

Original Research Article

Gibberellic acid (GA₃), an influential growth regulator for physiological disorder control and protracting the harvesting season of sweet orange

ABSTRACT

Citrus particularly sweet orange occupies an exalted position in fruit industry. Quality sweet orange production is affected by various factors including fruit physiological disorders and harvesting season which contribute towards consumer preference. This study was designed to find out an economically feasible solution to these problems. Three different GA₃ treatments (10, 20 and 30ppm) were applied as foliar spray to three different sweet orange cultivars (Blood Red, Mosambi and Succari) at full bloom stage to investigate its influence on cell division, Physiological disorder in fruits as well as in shoots, fruit growth and fruit maturity delay. The obtained results revealed that all GA₃ treatments specially 30ppm significantly controlled fruit as well as shoots physiological disorders and was also found efficient in case of fruit maturity delay as compared to untreated trees. Finally we were able to conclude that 30 ppm GA₃ should be applied as foliar spray to control fruit and shoot physiological disorders and to protract the harvesting season of sweet orange.

Key words: Foliar spray, Full bloom, Gibberellic Acid, Maturity delay, Physiological disorder, Sweet orange cultivars.

1. INTRODUCTION

Citrus is a group of fruits occupies a trenchant position in fruit industry all over the world. In Pakistan, citrus was grown on an area of 194.5 thousands hectares with an average production of 1982.2 metric tonnes, which ranks it first among fruits grown in country [1]. Likewise in United States the on tree crop value was estimated up to 1.35billion USD during 2011-12 which generated roughly 76,000 full and part time jobs [2]. The benefit-cost ratio of sweet orange is high as compared to lemon and mandarin [3]. Sweet orange is also the most important fruit through nutritional as well medicinal point of view. Several extracts from the peel of sweet orange have been reported which helps in curing of many diseases, like Naringin extracted from its peel has a therapeutic effect for Alzheimer type in humans [4], while the peel of citrus also proved helpful in insulin stimulation [5]. Several aromatic compounds extracted from sweet oranges have been used in various food products for colour and taste development [6]. The demand of sweet oranges among consumers is increasing day by day, to fulfill this need, good quality fruit production as well as high production per unit area is required. A huge amount of research work has been conducted on these two aspects, many cultural practices have been recommended in this regard like proper application of nutrients and irrigation [7], managing row to row and plant to plant distance, root stock selection [8] as well as the application of various growth regulators [9,10]. To be more specific, in sweet oranges the nutritional and water imbalance produce severe fruit disorders like fruit splitting, puffing, creasing and water marks etc. [11], which decreases the fruit quality and ultimately the consumer's preference. Gibberellic acid has been reported as an effective treatment in controlling bunch fading disorder in date palm [12], double fruit and fruit splitting disorder in peach [13], fruit creasing in Washington Navel sweet orange [14] and tipburn disorder in the leaves of several vegetables [15]. However in another study [16] NAA mentioned as an

effective treatment for improvement in physiochemical properties of date palm. In concern with fruit maturity delay, GA₃ has been reported as an influential treatment in date palm, protracting its harvesting season [17, 18]. With respect to these desirable and important impacts of growth regulators, the present research study has been designed with objectives; (1) to control fruit physiological disorder and (2) to prolong the harvesting season of sweet orange through the foliar application of GA₃, which are highly desirable in fruit industry.

2. MATERIALS AND METHODS

3.

2.1 Experimental site, design and plant material.

The experiment was carried out at Agricultural Research Institute (ARI) Tarnab, Peshawar-Pakistan, in year 2012. The statistical design used throughout the study was; RCBD- two Factors with 3 replications. Different gibberellic acid concentrations (0, 10, 20 and 30ppm indicated as G₀, G₁, G₂ and G₃) were considered as (Factor A), while different sweet orange cultivars (Blood Red, Mosambi and Succari indicated as C₁, C₂ and C₃) were taken as (Factor B). 36 trees of 3 different sweet orange cultivars (mentioned above) each having 12 trees were tagged. The tagging was based on the physical and micro environmental similarity among trees. 4 different concentrations of GA₃ including control (mentioned above) were sprayed at full bloom stage of sweet orange cultivars and their results were compared with control treatment. Each treatment was replicated 3 times.

