Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.4, No.2, 2014

Association of Gibberellic Acid (GA_3) with Fruit Set and Fruit Drop of Sweet Orange

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The research is financed by Pak-Australia ASLP Citrus Project Phase-II, ARI Tarnab, Peshawar-Pakistan.

Absract

To determine the association of Gibberellic acid with fruit set and fruit drop of sweet orange, a research study was conducted at Agricultural Research Institute Tarnab, Peshawar, Pakistan during the year 2012. Three different concentrations(10, 20 and 30ppm excluding control) of Gibberellic acid (GA_3) were applied as foliar spray at full bloom stage of three different sweet orange cultivars namely Blood Red, Musambi and Succari. Fruit set as well as fruit drop at different developmental stages of fruit were calculated. The results of the experiment revealed that 30 ppm GA_3 application significantly reduced the percent fruit drop, percent June drop and increased yield tree^{-1}. While fruit set branch^{-1}, pre harvest fruit drop and fruit weight was significantly affected by 10 ppm GA_3 application. It was concluded from the research study that the foliar application of 30 ppm GA_3 at blooming stage could be applied in order to improve fruit set, control fruit drop and to increase the yield of sweet orange.

Keywords: Gibberellic acid, sweet orange cultivars, Fruit set, June drop, fruit retention, Musambi, Succari, Blood Red.

1. Introduction

Sweet orange (Citrus sinensis L.) is a subtropical fruit, belongs to family Rutaceae and sub family Aurantioideae. Its origin is traced back to China, Northern India and Southern Asia (Young, 1929). Foremost citrus growing countries are Brazil, United States of America, Mexico, Australia, China and Egypt (FAO, 2011).Citrus is the prized fruit crop of Pakistan and holds 1st position among fruits grown in country both for area and production. In Pakistan Citrus fruits were cultivated on an area of 198.4 thousands hectares with an average production of 2150 metric tons, while in Khyber Pakhtunkhwa 4.3 thousand hectares gave an average production of 35.1 metric tons (MINFAL, 2009-10).The commercial cultivars of sweet orange are Blood Red, Pineapple, Musambi, Succari, and Valencia late (Wilfred et al., 1986).Sweet orange (*Citrus sinensis* L.) cv. Blood Red is the most important fruit through nutritional point of view, sixteen different fatty acids have been detected, while 46 aroma compounds are also identified in juices of Blood oranges, so dietary intake of Blood oranges may supply substantial health components (Kafkas et al., 2009). The peel of sweet orange (*Citrus sinensis* L.) exhibits antithyroidal, hypoglycemic and insulin stimulatory activities, it controls glucose concentration in blood by increasing insulin levels (Parmar and Kar, 2008).Fruit production is entirely dependent on good fruit set, and successful retention of fruit on tree up to fruit maturity. Keeping this fact in mind various research studies have been conducted to enhance flower initiation and fruit set in various fruit trees including sweet oranges. A single GA_3 spray of 5 mg L^{-1} followed by girdling at petal-fall to the entire tree enhanced initial set in the 'Navelate' sweet orange (*Citrus sinensis* L.) by increasing the final yield due to increase in number of fruits but having no effect on fruit size (Agusti, 1982). **Garcia-Martinez and Garcia-papi, (1979**) reported that GA_3 application increased fruit set in Clementine mandarin due to an increased availability of nutrients from the leaves. Spraying GA_3 (5–200 mg L^{-1}) to entire trees of cultivar 'Fino' proved to be more efficient in increasing the number of fruits tree^{-1} and finally an increase in the commercial yield. GA_3 application directly to the developing apex near to flower differentiation reduced the number of flowers panicle^{-1} by 25–35% in loquat and without modifying the morphological characteristics of the panicle (**Reig *et al.*, 2011**).GA_3 (45 mg L^{-1}) treated trees of Blood Red sweet orange showed a significant increase in term of fruit set and final yield as compared to control treatment (Saleem

et al., 2008). Late fruit growth and final fruit size were increased by the application of the synthetic auxin 2,4,5-trichlorophenoxyacetic acid, which had a specific effect on the enlargement of the juice vesicles (Guardiola *et al*., 1993). GA_3 alone and in combination with benzyladenine could increase initial fruit set in several cultivars of pear (Marcelle, 1984). Application of GA_3 (10 ppm) at balloon and anthesis results better fruit set as compared to petal fall (Herrero, 1984). With respects to these influential aspects of different growth regulators the present research study was designed to increase fruit set and to minimize fruit drop in sweet orange, which is a very critical problem associated with sweet orange under the agro-climatic conditions of Peshawar, Pakistan.

