Effect of Gibberellic Acid and 2,4-Dichlorophenoxyacetic Acid on Fruit Development and Fruit Quality of Wax Apple

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***Abstract*—**This study was conducted to evaluate the effects of gibberellic acid and 2,4- dichlorophenoxyacetic acid on flower number, fruit growth and fruit quality of wax apple. GA3 and 2,4-D were applied at small bud and petal fall stage. Number of flower, fruit set, fruit drop, fruit crack, fruit growth and fruit quality were recorded. Results indicated that spraying with 10 ppm GA3 had the best results in number of flower. GA3 spray at 30 ppm gave the faster rate of fruit growth than the other treatments. Fruit set, fruit size as well as fruit weight markedly improved by spraying 30 ppm GA3, followed by 10 ppm GA3 compared to untreated control. Moreover, spray GA3 at 30 ppm was the most effective and increased total soluble solids, reduced titratable acidity and fruit drop. On the other hand, it was noticed that with 10 ppm 2,4-D application also enhanced the fruit growth rate, improved physiological and biochemical characters of fruit compared to untreated control. It was concluded that both GA3 and 2,4-D spray have positive effects on fruit development, reduced fruit drop, fruit crack and improved fruit quality of wax apple under field conditions.

***Keywords*—**Wax apple, GA3, 2,4-D, fruit growth, fruit quality.

I. Introduction

WAX-APPLE (Syzygium samarangenese) is an important competitive tropical fruit in Taiwan [55]. It has also become economically important fruit crop in Southeast Asia such as Thailand, Malaysia and Indonesia [44]. Regular flowers appear in March and fruit ripen in May under natural condition in southern Taiwan. However, blooms and sets fruit produced almost year-round after forcing flower treatment [55]. The fruits are pear shaped, usually pink, light red or red, sometimes greenish-white or cream-color, often crisp, with a subtle sweet taste and an aromatic flavour [30]. It has become increasingly popular in this region and has the potential to bring great benefit to local farmers and the country's economy.

The plant growth regulators (PGR) act as messengers and are needed in small quantities at low concentrations. Generally their site of action and biosynthesis are different. Most of the plant growth regulators exhibit a broad spectrum and thus a single PGR may influence several entirely different processes [29]. Moreover, plant growth regulators enhance the rapid changes in physiological and biochemical characters and improve crop productivity. Reference [12] indicated that among agricultural practices which may increase the fruit production and improve the quality of several other fruit crops are the applications of plant growth regulators, especially gibberellic acid. Gibberellic acid has been reported to influence vegetative growth, flowering, fruiting and various disorders in many fruit crops [38]. It is also used widely in other horticultural crops for stimulating fruit set in various fruit species, such as peach [49], 'Clementine' mandarin [50], pear [19], also to control apple russeting [51], and cracking of pomegranate fruit [42]. Moreover, sprays of GA3 have been widely adopted in commercial orchards because they have consistently been shown to increase fruit size and firmness of cherry [14]. Moreover, GA3 increased the yield of fruit in Balady mandarin [23], and increases soluble solids as well as fruit weight in sweet cherry [6].

Furthermore, synthetic auxins are effective in enhancing fruit growth when applied during the second stage of fruit development [56]. According to [22] synthetic auxin increases total antioxidant capacity and nutritional quality in transgenic Silcora seedless grape. These auxins are known for their ability to increase cell enlargement [56], [5], thus enhancing fruit growth in certain species such as Citrus [2], peach [1], litchi [47]. Many studies have intended to prevent fruit abscission in lychee using synthetic auxins, mainly NAA (naphthaleneacetic acid), 2,4-D (2,4-dichlorophenoxyacetic acid), 2,4,5-T (2,4,5- trichlorophenoxyacetic acid) [46]. It was also reported that 2,4-D increased total sugar content and enhanced the activities of antioxidant enzymes [9]. Furthermore, the 2,4-D, GA3 application significantly reduced acidity percentage and increased vitamin C content of citrus fruits [57].

Although these references are available in the literature and efforts have been made to control fruit drop, fruit cracking as well as improve fruit quality by applying of plant growth regulators but there is no available literature on the effect of plant growth regulator on physiological and biochemical parameters of wax apple fruit. Therefore, this study was carried to evaluate the effects of GA3 and 2,4-D on fruit drop, fruit crack, fruit growth as well as fruit quality in wax apple.

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II. Materials and Method

A. Plant Materials and Treatments Design

The experiment was conducted at Tropical fruit orchard, Department of Plant Industry, National Pingtung University of Science and Technology from March to June 2012. Twenty trees were selected for the study. Eighty the uniform branches (four branches per tree) of about the same length and diameter from twenty trees were selected for the experiment. The experiment consists of four treatments including the control was design in Randomized Complete Block Design (RCBD) with four replicated and a singer uniform branch was taken as an experiment unit. Two growth regulators GA3 and 2,4-D was applied at small bud and petal fall stage on windless mornings with a truck- mounted motorized sprayed until dripoff.