2.2 Foliar application of growth regulator

The exact weight of GA₃ (product name, Pro-Gibb) for the preparation of 10, 20 and 30 ppm aqueous solutions was calculated through the following formula given in the product's user guide [19].

a) $2.5\text{g dissolved in } 100\text{ liters of water} = 10\text{ ppm}$ (1)

As tree⁻¹ requirement was found prior the actual spray by spraying distilled water to find the actual volume of water sufficient for each tree. Therefore weight calculations were made for 3 liters tree⁻¹ according to the following procedure.

b) $\text{No. of grams dissolved in } 3\text{L of water} = \frac{2.5\text{g} \times 3\text{L}}{100\text{L}} = 0.75\text{ g}$ (0.075g/ 3L=10 ppm GA₃)

c). $0.075\text{g} \times 2 = 0.15\text{g}$ (0.15g/3L= 20ppm GA₃)

d). $0.075\text{ g} \times 3 = 0.225\text{g}$ (0.225g/3L=30ppm GA₃)

Solutions prepared based on above mentioned calculations, were then applied as foliar spray on full bloom stage of sweet orange.

2.3 Observations

Before the application of GA₃ as foliar spray 4 branches(1 in each direction) were selected. The selection was made on the basis of branch size (having approximately same length and diameter) and vigor. The following attributes were determined as:

Cell division period (CDP)

To determine CDP, fruits were placed in a glass full of water, the fruits which started floating indicate the end of cell division period while sink fruits were still in cell division stage (Archimedes' Principle of buoyant force, see Figure 1a & b).

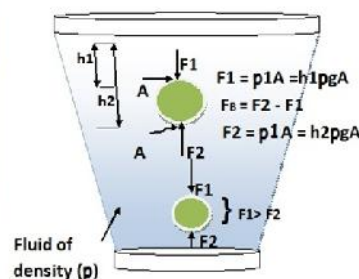


Figure 1a&b: Refers to the principle of buoyant force which states that; when the buoyant force exceeds the mass of an object in a liquid medium, the objects start floating. Likewise if an object has less M/V ratio its density will be low and it will float hence in Figure 1a the floating fruits have low M/V ratio (indicates cell elongation and expansion) while sunken fruits have high density due to cell division state; more no. of cells per unit volume tends them to stay at the bottom by suppressing buoyant force (Archimedes' Principle of

Physiological disorder percentage in shoots (PDS)

Those shoots which have the symptoms of nutrients deficiency like yellowing of old or new leaves, malformed or chlorotic leaves etc. which mainly involves environmental factors were carefully counted. The Physiological disorder percentage was then determined through the following formula.

$$\%PDS = \frac{\text{Number of abnormal shoots tree-1}}{\text{Total shoots tree-1}} \times 100 \quad (2)$$

Physiological disorder percentage in fruits (PDF)

Physiological disorder in fruits like fruit splitting, puffing, creasing, water marks and peel pitting etc. was found by counting the abnormal fruits as well as total fruits tree⁻¹. The percent physiological disorder in fruits was calculated using following formula.

$$\%PDF = \frac{\text{Number of abnormal fruits tree-1}}{\text{Total fruits tree-1}} \times 100 \quad (3)$$

Days to fruit maturity (DFM)

The number of days was counted from first day of fruit set to the initiation of fruit maturity indices (colour, taste and aroma), their mean was taken and presented graphically.

Fruit growth (mm)

Fruit growth was determined by randomly selected fruits on each tree. Their diameter was regularly measured on weekly basis through Fruit Size Meter (Figure 1c), made by (Cranston machinery co. oak grove, Oregon, Australia), their means were taken and then presented graphically to study the trend of fruit growth throughout the cell elongation and expansion stage.



Figure 1c: Fruit size meter used to determine the fruit diameter regularly on weekly basis.

2.4 Statistical analysis

The collected data for all parameters was analyzed through (Statistix8.1) statistical software and then LSD was computed for those parameters which were statistically significant, the graphical illustrations were done through MS excel.