2. Material and Methods

The experiment was conducted at Agricultural Research Institute (ARI) Tarnab, Peshawar, Khyber Pakhtunkhwa, Pakistan during 2012. The experiment was laid out in Randomized Complete Block Design (RCBD) with two factors factorial arrangement with three replications.

Factor A
GA_3 concentrations
G_0 = 0 ppm (Control)
G_1 = 10 ppm
G_2 = 20 ppm
G_3 = 30 ppm

Factor B
Sweet orange Cultivars
C_1 = Blood Red
C_2 = Musambi
C_3 = Succari

Thirty six trees (10-12 years old; receiving same cultural practices and were in healthy condition and vigor) of three different sweet orange cultivars grafted on sour orange rootstock were selected. Three different concentrations of GA_3 i.e.10, 20 and 30 ppm were sprayed at blooming stage of cultivar Blood Red, Musambi and Succari and their result was compared with control treatment. Each treatment was replicated three times.

2.1 Foliar application of Growth Regulator

The aqueous solution of 10ppm, 20ppm and 30ppm was prepared according to the standard formula(2.5g dissolved in 100 liter of water = 10 ppm) of product ProGibb. Which was given on the pack. Chemical weight for 10ppm was find out for 3L distilled water treatment^{-1}as (No. of grams dissolved in 3L $= \frac{2.5g \times 3L}{100L}$)and then multiplied by 2 and 3 for making 20ppm and 30ppm solution respectively. These treatments were applied when trees were at full bloom stage.

2.2 Observations

Four branches of approximately same length, diameter and vigor were tagged in each direction before foliar application of GA_3. Number of flowers branch^{-1}were counted 24 hours after foliar application of growth regulator while % fruit set branch^{-1} was determined by using the following procedure.

$$\%\ \text{Fruit set} = \frac{\text{Number of fruit set branch}-1}{\text{Number of flowers branch}-1} \times 100 \quad (1)$$

Similarly %fruit drop, %June drop and % pre-harvest fruit drop were find out through below given procedure

$$\%\ \text{Fruit drop} = \frac{\text{Number of fruits dorped branch}-1}{\text{Number of fruit set branch}-1} \times 100 \quad (2)$$

$$\%\ \text{June drop} = \frac{\text{Number of fruits branch}-1 \text{ at the end of June}}{\text{Number of fruits branch}-1 \text{ before June}} \times 100 \quad (3)$$

$$\%\ \text{Preharvest fruit drop} = \frac{\text{Number of fruits tree}-1 \text{ at the time of harvest}}{\text{Number of fruits tree}-1 \text{ before harvest}} \times 100 \quad (4)$$

After fruit harvest fruit weight and yield tree^{-1}was recorded and all parameters were analyzed through the standard procedure discussed below.

2.3 Statistical procedure

The data recorded on different parameters were subjected to analysis of variance (ANOVA) techniques to observe the difference, between the different treatment as well as their interactions. In case where the differences were significant, the means were further assessed for differences through least significant differences (LSD) test. Statistical computer software, MSTAT-C (Michigan State University, USA), was applied for computing both the ANOVA and LSD (Steel and Torrie, 1980).