B. Data Collection

For the number of bud and bud drop (%), the total number of buds was determined when the bud size was 0.8-1.0 mm. Bud dropping percentage was calculated according to the following formula:

$$\text{Bud drop (\%)} = \frac{\text{Total No. of buds at initial stage - Buds before bloom}}{\text{Total No. of buds at initial stage}} \times 100$$

For the determination percentage of fruit setting from tagged branches on the experimental tree, the percentage of fruit setting was calculated using the following formula:

$$\text{Fruit set (\%)} = \frac{\text{Total No. of fruitlets}}{\text{Total No. of flowers}} \times 100$$

Fruit dropping percentage was calculated at 35 days after anthesis using the following formula:

$$\text{Fruit drop (\%)} = \frac{\text{Total No. of fruitlets} - \text{No. of fruits in 35 days after anthesis}}{\text{Total No. of fruitlets}} \times 100$$

Number of inflorescences per shoot was determiner by choosing randomly 5 shoots on each tagged branches and the number of inflorescences were counted. For the flower count, 5 inflorescences on each of the tagged branches were randomly selected and the numbers of flowers on each inflorescence were counted. Later, fruit growth (length and diameter) were measured weekly with Vernier calipers. At harvesting, final fruit length, fruit diameter, flesh thickness was determined with the help of Vernier caliper. Average fruit weight was determined by weighing and number of fruit crack per cluster was determined.

Total soluble solid (TSS) were measured by using a hand refractometer (ATAGO Co. LTD., Tokyo, Japan) juice was squeezed from the fresh-cut wax apple and the result was expressed as ^{o}Brix. Titratable acidity (TA) was determined using the method described by [10]. The results were expressed as percentage of citric acid.

C. Statistical Analysis

The data obtained from the study were analyzed using SAS 9.1 statistical software. Duncan's multiple range tests was used to compare significant differences among treatment at P≤ 0.05

III. Results and Discussion

A. Number of Buds and Bud Drop

Number of buds per branch was significantly different by spraying with GA3 and 2,4-D (Table I). Spraying with 30 ppm GA3 resulted in the highest values (69.7 buds/branch), whereas the lowest values was obtained from the untreated control (44.0 buds/branch). The treatments spraying with 10 ppm GA3, and 10 ppm 2,4-D also produced higher number of buds per branch compared with the control, which is in accordant with reported by [35].

References [4] reported that endogenous hormones and their balance play a modulating role in the mobilization of nutrients to the developing organs and can influence the longevity of a bud. The perusal of the Table I shows that all the growth regulators treatments (2,4-D, GA3) significantly reduced the buds drop compared to control. Furthermore, application of GA3 had a significant effect on the percentage of bud drop, which was the lowest (29.5%) for treatment with 30 ppm GA3 spray. On the other hand, treatment sprayed with 10 ppm 2,4-D also produced the minimum bud drop (34.9%). However, the control treatment resulted in the highest bud drop (47.2%) compared to other treatments in this study.

TABLE I
Effect of GA3 and 2,4-D on Number of Bud, Bud Drop, Number of Flower per Inflorescence, Number of Inflorescence per Shoot, Fruit Set and Fruit Drop of Wax Apple[1]

Treatment	Number of bud/ branch	Bud drop (%)	Number of flower/ inflorescence	Number of inflorescence/ shoot	Fruit set (%)	Fruit drop (%)
Control	44.0^{b}	47.2^{a}	5.10^{c}	3.36^{b}	24.4^{b}	56.0^{a}
GA3 10 ppm	66.4^{a}	32.1^{b}	7.28^{a}	4.21^{a}	40.7^{a}	38.5^{b}
GA3 30 ppm	69.7^{a}	29.5^{b}	6.46^{ab}	4.18^{a}	42.2^{a}	37.4^{b}
2,4-D 10ppm	64.7^{a}	34.9^{b}	5.45^{bc}	3.95^{a}	36.6^{a}	39.6^{b}

[1] Mean in each column followed by the same letters are not significantly different at P≤ 0.05 according to Duncan's multiple range test.

B. Number of Flowers per Inflorescence and Number of Inflorescence per Shoot

The results summarized in Table I showed that, the application of different plant growth regulator had significant effects on number of flowers per inflorescence and number of inflorescences per shoot. With GA3 application, the highest number of 7.28 flowers per inflorescence was recorded in 10 ppm GA3 treatment, followed by spraying at 30 ppm GA3 with value of 6.46 numbers of flowers per inflorescence. However, there was no effect of spraying with 10 ppm 2,4-D on number of flower per shoot as compared to control. Moreover, maximum number of inflorescence per shoot (4.18-4.21) was obtained when the treatments were sprayed with 30 ppm GA3 or 10 ppm GA3. On the other hand, spraying with 10 ppm 2,4-D resulted in higher (3.95) number of inflorescences per shoot than the control (3.36) as shown in Table I. It seems that GA3 application had affected the initiation flower number significantly over control. Increase in flower number following GA application may be due to its known effect on flowering of various fruit crops [28], [45]. These are in accordant with Khassawneh et al [32] who found that gibberellins are involved in several plant development processes and promote a number of desirable effects including stem elongation, uniform flowering, reduced time to flowering, and increased flower number.

