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EFFECT OF EXOGENOUS GROWTH REGULATORS APPLICATION ON JUNE FRUIT DROP AND FRUIT QUALITY IN *CITRUS SINENSIS* CV. BLOOD RED

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Two plant growth regulators gibberellic acid (GA_3) and 2,4-D were exogenously applied in different concentrations alone and their combinations on Blood Red sweet orange trees two months after fruit set. June fruit drop and different fruit quality parameters were studied to evaluate the optimum concentration of the growth regulators. Fruit drop was non significant among treatments with a range of 10.87 % to 33.82 %. Fruit diameter and seed health was not affected by any of the treatments. Fruit weight was decreased by most of the growth regulator treatments compared with control. Juice quantity, TSS, total sugars and reducing sugars were improved by most of the treatments compared with control but in case of acidity and vit. C, there was not any clear cut trend of treatment effect.

Keywords: Citrus, GA_3, 2,4-D, fruit abscission, fruit quality

INTRODUCTION

The depletion of sweet oranges from citrus industry in Pakistan has been a matter of great concern since long as the industry has turned into monoculture by the dominance of Kinnow mandarin having more than 70% area. Sweet oranges are established crop having maximum area under cultivation and production as well throughout the world (Davies & Albrigo, 1994).

The main obstacle in the success of sweet orange culture in Pakistan especially Punjab province is its shy bearing, poor quality fruit and short lived orchards (Malik *et al*., 1993) although its production in some parts of the world is 60-80 tonnes ha^{-1} (Davies & Albrigo, 1994) with commercial orchard age of over 60 years. If we can increase the fruit yield and commercial production age of sweet oranges, still they have very suitable place among citrus industry of Pakistan.

Besides other factors, fruit drop has been considered a major cause of low fruit yield in fruit trees like citrus. Fruitlet abscission is a common phenomenon that occurs in many crop plants in response to developmental and environmental cues, leading to significant crop losses (Marcelis *et al*., 2004).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 also called as cleaning drop (Racsko *et al*., 2006). 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' (Stewart and Klotz, 1947; Agusti *et al*., 1982; Racsko *et al*., 2006). It was reported by Saleem *et al*., (2005) that most of the fruit set was dropped (80-91%) during the first month after final fruit set.

Improved fruit yield and quality may be obtained by reducing heavy fruit drop (Lima and Davies, 1984; Malik *et al.* 1993; Penter and Stassen, 1999).Plant growth regulation chemicals have been used extensively both in basic citrus research and numerous commercial crop applications. They have been used to control citrus fruit production by influencing flowering, fruit set and fruit drop (El-Otmani *et al*., 1995; Berhow, 2000). These have also been used to influence fruit quality factors like peel quality, colour, fruit size, juice acidity and to improve TSS in different citrus species in the world (Berhow and Vandercook, 1992). Application of 2, 4-D (17-20 ppm) at flowering reduced transiently fruitlet growth rate and delayed abscission in Esbal clementine (Duarte *et al*., 1996). The auxins have direct effect on abscission which causes a delay of abscission and may result eventually in an increased fruit set in citrus (Greenberg and Goldschmidt, 1992; Erner *et al*., 1993). Lima and Davies (1984) successfully reduced summer drop with 20ppm 2,4-D or in combination with 20ppm GA applied to nine weeks after midbloom. Similarly in a study by Kaur *et al.* (2000), growth regulators treatments 2,4-D, GA, NAA at 15 and 20ppm concentrations respectively reduced fruit drop in Kinnow mandarin. The highest fruit drop control was exhibited by 2,4-D resulting in high yield and quality. It was reported by Gomez-Cadenas *et al*. (2000) that exogenous application of gibberellins had no effect on abscission in citrus.

Application of different growth regulators (GA, 2,4-D and NAA alone and in combination) on 'Pera' orange had no influence on the development of the fruit such as length; diameter and fresh fruit mass (Almeida *et* *al*., 2004). Fruit quality analysis after treatments with different concentrations of 2,4 D on Valencia oranges revealed no significant differences in TSS, total acids and pH or ascorbic acid. Similar was the case with physical characters of fruit, however some fruit treated with higher concentration (225ppm) of 2,4-D developed a thick rind and grew excessively large, protruding navels; other fruits became cylindrical in shape (Stewart and Klotz, 1947).