3. Results

3.1 Fruit set

Fruit set and Percent fruit set branch^{-1}

The statistical analysis of data showed significant differences among different GA_3 concentrations, cultivars and their interaction for fruit set and Percent fruit set branch^{-1}(Table 1). More number of fruits branch^{-1} (13.58) were obtained when the plants were treated with the foliar application of 10 ppm GA_3 closely followed by 20 ppm (13.14) which have no significant difference with each other while significantly different from the rest of

treatments while less number of fruits (8.08) were observed in control treatment. Similarly, among cultivars the maximum number of fruit set was observed in Musambi (14.17) followed by Blood Red (11.90) while minimum number of fruit set was noted in cultivar Succari (7.21). The interactive effect of GA_3 concentrations and cultivars was also significantly different among treatments and cultivars, having the highest values (21.25 and 20.25) for 20 and 10 ppm on Musambi and Blood Red respectively, while the lowest value (6.17) was obtained from control treatment on Cv. Succari (Table-1).Similarly maximum percent fruit set (27.77) was observed by the application of 20 ppm GA_3 followed by 30 ppm (22.25) while minimum percent fruit set (17.34) was obtained from control treatment. Accordingly the maximum percent fruit set (30.10) was given by Musambi followed by Succari (18.23) whereas less percentage of fruit set (15.82) was noted in Blood Red. The interaction of both treatments and cultivars were also significant. The maximum interactive value (45.59) of percent fruit set was noted in 20 ppm treated trees of cultivar Musambi while the minimum value (10.99) was given by cultivar Blood Red which was kept control.

3.2 Fruit retention

% fruit drop, % June drop and %Pre harvest fruit drop branch^{-1}

The analysis of variance showed that foliar application of GA_3, cultivars and their interaction significantly influenced regarding % fruit drop, % June drop and %Pre harvest fruit drop branch^{-1}. According to the data given (Table-1) the foliar application of 20 ppm GA_3 gave more percent fruit drop (68.65) which was statistically different from the rest of treatments followed by control and 10 ppm treatment (56.95 and 54.96) respectively while the minimum percent fruit drop (49.31) was obtained from 30 ppm GA_3. Similarly cultivar Musambi showed higher percentage of fruit drop (62.64) followed by Succari (58.37) whereas lower value (51.40) was observed in Blood Red. The interactive effect among different treatments and cultivars was also significant, having a highest values of percent fruit drop (77.24 and 77.05) for 20 ppm in Musambi and Succari respectively, which have a non significant difference with each other while significantly different from the rest of interactions whereas the lowest value (39.05) was that of 30 ppm GA_3 in Blood Red. Similarly maximum percentage of June drop (30.65) was noted in control followed by 20 ppm (18.49) while the minimum June drop (9.47) was given by trees treated with 30 ppm GA_3 sprays. Regarding cultivars; highest June drop (23.35 %) was observed in Cv. Succari followed by Musambi (19.03 %) while lowest value (12.53 %) was noted in Cv. Blood Red. There were also significant differences among cultivars with respect to GA_3 application. According to the means (Table-1), highest interactive value (44.70) in term of percent June drop was noted in control on Succari while lowest values (5.33 and 5.56) were observed in 10 ppm and 30 ppm on Blood Red and Succari respectively. Accordingly more %Pre harvest fruit drop (56.95) was observed in trees considered as control followed by 20 ppm (54.53) while less percent pre harvest fruit drop (49.33 and 49.49) was given by trees treated with 10 and 30ppm GA_3 sprays respectively. Similarly maximum value (58.72)in term of %Pre harvest fruit drop was observed in Cv. Musambi followed by Succari (52.27) while minimum value (46.73) was obtained from Blood Red sweet orange. According to the means (Table-1), highest interactive values (63.22 and 61.54) were shown by control and 20ppm GA_3 treated trees of Musambi accordingly while lowest value (39.05) in term of percent pre harvest fruit drop was observed in 30 ppm treated trees of cultivar Blood Red.