C. Fruit Set and Fruit Drop

Reference [21] indicated that external application of gibberellin induces fruit set in several species. Similar to gibberellin, external application of auxin induces fruit set in tomato [43]. As can be seen from Table I, the treatment that spraying with 30 ppm GA3 produced the maximum fruit set (42.2%), whereas the control treatment produced the least percentage of fruit set (24.4%). The results are in agreement with the finding of Voyiatzis and Paroussi [54] who started that GA3 had resulted in the production of larger number of flowers with rapid elongation of peduncle, leading to full development of flower buds having all functional reproductive parts, which increased fruit set tremendously over control in strawberry. Moreover, the use of GA3 as a growth regulator to promote size and to control fruit drop was reported by [5]. On the other hand, the percentage of fruit set was greatly increased with 10 ppm 2,4-D spray (Table I). Similar finding was reported by Davies et al [16] who reported that application of 2,4-D, GA3 significantly reduced the preharvest fruit drop in citrus species.

Moreover, the minimum percentage of fruit drop (37.4%) was obtained with a 30 ppm GA3, followed by spraying with 10 ppm GA3, whereas the maximum percentage of fruit drop (56.0%) was recorded for untreated control. The effect of GA3 marked reduced fruit drop, which is in agreement with the work of Mengel and Kirkby [34]. The authors reported GA3 has significant influences on the development of fruit and preventing the drop off of young fruits. Furthermore, application of 2,4-D at 10 ppm was also drastically reduced the percentage of fruit drop with value of 39.6 % (Table I), which is in agreement with the finding of Stern et al [47]. Similar findings were reported by [17] who exhibited that application of 2,4-D has been an effective means of reducing fruit drop of citrus for many years.

D. Fruit Growth Length and Diameter

In fruit growing, gibberellic acid is frequently applied as it affects the shape of fruits. Gibberellins are known for their ability to increase cell enlargement [5], thus enhancing fruit growth in certain species such as citrus [23], litchi [11], guava [25], and pear [58]. The Fig. 1 showed that, application GA3 and 2,4-D has significant influenced the fruit growth rate like fruit length and fruit diameter. Maximum fruit length growth rate (6.08 cm) was recorded when application GA3 with the dose of 30 ppm, followed by spraying with 10 ppm 2,4-D or 10 ppm GA3 at the 7th week of observation, while the untreated control had the least fruit length growth rate with value of 5.29 cm. It seems that the enhanced fruit growth rate stimulated by the GA3 and 2,4-D treatments.

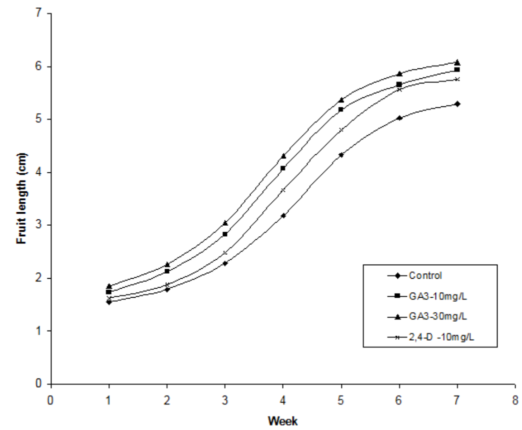

Fig. 1 Effect of GA3 and 2,4-D on fruit growth (length/week)

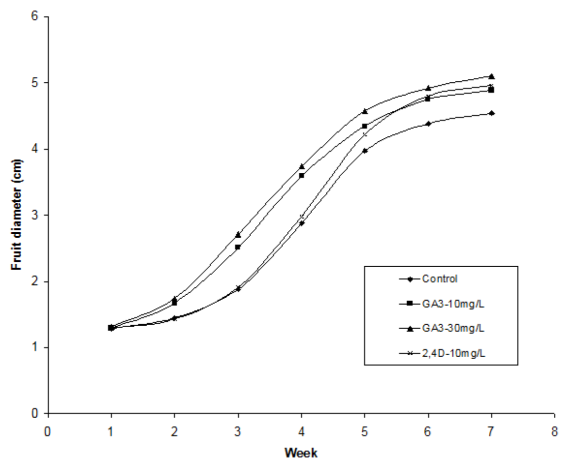

Fig. 2 Effect of GA3 and 2,4-D on fruit growth (diameter/week)

For the fruit diameter development, at the 7th week of observation spraying with 30 ppm GA3 recorded the highest fruit diameter growth rate (5.1 cm), followed by the treatment with 10 ppm GA3 application, whereas the control had the lowest fruit growth rate (4.54 cm). Moreover, spraying with 10 ppm 2,4-D was also drastically increased fruit diameter growth rate (Fig. 2). According to [33] gibberellins influence fruit development, especially at the younger stage of fruit. Moreover, reference [48] indicated that application synthetis auxins in 'Bing' cherry had fruit grew at a faster rate than untreated control. In the current study, the fruit growth rate with GA3 and 2,4-D spray was considerably faster compared to untreated control. Hence, the rate of fruit growth (length and diameter) was greatly accelerated by the GA3 or 2,4-D application.