Certain growth regulators have been tried in Faisalabad (Punjab) Pakistan for the control of fruit drop (Malik *et al*., 1993), diseases (Aziz, 1998) on Washington Navel during full bloom or fruit set but little is known about their effect on June fruit drop and fruit quality in Blood Red sweet oranges.

The objectives of this project were to improve the production and quality of sweet oranges in Punjab (Pakistan) for their successful induction in our citrus industry. Present research was conducted to know the effects of exogenous applications of 2,4-D, GA_3 or their combinations on June fruit drop and fruit quality of Blood Red sweet oranges in Faisalabad, Pakistan.

MATERIALS AND METHODS

The study was conducted on a 12-15 years old sweet orange (*Citrus sinensis* Osbeck L 'Blood Red'.) trees growing at Experimental Fruit Garden, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, province Punjab, Pakistan. The experimental trees were spaced at about 7 m x 7 m, growing under similar agroclimatic conditions and recieved same cultural practices during the period of investigation.

At the beginning of the experiment, the trees were evaluated for uniformity of growth, fruit yield potential and possible disease incidence. A randomized complete block design was followed with 3 replications. A single tree was selected as a treatment unit and 12 branches (of 2.5 cm diameter) per treatment were tagged for data collection.

Exogenous Growth Regulator application

Efficacy of wide range of concentrations of GA_3 and 2,4-D and their mixtures was tested on Blood Red sweet oranges to control the June drop and improve fruit quality during the years 2004. Aqueous solution of all the treatments was sprayed on whole trees to run off two months after fruit set (end of May 2004). The GA_3 was directly dissolved in distilled water while 2,4-D was first dissolved in ethanol and then water was added. The control trees were sprayed with simple water. Following treatment combinations were used in the experiment.

T_0	Control
T_1	10ppm GA_3
T_2	20ppm GA_3
T_3	25ppm GA_3
T_4	10ppm 2, 4-D
T_5	20ppm 2, 4-D
T_6	25ppm 2, 4-D
T_7	GA_3 +2,4-D 10ppm each
T_8	GA_3 + 2,4-D 20ppm each
T_9	GA_3 + 2,4-D 25ppm each

Observations

Fruit Drop (%)

Before treatment application, the number of fruit present on tagged branches was recorded and then the fruit counting was done before final sampling for fruit analysis to calculate fruit drop percentage with the following formula:

$$\%\,\text{Fruit Drop} = \frac{\text{Fruit at final count before Sampling}}{\text{Total Fruit Count before Treatment}} \times 100$$

Fruit Quality

About two weeks prior to fruit harvest, 30 fruits were sampled from each of the tree and weighed on balance. The fruit diameter and peel thickness were measured using a caliper. Number of seeds/fruit, juice percentage, rag and peel weight were recorded using the standard procedure described by Sattar (1999).

The fruit juice quality analysis including TSS, Total acidity (TA), TSS/ Acidity ratio, Vitamin C, Total sugars, reducing sugars and non-reducing sugars was done following methods described by Sattar (1999).

RESULTS

June Fruit Drop

Foliar application of GA_3, 2,4-D and their mixtures at different concentrations did not significantly affect the June fruit drop of Blood Red sweet oranges (**Table 1**). June drop in citrus is considered limiting factor for yield. It seemed that due to low yielding trend of trees, maximum set fruit were dropped before the application of treatments so the plant growth regulators gave least response to the fruit drop.

Fruit Weight and Diameter

Statistical analysis of data regarding average fruit weight revealed that there were significant differences among different treatments (**Table 1**). The control trees gained maximum average fruit weight (175.50g) which was similar to 2,4-D (25ppm, 10ppm), and GA_3 (10, 25ppm). The mixture of both growth regulators @ 20ppm gave minimum fruit weight (123.70g) similar to 25, 10ppm mixture, 20ppm 2,4-D and 20ppm GA_3. On the other hand none of the treatments had any significant effect on fruit diameter (**Table 1**).