3.3 Yield

Fruit weight (g) and yield tree^{-1}

The Analysis of Variance showed that GA_3 treatments, cultivars and their interaction were significantly different at ($p<0.05$) level of significance for fruit weight and yield tree^{-1}. However the application of 10 ppm GA_3 gave maximum fruit weight (149.92g) closely followed by 30ppm (149.25g) while minimum fruit weight (138.90g) was observed in control treatment. Similarly cultivar Blood Red showed higher fruit weight (145.90g) followed by Musambi (144.53g) whereas lower value (142.50g) was observed in Succari sweet orange. The interactive effect among different treatments and cultivars was also significant, having a highest value of fruit weight (152.18g) for 10 ppm in Blood Red followed by the application of 30ppm to Musambi (151.85g) while the minimum fruit weight (136.71g) was noted in control treatment of Musambi (Table-1). Similarly the highest value (62 Kg) for yield tree^{-1}was obtained by the application of 30 ppm GA_3 followed by 10 ppm (60.71 Kg) while lowest values (58.90 and 58.93 Kg) were noted in 20ppm and control respectively. Accordingly maximum yield tree^{-1}(64.28 Kg) was noted in Blood Red followed by Succari (59.74 Kg) whereas minimum yield (56.40 Kg) was given by Musambi sweet orange. Similarly more interactive value in terms of yield tree^{-1} (67.22 Kg) was observed in 30 ppm treated trees of cultivar Blood Red while least value (54.95 Kg) was given by cultivar Musambi which was kept as control.

Table-1: Fruit set, fruit drop and yield of sweet orange cultivars as affected by GA_3 treatment.

GA_3 (Conc.)	FS	%FS	%FD	%JD	%PHFD	F Wt. (g)	Yt^{-1}(kg)
G_0	8.08b	17.34b	56.95b	30.65a	56.95a	138.90b	58.96b
G_1	13.58a	18.89b	54.96b	14.62c	49.33c	149.92a	60.71a
G_2	13.14a	27.77a	68.65a	18.49b	54.53b	139.17b	58.90b
G_3	9.56b	22.25a	49.31c	9.47d	49.49c	149.25a	62.00a
significance	*	*	*	*	*	*	*
Cultivars							
C_1	11.90a	15.82b	51.40c	12.53c	46.73c	145.90a	64.28a
C_2	14.17a	30.64a	62.64a	19.03b	58.72a	144.53a	56.40c
C_3	7.21b	18.22b	58.37b	23.35a	52.27b	142.50b	59.74b
significance	*	*	*	*	*	*	*
Interaction							
$G_{0\times}C_1$	7.83	10.99	50.27	14.67	50.28	142.59	63.22
$G_{0\times}C_2$	10.25	24.71	63.22	33.07	63.22	136.21	54.95
$G_{0\times}C_3$	6.17	16.34	57.36	44.70	57.35	137.91	58.73
$G_{1\times}C_1$	20.25	23.10	64.61	5.33	47.94	152.18	67.22
$G_{1\times}C_2$	12.00	15.02	53.32	17.59	53.32	150.10	55.97
$G_{1\times}C_3$	8.50	18.55	46.95	20.92	46.74	147.51	58.92
$G_{2\times}C_1$	10.25	16.47	51.66	21.72	49.66	139.84	60.55
$G_{2\times}C_2$	21.25	45.59	77.05	11.51	61.54	140.00	60.97
$G_{2\times}C_3$	7.92	21.26	77.24	22.22	52.40	137.62	59.17
$G_{3\times}C_1$	9.25	12.74	39.05	8.91	39.05	149.00	66.14
$G_{3\times}C_2$	13.17	37.26	56.96	13.93	56.82	151.85	57.72
$G_{3\times}C_3$	7.21	16.75	51.92	5.56	52.59	146.92	62.41
significance	*	*	*	*	*	*	*

*significance at α=0.05
FS (fruit set $branch^{-1}$), %FS (%fruit set $branch^{-1}$), %FD (%fruit drop $branch^{-1}$), %JD (%June drop $branch^{-1}$) %PHFD (%pre harvest fruit drop $branch^{-1}$), F Wt. (Fruit weight) and Yt^{-1} ($Yield\ tree^{-1}$)