E. Effect of GA3 and 2,4-D on Quality Parameters of Fruit

Fruit Weight

Reference [26] showed that GA3 applications delayed the harvest time and significantly contributed to the weight increases. The role of GA in improving fruit quantity namely, fruit weight and fruit size may be due to its role in increasing cell elongation [24]. Data in Table II revealed that there was significant fruit weight among treatments. Spraying with 30 ppm GA3 resulted in the greatest fruit weight (75.9 g), followed by 10 ppm GA3 and 10 ppm 2,4-D application with values of 64.7 g, 62.4 g, respectively. The lowest fruit weight (48.0 g) was obtained for untreated control. Reference [32] indicated that spraying with GA3 seem stimulate both cell division and cell enlargement which by their turn are reflected on fruit weight increase. Moreover, the increase in fruit weight also due to application of 2,4-D was reported in pomegranate cv. Mridula [53] and in Pant lemon-1 [41]. Therefore, the application GA3 and 2,4-D relatively increased fruit weight in comparison with the control in a previous study. Moreover, spraying with 30 ppm GA3 had a much greater influence on fruit weight. It was considerable the higher fruit weight in GA3 and 2,4-D treatments could be attributed to its favourable effect on fruit characters (fruit length, diameter) as shown in Table II. The same has been reported by Basak et al [6] who reported that application GA3 increased fruit weight in sweet cherry fruit. This is also in agreement with Khan et al [31] who found that an increase in fruit size due to 2,4-D application which could be due to stimulation of parthenocarpic fruit growth that resulted in increased fruit weight.

TABLE II
EFFECT OF GA3 AND 2,4-D ON FRUIT CHARACTER OF WAX APPLE [1]

Treatment	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Flesh thickness (mm)	Fruit crack/cluster	TTS (°Brix)	TA (%)
Control	48.0[c]	57.4[b]	47.8[c]	10.9[c]	1.81[a]	8.75[c]	0.67[a]
GA3 10ppm	64.7[b]	60.6[a]	50.7[b]	13.6[b]	1.18[b]	11.2[b]	0.60[b]
GA3 30ppm	75.9[a]	61.6[a]	53.0[a]	14.9[a]	0.68[b]	12.3[a]	0.50[c]
2,4-D 10ppm	62.4[b]	60.1[a]	51.4[b]	13.0[b]	0.83[b]	11.3[b]	0.57[b]

1. Mean in each column followed by the same letters are not significantly different at P≤ 0.05 according to Duncan's multiple range test.

1. Fruit Length and Fruit Diameter

The fruit size is one of the most important quality parameter in sweet cherry. For this reason, as the big fruits are much more flesher, they are preferred more by the consumers [26], 15]. According to [47] application of synthetic auxins, such as 2,4,5-TP or 3,5,6-TPA, at this stage of litchi fruit growth not only reduced abscission but also accelerated fruit size, due to the enhanced strength of the sink for carbohydrate. Moreover, gibberellic acid (GA3) significantly increased fruit size of several other fruit types [56] possibly by increasing cell size and/or cell numbers and increased sink demand [58]. In the case of the study, there were significant differences in fruit length, fruit diameter between treatments (Table II). In term, the treatment with 30 ppm GA3 application produced the highest fruit length (61.6 mm), whereas the lowest fruit length (57.4 mm) was recorded for untreated control. It seems that spray 30 ppm GA3 markedly increased fruit length compared with the control. These results are in agreement with Usenik et al [52] who found that GA3 application increased cell division and elongation and had a positive effect on fruit size. On the other hand, fruit length with 2,4-D application was also significantly higher compared to untreated control (Table II). It seem be attributed to nature of auxins to increase the osmotic pressure of cell sap which is responsible for uptake of water and consequently results in increased growth, which is accordant with previous studies of [53] in pomegranate, Baghel and Sarnaik [7] in sweet orange, Babu and Lavaniya [8] in Pant Lemon-1. Similar finding was reported by Agusti et al [3] who indicated that treatment with synthetic auxins, such as 2,4-D increase fruit size in apricot.