3. RESULTS AND DISCUSSION

3.1 CDP

The information pertaining CDP is presented in Figure 2 and 4. The graphical presentation reveals; CDP in cv. Blood Red lasted for 52 days in trees which were kept Control as well as in 10 ppm and 30 ppm treated trees while 20 ppm treated trees took 54 days to complete CDP. Similarly in cv. Mosambi the CDP took 52 days in trees that were tagged as control, 20 and 30 ppm while 10 ppm treated trees took 56 days. In cv. Succari it lasted for 56 days in control and 30 ppm treated trees while in 10 and 20 ppm tagged trees the CDP was completed in 58 days.

These differences might be due to GA_3 application because it might cause a rapid increase in the cell division of the ovary wall when applied at flower opening, however there might also be some genetic and environmental factors which can affect CDP. The present findings are in line with the previous findings [20], that the application of gibberellic acid or benzyl adenine at flower opening caused a transient increase in cell division in the ovary wall of fruit. While it could also be justified that the dipping of flower and fruit clusters twice (1st at flowering and 2nd after 27 to 58 days after first treatment) of *Eriobotrya japonica* in the aqueous solution of 200 ppm GA_3 + 20ppm CPPU caused flesh thickness due to cell division and elongation through these treatments [21]. Figure 3 reveals that the tendency of increase in cell division decreases with increase in GA_3 concentration. Similarly the cell division activity was maximum (223.30 and 171.34 times) either with benzyl adenine or with gibberellic acid respectively, within a week, however the growth stimulation fall with increase in the concentrations of these synthetic PGRs [22]. While the most recent studies [23] discussed that GA_1 and GA_4 are very critical for fruit growth and development which is co-ordinated with cell division, differentiation and expansion.

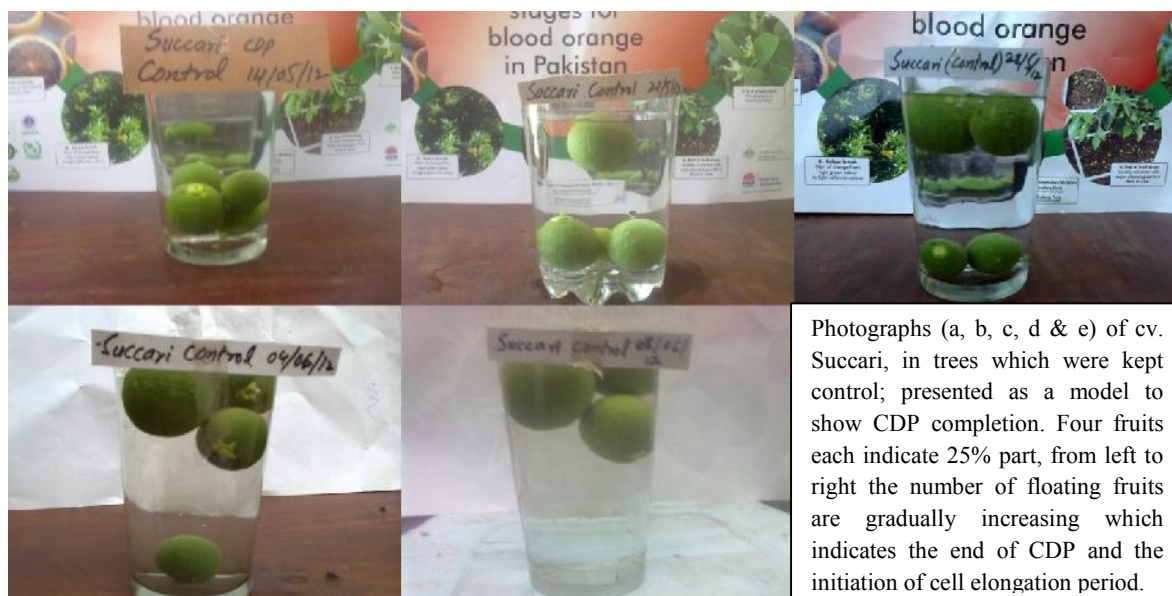


Figure 2: Various stages of fruit growth and the tendency of CDP completion and initiation of cell expansion and elongation.