4.Discussion

4.1 Fruit set

The increase in the fruit set and %fruit set might be due to the increased availability of nutrients from leaves by GA_3 while it may also be due to varietal genetic capability to set high or low percentage of fruits. In the findings of present research all treatments showed a significant increase in fruit set of sweet orange cultivars as compared to control treatment. These findings are in line with that of Garcia-Martinez and Garcia-papi, (1979) who reported that the increase in fruit set after GA_3 application was due to the increased availability of nutrients from leaves. While a single spray of GA_3 at petal fall to the entire tree enhanced initial fruit set (Agusti et al., 1982), similarly a GA_3 spray of (10 ppm) at anthesis resulted in higher set in pear (Herrero 1984). These findings are also in line with that of Saleem et al., (2008) who observed the maximum fruit set in 45 mg L^{-1} treated trees of sweet orange with GA_3 alone or in combination with 2,4-D. The application of GA_3 alone or in combination with benzyl adenine increased the initial fruit set in Pear **(**Marcelle, 1984**),** similarly the application of GA_3 to the inflorescences 14 days after anthesis significantly increased the fruit set in seedless Clementine Mandarin cultivar 'Fino' (Garcia-Martinez and Garcia-Papi, 1979).

4.2 Fruit retention

These significant differences among treatments and cultivars towards % fruit drop, %June drop and %pre-harvest fruit drop might be due to the fruit retentive response of cultivars to these treatments while it might also be due to weather fluctuations apart from genetic differences. The findings of the present research were similar to that of Yamamura et al., (1989) that the application of GA_3 at the rate of 25, 50 and 100 ppm significantly reduced fruit drop in 'Saijo' and 'Fuyu" cultivars of persimmon. The external application of GA_3 was proved very helpful in preventing fruit drop in mandarins (Tominaga, 1998) and sweet orange (Liao et al., 2006) These reasons given above can also be supported as high light intensity and dry weather are main factors which accelerate fruit drop. Environmental, nutritional and hormonal factors can cause fruit abscission (Gillaspy et al., 1993, Gomez et al., 2000). The external application of GA_3 was proved very helpful in preventing fruit drop in mandarins (Tominaga, 1998) and sweet orange (Liao et al., 2006).

4.3 Yield

These differences in term of fruit weight and Yield might be due to the application of gibberellic acid besides all other factors like light, temperature, nutrients availability and disease incidence. The present findings of the

research study supported the findings of *Ramezani and Shekafandeh (2008), who reported that all GA_3 treatments (0, 15, 30 and 45 ppm)* significantly increased fruit weight in olive. However it antagonizes the findings of Garcia-Martinez and Garcia-papi, (1979) that (5-200 mg L^{-1}) GA_3 application to Clementine mandarin increased the number of fruits but decrease the average weight $tree^{-1}$**.** Similarly, increase in yield might be due to the application of GA_3 which significantly increased fruit set, decreased fruit drop and also increased the individual fruit weight which in turn increased the final yield $tree^{-1}$. The difference in yield $tree^{-1}$ among different sweet orange cultivars might be due to their varietal difference and suitability or unsuitability of different cultivars to a particular area. The findings which discussed above are in line with that of Agusti et al., (1982) who also reported that (5 mgL^{-1}) of GA_3 followed by girdling markedly increased the fruit set and final yield in the 'Navelate' sweet orange. It also supports the conclusion made by Garcia-Martinez and Garcia-papi, (1979) that commercial yield was increased through application of (5-200 mgL^{-1}) GA_3 to Clementine Mandarin.

5. Conclusion and Recommendations

The use of plant growth regulators to modify various plant processes is very common in different parts of the world in various crops including citrus. However the application rate and proper time of application is still a limiting factor in achieving the desired goals. So it might be concluded from the present research study that 30ppm GA_3 application at blooming stage increased fruit set and controlled fruit drop at various fruit maturity stages. By increasing fruit set and reducing fruit drop the final yield was increased to very appreciable extent. On the basis of above drawn conclusion it could be recommended that GA_3 application as foliar spray @ 30ppm at full bloom stage should be applied as foliar spray to increase the yield of sweet orange.

Acknowledgments

This work was supported by Pak-Australia citrus ASLP (Agriculture Sector Linkages Program) at Agricultural Research Institute Tarnab, Peshawar, Pakistan under the Kind supervision of Dr. Ghulam Nabi (Former Research Officer ARI, Tarnab) and Dr. Muhammad Sajid (Associate Prof. Horticulture, the University of Agriculture Peshawar) whose support enabled me to complete this task.

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