Table 1. Effect of different growth regulators, on June drop and external fruit quality, of Blood Red sweet orange

	Fruit Drop %	Fruit Weight (g)	Fruit Dia (cm)	Peel Thickness (mm)	Juice (%)	Pulp (%)	Peel (%)	Total seeds/fruit	Seed wt./fruit (g)
T_0	20.87	175.5a	7.00	3.40abc	35.26e	29.13a	35.08abc	6.70d	0.95bc
T_1	30.32	162.3ab	7.02	3.16bc	36.43e	32.63a	30.13bc	8.30abcd	1.30ab
T_2	24.89	127.83d	6.01	2.65c	49.31ab	22.65bc	27.04c	10.10a	1.27ab
T_3	29.97	153.7abc	6.72	2.89bc	41.35bcde	28.13ab	29.65bc	8.20bcd	1.30ab
T_4	33.82	163.4ab	6.30	2.87bc	39.36cde	12.82d	47.40a	8.30abcd	1.20abc
T_5	20.83	136.9cd	6.53	3.21bc	38.66de	12.13c	38.81abc	9.90ab	1.60a
T_6	28.57	163.8ab	6.71	5.12a	38.18de	17.74cd	43.25ab	7.40cd	1.20abc
T_7	22.34	135.45cd	6.39	4.71ab	48.01abc	17.79cd	33.85bc	7.20cd	0.85c
T_8	10.87	123.7d	6.40	3.18bc	52.22a	18.36cd	28.74c	8.80abc	1.25abc
T_9	31.39	146.28bcd	6.77	3.99abc	46.73abcd	22.52bc	30.15bc	7.50cd	0.90bc
	NS	*	**NS**	*	*	*	*	*	*

Peel Thickness

Significant differences were observed among different treatments (**Table 1**). The trees sprayed with 25ppm 2, 4-D had maximum peel thickness (5.12mm) of fruit which was statistically similar to 10, 25 ppm mixture as well as control trees. 20 ppm GA_3 gave minimum peel thickness (2.65 mm), statistically similar to that of 20, 25 ppm mixture, 10, 25 ppm GA_3 and control trees. Maximum treatments were statistically similar to each other.

Pulp, Peel and Juice (%)

GA_3 (10ppm) treated fruit had maximum pulp (32.63%) similar to control and 25 ppm GA_3 while minimum (12.82 %) pulp was found in 2,4-D (10ppm) trees which was statistically similar to 10, 20ppm mixture and 25ppm 2,4-D treated trees. All other treatments were in between the two and mostly were statistically similar to each other (**Table 1)**.

All the trees sprayed with three concentrations (10, 20 and 25 ppm) gave similar peel percentage in fruit along with control with maximum peel on fruit from trees sprayed with 10ppm (47.4%). Minimum peel percentage (27.04%) was recorded in trees treated with 20ppm GA_3 which was similar to most of the treatments including control (**Table 1**).

Most of the treatments significantly affected the juice percentage as compared to control with maximum juice (52.22%) in 10ppm mixture treated trees similar to those treated with 20ppm GA_3 and 10,25ppm mixture (**Table 1**). Minimum juice (35.26%) was achieved from fruit of control trees which was similar to those 2,4-D and 10ppm GA_3 treated trees.

Seed Quantity and Quality

The data regarding seed quantity and quality is depicted in **Table 1 and 2.** Total number of Seeds per fruit was increased with the spray of GA_3, 2, 4-D and their mixture by all the concentrations as compared to control**.** Maximum seeds per fruit (10.10) were obtained from trees treated with 20 ppm GA_3 similar with 10 ppm, 20 ppm GA_3, 25 ppm 2, 4-D and 20 ppm mixture treated trees. Minimum number of seeds (6.70) was observed in control trees which were similar to remaining treatments.

Most of the treatments significantly affected weight of the seed (**Table 1**). Maximum Seed weight per fruit (1.60 g) was recorded in 20 ppm 2, 4-D treated trees statistically similar to most of the treatments except control and 10 ppm, 25 ppm mixture treated trees. Minimum seed weight per fruit was observed in 10 ppm mixture treated trees similar to control as well as 20, 25 ppm mixture, 10, 25 ppm 2, 4-D treated trees.