3.2 PDS

Data regarding PDS is graphically presented in Figure 4. The graphical illustration shows that there were significant differences among different treatments and cultivars regarding PDS however the interactive effect was non-significant. According to the mean values a higher percentage (3.1) of PDS was observed in trees which were kept control while low intensity of PDS was observed in treated trees that were (1.15, 1.18 and 1.46) in 20, 10 and 30ppm respectively. Among different Cultivars the maximum value (2.33%) was observed in Blood Red while the Succari (1.27%) and Mosambi (1.48%) showed minimum counts of PDS.

These differences among different treatments and cultivars might be due the physiological response to the application of growth regulator (GA_3) however there might also be some genetic and environmental factors responsible for these differences. In previous studies certain vitamins were also used as foliar spray, dusting or drench application to overcome nutrients deficiency by strengthening the plants to absorb more nutrients from soil and those treatments caused several desirable changes within plant body, like stimulation of root formation and flower induction under non inductive conditions as well as protecting plants from several air pollutants i.e. O_3 and SO_2 [24]. Plants growing in stress free environment have more physiologically active gibberellins which tend to increase the permeability of cell membrane and facilitate the distribution of Ca^{2+} to rapidly growing tissues, consequently make it resistant towards tipburn disorder [15].

3.3 PDF

Figure 3 and 4 represents the severity of fruit disorders and its response to different levels of gibberellic acid respectively. According to Figure 4, different GA_3 treatments significantly influenced PDF in all tested sweet orange cultivars. With reference to Figure 4, a higher percentage (2.76) of PDF was observed in untreated trees which was significantly higher than (0.96, 0.82 and 0.76%) recorded in 30, 10 and 20 ppm respectively. The inter varietal

differences were also significant, with a highest value (1.76%) of PDF observed in cv. Blood Red followed by cv. Succari (1.15%) and cv. Mosambi (1.07%). While the interaction of different treatments and cultivars was non-significant.

These differences among different treatments and cultivars might be due to the influence of GA₃ by preventing calcium deficiency which can leads to fruit splitting, however there might be some other environmental reasons for fruit disorders as in sweet oranges the nutritional and water imbalance produce severe fruit disorders like fruit splitting, puffing, creasing and water marks etc. [11]. The intensity of double fruit and fruit splitting disorder in peach was successfully controlled through the application of gibberellic acid and nitrogen to the trees with no water stress [13]. GA₃ and NAA sprays in June and July to Washington Navel Sweet orange reduced the incidence of fruit creasing upto 25 and 14% respectively [14] and bunch fading disorder in Date palm [12].



Figure 3: Intensity of fruit splitting disorder increasing with passage of time and fruit size.

3.4 DFM

The data regarding DFM is presented in Figure 4. According to Figure 4 there were highly significant differences among different treatments and cultivars regarding DFM as well as the interaction of both factors was also significant at ($p=0.05$) (data not mentioned in Table form) level of significance. Accordingly, more number of days to fruit maturity (197.89) was observed in 30 ppm treated trees closely followed by 10 ppm (196.78) and 20 ppm (196.78) which have non-significant difference with each other, while less number of days (187.22) was taken by trees which were kept control. Likewise, maximum number of days to fruit maturity (195.75) was recorded for cv. Blood Red and Succari and minimum number of days (192.50) was taken by Mosambi sweet orange.

Almost all GA₃ treatments showed a delaying effect in terms of fruit maturity, it might be due to the influence of GA₃ on chemical compositions of sweet orange fruits. It might also be due to varietal differences with respect to number of days required to attain fruit maturity by different cultivars. GA₃ reduces chlorophyll depletion and carotenoid accumulation, and hence causes colour break delay in fruit's peel [25]. Similarly GA₃ application results fruit ripening delay in Strawberry which is a highly perishable fruit crop [26].