Moreover, the maximum fruit diameter (53.0 mm) was recorded with a 30 ppm GA3 application, followed by 10 ppm GA3 spray with value of 50.7 mm, while the minimum fruit diameter (47.8 mm) was found in the control treatment (Table II). The results are shown that the use of 30 ppm GA3 resulted in improvement of fruit diameter compared to the control. This is in accordance with the finding reported by Ranjan et al [40] who demonstrated that the increase in fruit size may be attributed to the increase in cell division and cell elongation caused by GA3. Furthermore, spraying with 10 ppm 2,4-D also produced greater fruit diameter than the untreated control, the differences were statistically significant at (P≤ 0.05) (Table II). Similar finding was reported by Arteca [5], started that the increase fruit size demonstrated here in response to auxin application which may indicate their ability to stimulate carbohydrate translocation to the fruit in combination with their effect on increasing cell wall elasticity. Therefore, it was determined that GA3 or 2,4-D applications relatively increased the fruit length and fruit diameter in comparison with the control in this study.

2. Flesh Thickness

As can be seen from the Table II, the flesh thickness was significantly influenced by application PGRs. Treatment with 30 ppm GA3 application produced the highest flesh thickness (14.9 mm). This was followed by GA3 10 ppm and 2,4-D ppm spray with flesh thickness of 13.6 mm, 13.0 mm, respectively. However, the worst flesh thickness (10.9 mm) was recorded for control treatment. Hence, spray GA3 or 2,4-D considerable increased flesh thickness after application compared to the untreated control. This increase in the flesh thickness was statistically significant (P≤ 0.05) (Table II). These results are in agreement with Dawood [18] who indicated that spray paclobutrazol and GA3 increased the thickness of the fruit cuticle and the epidermal layers. Similar finding were reported by Agusti et al [1], demonstrated that application synthetis auxins increased fruit size in peach fruit.

3. Fruit Cracking

Reference [15] indicated that the cracking resulting from the rain that happens closer to the harvest time is an another significant factor affecting the quality of the sweet cherries fruit. The cracking that causes the fruit to get easily wrinkled may change according to the genetic characteristics of the varieties. In addition, GA3 decreases the cracking in fruit by delaying maturity time of fruits and getting over critical rain period [52]. The data presented in Table II showed that, treatment with GA3 application resulted in lower fruit cracking than the control treatment. In contract, spraying with 30 ppm GA3 produced the minimum fruit cracking (0.68 fruit crack/cluster), whereas the control treatment showed the highest fruit cracking (1.81 fruit crack/cluster). Similarly, with 2,4-D application also had the lower fruit cracking amount of 0.83 fruit crack/cluster compared to untreated control (Table II). For this reason, applications that increase the resistance against cracking are being applied to the varieties that are preferred by the consumers and have good fruit quality. One of the leading applications in the world is chemical substance applications such as gibberellic acid (GA3), Ca, K, NO3, and N2 [13]. Therefore, the resulted in this study revealed that the control treatment considered more susceptible to cracking, showed greater levels of cracking in comparison with other treatments. Application GA3 greatly reduced fruit cracking, thereby increasing the production of healthy fruit with better quality, which is in agreement with Demirsoy & Bilgener, [20] who stated that gibberellic treatment decreased cracking indices in sweet cherry.

4. Total Soluble Solids (TTS)

Total soluble solids measurement is considered to be an important parameter of quality of wax apple fruits. As can be seen from Table II, the growth regulators treatments significantly increased the TSS compared to control. In this case, spraying with 30 ppm GA3 resulted in the highest TSS (12.3 ^{o}Brix), whereas the control produced the lowest TSS (8.75 ^{o}Brix). On the other hand, treatment with 2,4-D at 10 ppm application also clearly increased TSS with values of 11.3 ^{o}Brix. These values were statistically significant at ($P\leq 0.05$). So it becomes markedly that application GA3 and 2,4-D significant increase TSS as compared to untreated control. These results are in agreements with Huang & Huang [27] who reported that by application of growth regulators significantly increase the TSS of fruit in citrus species.

5. Titratable Acidity (TA)

Gibberellins primarily affect growth by controlling cell elongation and division, which is reflected on yield and its components and fruit quality of various grape cultivars [39]. The result of Table II showed that application GA3 and 2,4-D had a significantly affected on TA, in which all the growth regulators decreased the acidity percentage. The control treatment produced the highest TA amount of 0.67%, whereas the minimum TA (0.50 - 0.60%) was recorded with 30 ppm or 10 ppm GA3 application. As a result it seems that GA3 application had a reducing effect on the acidity acid values drastically. On the other hand, the minimum TA (0.57%) was also found in 10 ppm 2,4-D spray. Therefore, from the data presented in this study indicated that GA3 and 2,4-D applications greatly decrease effect on the acidity value compared to the control treatment, in term the lowest acidity was clear found in 30 ppm GA3 spray. The reduction in titratable acidity observed seems be attributed to the conversion of the organic acids to sugar during fruit ripening by applying of plant growth regulators. These results are in agreement with Nawaz et al [36] who indicated that spraying 10 ppm 2,4-D markedly decreased acidity in Kinnow mandarin fruit. Moreover, this results are also in accordant with Otmani et al [37] who reported that acidity percentage was significantly reduced by the application of 2,4-D, GA3.

