg/100 ml) treatment.

Amount of total sugars was found significantly different among various treatments with maximum total sugars (9.1%) in 20 mg L^{-1} GA_3 treated trees which was significantly higher from all other treatments compared with control. Most of the treatments had decreasing trend in total sugars compared with control with minimum total sugars (3.9%) in 25 mg L^{-1} 2, 4-D, statistically similar to all other concentrations of 2, 4-D. Reducing sugars were also significantly affected by different treatments compared with control being maximum (3.92%) in juice of fruit harvested from 20 mg L^{-1} GA_3 treated trees, significantly different from all other treatments. Minimum reducing sugars (2.2%) were obtained from 25 mg L^{-1} 2, 4-D, treatment, statistically similar to all other treatments of 2, 4-D and control as well. Non reducing sugars were also significantly affected by the treatments compared with control, being maximum (5.14%) in 20 mg L^{-1} GA_3, significantly superior to all other treatments followed by 25 mg L^{-1} GA_3 (4%), 25 and 30 mg L^{-1} (3.8% and 3.72%) respectively. Mixture treatments @ 20 mg L^{-1} and 45 mg L^{-1} had non-reducing sugars of 3.11% and 3.09% respectively, statistically similar to control (2.85%). Minimum non-reducing sugars (1.6%) were recorded in 45 mg L^{-1} 2, 4-D, statistically similar to 25 mg L^{-1} 2, 4-D (1.7%), 45 mg L^{-1} GA_3 (2.04%), 20 mg L^{-1} 2, 4-D (2.04%) and 30 mg L^{-1} 2, 4-D (2.11%).

There were significant differences among treatments in case of TA and Vitamin C, but with no clear trend of treatments and thus could not be explained whether it was the effect of treatments or any other factor. However, the determined values of different parameters were found according to previous findings of Stewart & Klotz (1947), Wright & Pena (2002) and Barry *et al.*, (2004). The plant physiologists have been studying the effect of PGR on citrus fruit quality and had often found no or inconsistent effect of exogenous application of PGR on fruit quality parameters like TSS, sugars, TA, Vitamin C etc., (Stewart & Klotz, 1947; Hield *et al*., 1965; Lima & Davies, 1984).

Conclusion

From the investigations it is clear that with application of PGR at full bloom stage, fruit quality can be positively manipulated in Blood Red sweet orange. The growth regulators especially all mixture treatments had pronounced effect on improving fruit quality in citrus.

Acknowledgements

We are thankful to (Late) Professor Dr. Muhammad Ibrahim Chaudhary Institute of Horticultural Sciences, University of Agriculture, Faisalabad, for his kind help in designing and executing the experiment. This research was supported by Higher Education Commission, Islamabad, Pakistan through financial help in the form of indigenous scholarship scheme for Ph.D. students.

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(Received for publication 20 December 2007)