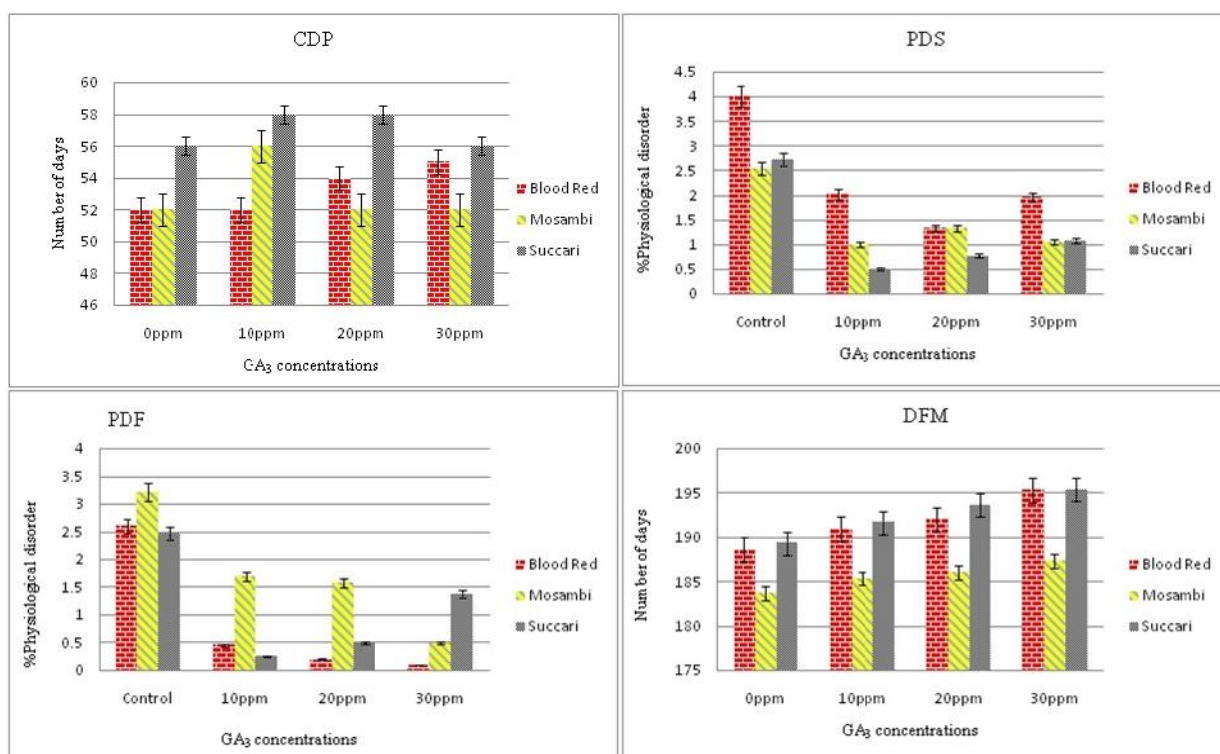


Figure 4: Graphical illustrations of CDP, PDS, PDF and DFM as influenced by different GA_3 application as foliar spray.

Supplementary information

3.5 Fruit growth (mm)

A continuous fruit growth recorded on weekly bases is presented in Figure 5. Accordingly, cultivar Blood Red and Succari showed very minor increase in fruit diameter for treated trees as compared to untreated (control) trees while Mosambi remained unresponsive to GA_3 applications. The graphical presentation of fruit growth showed non-significant differences because the bars representing different concentrations followed almost same pattern for fruit growth.

All sweet orange cultivars started cell expansion in early June and attained maximum average fruit diameter (60 mm with little fluctuation) in early November. The main reason for following same fruit growth pattern might be due to the fact that all cultivars belong to the same species, received same concentrations of GA_3 and almost same environmental conditions. The application of (20 mg L^{-1}) GA_3 delayed fruit maturity 5-8 days only for the late-maturing genotypes, but did not affect early fruit maturing genotypes, while GA_3 application to Strawberry significantly increased fruit weight and size as compared to untreated plants [26]. Gene ontogeny of plum fruit revealed that GA_1 and GA_4 are very important for fruit growth and development. Further several genes have been believed to be involved in GA signaling prior fruit development.