IV. Conclusion

From the experiment results, it can be concluded that application of 10 ppm GA3 markedly stimulated number of flower. In the case of GA3 at 30ppm application indicated the better results in the physiological and biochemical parameters of wax apple fruit with improved fruit size, fruit weight, stimulated fruit growth, and increased total soluble solids. Moreover, spray GA3 with 30 ppm markedly reduced fruit crack, fruit dropping and TA. On the other hand, with 2,4-D 10 ppm application had also a positive effective for enhancing fruit set, improved fruit weight and fruit quality, with less number of fruit crack and proportion of fruit drop. From the results, we concluded that application 10 ppm GA3, 30 ppm GA3, and 10 ppm 2,4-D at small bud and petal fall may be recommended as practical tools for improving fruit set, fruit weight, stimulated fruit growth, reduced fruit drop, fruit crack and improving fruit quality of wax apple under field conditions.

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References

[1] M. Agusti, V. Almela, I. Andreu, M. Juan, and L. Zacarias, “Synthetic auxin 3,5,6-TPA promotes fruit development and climacteric in Prunus persica L. Batsch,” J. Hort. Sci. Biotech, 74, pp 556–660. 1999.

[2] M. Agusti, M.E. Otmani, M. Juan, and V. Almela, “Effect of 3,5,6-trichloro-2-pyridyloxyacetic acid on clementine early fruitlet development and on fruit size at maturity,” J. Hort. Sci, 70, pp 955–962. 1995.

[3] M. Agusti, M. Juan, V. Almela, and C. Speroni, “The effect of 2,4-DP on fruit development in apricots (Prunus armeniaca L.),” Scientia Hort, 57, pp 51– 57. 1994.

[4] I. Almeida, I.M. Leite, J.D. Rodrigues, and E.O. Ono, “Application of plant growth regulators at pre-harvest for fruit development of ‘PERA’ oranges,” Braz. Arch. Biol. Technol, 47, pp 658-662. 2004.

[5] R.N. Arteca, “Plant Growth Substances: Principles and Applications,” Chapman and Hall Press, New York, USA, 332 pp, 1996.