As far as healthy seed count is concerned, its difference was statistically non significant among treatments. Aborted seed count was also similar in most of the cases except maximum in case of 10 ppm mixture similar to 25 ppm mixture. Minimum aborted seeds were observed in 10 ppm GA_3 treated trees similar to remaining treatments including control.

Juice Quality

Juice quality included TSS, sugars profile, acidity, Vit. C and TSS/acidity ratio presented in **Table 2.** The perusal of the analyzed data regarding TSS revealed that there were significant differences among treatments, control lying in between. Maximum TSS (8.93) was observed in fruit harvested from trees

Table 2. Effect of different growth regulators, on Internal Fruit quality of Blood Red sweet orange

	Healthy seeds (%)	Aborted seeds (%)	TSS (%)	Total Sugars (%)	Reducing Sugars (%)	Non Reducing sugars (%)	Acidity (%)	Vit. C
T_0	79.31	20.68b	8.15bcd	4.37c	2.64cd	1.73d	0.85ab	42.66ab
T_1	83.51	16.49b	8.29bc	5.96a	2.46d	3.47ab	0.55bc	42.66ab
T_2	57.48	23.52b	7.81d	6.21a	2.99a	3.23abc	0.58ab	34.66d
T_3	80.57	19.43b	7.30e	6.20a	2.53d	3.67a	0.52c	47.15a
T_4	81.68	18.31b	7.94cd	5.80a	2.79bc	3.01bc	0.61a	37.32cd
T_5	82.69	17.30b	7.29e	4.75bc	3.12a	1.63d	0.56abc	39.96bc
T_6	76.36	23.64b	8.43b	4.75bc	2.94ab	1.79d	0.55bc	45.32a
T_7	54.98	45.02a	8.41b	5.86a	2.97ab	2.89c	0.61a	42.66ab
T_8	73.73	26.27b	8.86a	5.77a	2.93ab	2.85c	0.60ab	42.66ab
T_9	67.07	32.93ab	8.93a	5.10b	2.96ab	2.15d	0.58ab	42.66ab
	NS	*	*	*	*	*	*	*

treated with 25ppm mixture statistically similar to 20ppm mixture while minimum TSS (7.29) was recorded in 20ppm 2,4-D similar to 25ppm GA_3 treatment.

Total sugars were significantly affected by all treatments as compared to control with maximum (6.21%) in 20ppm GA_3 treated trees similar to 25ppm , 10ppm GA_3, 10, 20ppm mixture, 10ppm 2,4-D treated trees. Minimum total sugars were observed in control trees followed by two concentrations of 2,4-D (20, 25ppm).

The data pertaining to reducing sugars showed significant differences among the treatments with maximum amount (3.13%) in 20ppm 2,4-D treated trees similar to 20ppm GA_3, 10, 20, 25ppm mixture and 25ppm 2,4-D. The minimum amount of reducing sugars (2.46%) was recorded in 10ppm treated trees similar to 25ppm GA_3 and control trees.

The analyzed data regarding non reducing sugars revealed that maximum non reducing sugars (3.67%) were found in fruit from 25ppm GA_3 treated trees similar 10, 20ppm GA_3 treated trees while minimum non reducing sugars were recorded in fruit from 20ppm 2,4-D treated trees similar to control along with 25ppm 2,4-D and 25ppm mixture treatment.

Acidity in juice had significantly different values among the various treatments with maximum value in 10ppm mixture treated trees which was similar to control along with 20ppm , 25ppm mixture, 10, 20ppm 2,4-D treated trees. Minimum value of acidity (0.52) was observed in 25ppm GA_3 treated trees similar to 10ppm GA_3, 25, 20ppm 2,4-D treated trees.

Maximum vit. C was recorded in fruit from trees sprayed with 25ppm GA_3 similar to all three concentrations of mixture, 25ppm 2,4-D as well as control. Minimum vit. C was found in 20ppm GA_3 treated trees similar to 10ppm 2,4-D treatment.