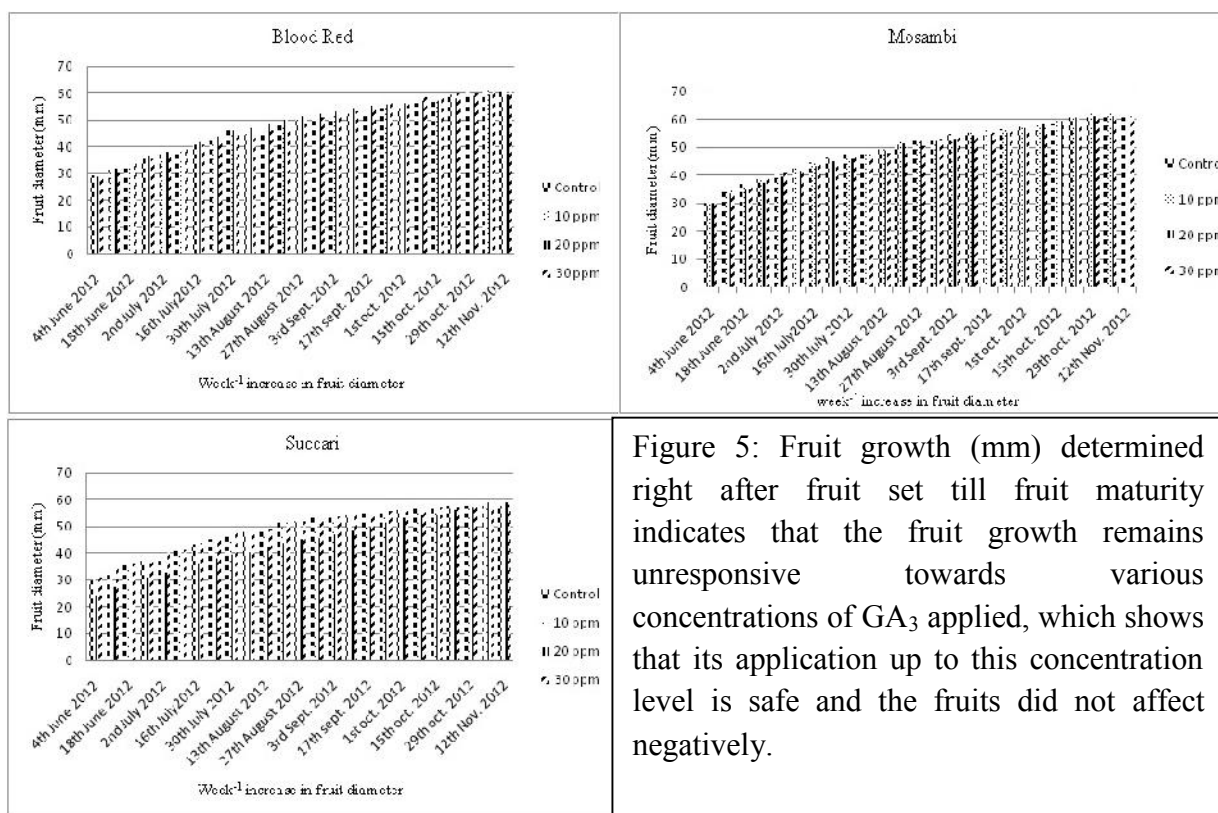


Figure 5: Fruit growth (mm) determined right after fruit set till fruit maturity indicates that the fruit growth remains unresponsive towards various concentrations of GA₃ applied, which shows that its application up to this concentration level is safe and the fruits did not affect negatively.

Figure 5: Response of fruit growth towards different GA₃ concentrations applied as foliar spray in the period from fruit set till fruit maturity.

4. Conclusion

The results revealed that 30 ppm GA₃ application is the best treatment to control fruit and shoot physiological disorder along with prolonging the harvesting season of sweet orange. Therefore it is recommended that 30 ppm GA₃ should be applied at full bloom stage of sweet orange in order to get these desirable effects under similar environmental conditions.

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