[6] A. Basak, E. Rozpara, and Z. Grzyb, "Use of Bioregulators to Reduce Sweet Cherry Tree Growth and to improve Fruit Quality," Acta Horticult, 468, pp 719-723. 1998.
[7] B.S. Baghel and D.A. Sarnaik, "Effect of 2,4-D on yield and physic-chemical composition of mrigbahar sweet orange variety, Poona Mosambi," South Indian Hort, 33, pp 395-396. 1985.
[8] G.H.V.R. Babu and M.L. Lavaniya, "Effect of plant growth regulators on fruit set and fruit drop of Pant lemon-1," Indian J. Hort, 42, pp 237-240. 1985.
[9] W. Baogang, W. Jianhui, and L. Hao, "Reduced chilling injury in mango fruit by 2,4-dichlorophenoxyacetic acid and the antioxidant response," Postharvest Biology and Technology, 48(2), pp 172–181. 2008.
[10] D.R. Bhattarai and D. M. Gautam, "Effect of harvesting method and calcium on post harvest physiology of tomato," Nepal Agriculture Research Journal, 7, pp 37–41. 2006.
[11] J.C. Chang, and T.S. Lin, "GA3 increases fruit weight in 'Yu Her Pau' litchi," Sci. Horticult, 108(4), pp 442-443. 2006.
[12] C.T. Chao and C.J. Lovatt, "Foliar applied 3,5,6-trichloro-2-pyridoxylacetic acid (3,5,6-TPA) increases yield of commercially valuable large-size fruit of "Fina Sodea" clementine mandarin," Acta Hort, 884, pp 433-440. 2010
[13] M. Clayton, W.V. Biasi, I.T. Agar, S.M. Southwick, and E.J. Mitcham, "Postharvest Quality of 'Bing' Cherries Following Preharvest Treatment with Hydrogen Cyanamide, Calcium Ammonium Nitrate, or Gibberellic Acid," Hort. Sci, 38(3), pp 407-411. 2003.
[14] M. Clayton, W.V. Biasi, I.T. Agar, S.M. Southwick, E.J. Mitcham, "Sensory quality of 'Bing' sweet cherries following preharvest treatment with hydrogen cyanamide, calcium ammonium nitrate, or gibberellic acid," HortScience, 41, pp 745–748. 2006.
[15] J.A. Cline and M. Trought, "Effect of Gibberellic Acid on Fruit Cracking and Quality of Bing and Sam Sweet Cherries," Can. J. Plant Sci, 87(3), pp 545-550. 2007.
[16] F.S. Davies and G. Zalman, "Gibberellic acid, fruit freezing, and post-freeze quality of Hamlin oranges," Hort. Tech, 16(2), pp 301-305. 2006.
[17] F.S. Davies, "Growth regulator improvement of post-harvest quality," In: Fresh citrus fruit. W. Wardowski, S. Nagy, W. Grieson (eds.), AVI Press, Westport, Conn 77-99 pp. 1986.
[18] Z.A. Dawood, "Studies into fruit splitting and quality of sweet cherry (Prunus avium L.), Tomato (Lycopersicon esculentum L.), and grape (Vitis vinifera L.)," Ph.D thesis. Department of Horticulture, Wye College, University of London, Wye, UK ,256 pp. 1986.
[19] T. Deckers and H. Schoofs, "Improvement of fruit set on young pear trees cultivar Conference with gibberellins," Acta Hort, 596, pp 735–743. 2002.
[20] L.K. Demirsoy and S.Bilgener, "The Effects of Preharvest Calcium Hydroxide Applications on Cracking and Fruit Quality in 0900 Ziraat, Lambert and Van Sweet Cherry Varieties," Acta Horticult, 468, pp 657-662. 1998.
[21] E. Dorcey, C. Urbez, M.A. Blazquez, J.Carbonell, and M.A. Perez-Amador, "Fertilization dependent auxin response in ovules triggers fruit development through the modulation of gibberellin metabolism in Arabidopsis," Plant Journal, 58, pp 318-332. 2009.
[22] C. Elisa, L. Lucia, S. Oriana, P. Tiziana, S. Angelo, B. Mezzetti, "Auxin synthesis-encoding transgene enhances grape fecundity," Plant Physiology, 143(4), pp 1689– 1694. 2007.
[23] A.M.A. El-Sese, "Effect of gibberellic acid 3 (GAs) on yield and fruit characteristics of Balady mandarin," Assiut. J. Agri. Sci, 36, pp 23-35. 2005.
[24] A.A. Eman, M.M.M.A. El-moneim, O.A. El- Migeed, and M.M. Ismail, "GA3 and Zinc Sprays for Improving Yield and Fruit Quality of Washington Navel Orange Trees Grown under Sandy Soil Conditions," Res. J. Agric. Biol. Sci, 3(5), pp 498-503. 2007.
[25] S.H.M.M. El-Sharkawy and S.M.A. Mehaisen, "Effect of gibberellin and potassium foliage sprays on productivity and fruit quality of guava trees," Egypt J. Appl. Sci, 20(3), pp 151-162. 2005.
[26] S. Horvitz, C. Godoy, A.F. Lopez Camelo, A. Yommi, "Application of Gibberellic Acid to 'Sweetheart' Sweet Cherries:Effect on Fruit Quality at Harvest and During Cold Storage," Acta Horticult, 628, pp 311-316. 2003.
[27] J.H. Huang and L. Huang, "The application of GA3 in citrus orchards," South China Fruits, 3, pp 32-36. 2005.
[28] F. Kappel and R. MacDonald, "Early gibberellic acid spray increase fruiting and fruit size of Sweetheart sweet cherry," J. Am. Pomol. Soc, 61(1), pp 38–43. 2007.
[29] H.A. Kassem, A.M. El-Kobbia, H.A. Marzouk, M.M. El- Sebaiey, "Effect of foliar sprays on fruit retention, quality and yield of Costata persimmon trees," Emir. J. Food Agric, 22 (4), pp 259-274. 2010.
[30] M.M. Khandaker, A.N. Boyce, and N. Osman, "The influence of hydrogen peroxide on the growth, development and quality of wax apple (Syzygium samarangense, [Blume] Merrill & L.M. Perry var. jambu madu) fruits," Plant Physiology and Biochemistry, 53, pp 101-110. 2012.
[31] M.M.A. Khan, A.C. Gautam, F. Mohammad, M.H. Siddiqui, M. Naeem, and M.N. Khan, "Effect of gibberellic acid spray on performance of tomato," Turk. J. Biol, 30, pp 11-16. 2006.
[32] N.M.A. Khassawneh, N.S. Karam, and R.A. Shibli, "Growth and flowering of black iris (Iris nigricans Dinsm.) following treatment with plant growth regulators," Scientia Horticulturae, 107, pp 187–193. 2006.
[33] S. Kondo and N. Mizuno, "Relation between early drop of apple fruit and endogenous growth regulators and effects of MCPB, GA3 plus GA4 and BA sprays on fruit abscission," Journal of Japanese Society for Horticultural Science, 58, pp 9-16. 1989.
[34] K. Mengel and E.A. Kirkby, "Principles of Plant Nutrition," 4th End., International Potash Institute, Bern, Switzerland, 687 pp. (1987).
[35] J. Morton, "Loquat," In: Morton JF (Ed.). Fruits of Warm Climates. Miami FL. Inc. Winter vile, NC, 103-108 pp. 1987.
[36] M.A. Nawaz, W. Ahmad, S. Ahmad, and M.M. Khan, "Role of growth regulators on preharvest fruit drop," Pak. J. Bot, 40(5), pp 1971-1981. 2008.
[37] M.E. Otmani, A. Ait-Oubahou, C.J. Lovatt, F. El-Hassainate, "Effect of Gibberellic acid, Urea and KNO3 on yield, composition and nutritional quality of Clementine mandarin fruit juice," ISHS Acta Horticulturae, 632. 2004. XXVI International Horticultural Congress: Citrus and other subtropical and tropical fruit crops: issues, advances and opportunities.
[38] G. Paroussi, D.G. Voyiatzis, E. Paroussi, P.D. Drogour, "Growth, flowering and yield responses to GA3 of strawberry grown under different environmental conditions," Scientia Hortic, 96, pp 103–113. 2002.
[39] E.J.P. Pires, M.M. Terra, C.V. Pommer, I.R.S. Passos, "Improvement of cluster and berry quality of Centennial Seedless grapes through gibberellic acid," Acta Horticulturae, 526, pp 293-299. 2000
[40] R. Ranjan, S.S. Purohit, V. Prasad, "Plant Hormones: Action and Application," Agrobios, India, 2003. pp183–189
[41] G.H.V. Ratnababu, M.L. Lavania, K.K. Misra, "Effect of plant growth regulator sprays on yield and physic-chemical composition of Pant lemon-1 (Citrus limon Burm.) fruits in the off-season flush," Prog. Hort, 16 (3-4), pp 191-198. 1984.
[42] A. Sepahi, "GA3 concentration for controlling fruit cracking in pomegranates," Iran Agric. Res, 5, pp 93–99. 1986.
[43] J.C. Serrani, R. Sanjuán , O. Ruiz-Rivero , M. Fos , J.L. Garcia-Martinez, "Gibberellin regulation of fruit set and growth in tomato," Plant Physiology, 145, pp 922-934. 2007.
[44] Z.H. Shü, C.C. Chu, L.C. Hwang, C.S. Shieh, "Light, temperature, and sucrose affect color, diameter, and soluble solids of disks of wax apple fruit skin," HortScience, 36, pp 279–281. 2001.
[45] A. Singh and J.N. Singh, "Studies on the influence of biofertilizers and bioregulators on flowering, yield and fruit quality of strawberry Cv. Sweet Charlie," Ann. Agri. Res, 27 (3), pp 261–264. 2006.
[46] R.A. Stern, J. Kigel, E. Tomer, S. Gazit, "'Mauritius' Lychee Fruit Development and Reduced Abscission after Treatment with the Auxin 2,4,5-TP,"J. Amer. Sos. Hort. Sci, 120(1), pp 65-70. 1995.
[47] R.A. Stern and S. Gazit, "Reducing fruit drop in lychee with PGR sprays," In: Basra, A. (Ed.), Plant Growth Regulators in Agriculture and Horticulture. The Haworth Press Inc., New York, USA, 211– 222 pp. 2000.
[48] R.A. Stern, M. Flaishman, S. Applebaumc, R. Ben-Arie, "Effect of synthetic auxins on fruit development of 'Bing' cherry (Prunus avium L.)," Scientia Horticulturae, 114, pp 275–280. 2007.
[49] G.W. Stutte and J. Gage, "Gibberellins inhibit fruit abscission following seed abortion in peach," J. Amer. Soc. Hort. Sci, 115, pp 107–110. 1990.
[50] M. Talon, L. Zarcarias, E. Primo-Millo, "Gibberellins and parthenocarpic ability in developing ovaries of seedless mandarins," Plant Physiol, 99, pp 1575–1581. 1992.