There were significant differences among various treatments with respect to TSS/acidity ratio which determines the taste of the fruit. Maximum ratio was recorded in 25ppm 2,4-D similar to most of the treatments including control, all three concentrations of mixture and 10, 25ppm GA_3 treated trees.

DISCUSSION

Fruit Drop

June drop in citrus is considered limiting factor for yield. It seemed that due to general weakness and resultantly low yielding trend of trees, maximum set fruit was dropped before the application of treatments so the plant growth regulators gave least response to the fruit drop (Lima and Davies, 1984). There might be no effect of treatments on fruit as already Gomez-Cadenas *et al*., 2000 found no effect of gibberellins spray on citrus abscission.

Fruit Weight and Diameter

Fruit weight was reduced by growth regulators treatments which might be due to more number of fruit on treated trees; similarly reduction in fruit weight has also been reported due to decrease in fruit size by 2,4-D (Stewart *et al*., 1951). Fruit diameter was not significantly affected by treatments which might due to time of application as there was found increase in fruit size by auxins application just after bloom (Stewart *et al*., 1951) but it was also reported by Almeida *et al*., 2004 that there was no effect of growth regulators spray on fruit development or size.

Peel Thickness

Although there were significant differences among treatments in peel thickness but the effect of growth regulators could not be decided as the response was not uniform in different treatments. However 25ppm 2,4-D gave maximum peel thickness which is in accordance with reports by Stewart *et al*., 1951 reporting increased peel thickness by application of 2,4-D during bloom but later they reported variable response about peel thickness of this auxin with later application (Coggins and Hield, 1968). Lower peel thickness by GA spray in summer is in contrary to Hield *et al*., 1965 who reported increased peel thickness by GA spray on Washington navel during June.

Pulp, Peel and Juice (%)

Most of the treatments had lower quantity of pulp compared with control which might be due to increased quantity of juice or peel in fruit by the treatments (**Table 2**). It has been reported that spray applications of 2,4-D, GA or their combination did not affect the juice contents of Washington Navel (Lima and Davies, 1984). In our case it might be due to very less number of fruit per tree and lower produce mostly do not deteriorate quality of fruit.

Seed Quantity and Quality

Number of seeds determines the quality of fruit as seediness is not favourite in different parts of the world and sometime export of fruit in such markets becomes a problem. Total number of seeds per fruit was increased by most of the treatments compared with control although is not a problem in 'Blood Red' sweet orange. The exogenous supply of growth regulators might have improved the development of seeds in fruit as the seeds are the main source of growth regulators. In seedy citrus cultivars sometimes seed number is reduced by spray of GA_3, however it is cultivar dependent and it also may not occur in Blood Red sweet orange which is always less seeded. Variation in seed weight was due to different number of seeds and not due to seed health as it was not affected by treatments however seed abortion was increased by mixture treatments which might be to some antagonistic effect on seed development and it will be beneficial in decreasing seediness in seedy cultivars.

Juice Quality

The growth regulators treatments had an increasing trend towards TSS, total sugars and reducing sugars which is a good sign and the treatments might be selected for the improvement of fruit quality of different varieties although many scientists had reported no effect of growth regulators on fruit quality parameters like TSS, sugars, acidity, TSS/ acidity ratio etc (Lima and Davies, 1984; Stewart and Klotz, 1947; Hield *et al*., 1965). Although there were significant differences among treatments in case of acidity, vit. C and TSS/ acidity ratio yet most of the treatments are sharing the same letters.

CONCLUSION

Use of plant growth regulators has been a regular practice in fruit crops especially citrus for modifying various plant processes since long. The use of GA_3 and 2, 4-D is quite common in some parts of the world to improve fruit set and prevent preharvest drop respectively. Improvements in fruit size, peel thickness, disease control, on tree storage of citrus fruit, delay in peel senescence are mostly achieved through exogenous application of these plant growth regulators. From results it is clear that with exogenous application of plant growth regulators, positive results can be achieved provided the limitations are overcome and we use the right time of spray and required quantity of growth regulator.

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