[51] D.R. Taylor and J.N. Knight, "Russeting and cracking of apple fruit and their control with plant growth regulators," Acta Hortic, 2, pp 819–820. 1986.
[52] V. Usenik, D. Kastelec, F. Stampar, "Physicochemical Changes of Sweet Cherry Fruits Related to Application of Gibberellic Acid," Food Chem, 90, pp 663-671. 2005.
[53] K. Venkatesan and M.K. Mohideen, "Effect of growth regulators on fruit characters and yield of pomegranate (Punica granatum L.) cv. Ganesh," South Indian Hort, 42 (4), pp 239-244. 1994.
[54] D.G. Voyiatzis and G.P. Paroussi, "The effect of photoperiod and gibberellic acid on strawberry pollen germination and stamen growth," Acta Hortic, 567, pp 257–260. 2002.
[55] D.N. Wang, "The study of the advance flower forcing promotion of wax-apple. The effect of forcing flower by chemical and culture treatment of wax-apple," in Chinese J. Agric. Res. China, 32(2), pp129-138. 1983.
[56] M.N. Westwood, "Temperate-Zone Pomology: Physiology and Culture," third ed. Timber Press, Portland, OR, USA 523 pp. 1993.
[57] J.X. Xiao, S. Peng, H.P. Hua, L.H. Jiang, "Effects of calcium nitrate and IAA on calcium concentration and quality of Satsuma mandarin fruit," J. Fruit Sci, 22(3), pp 211-215. 2005.
[58] C. Zhang, K. Tanabe, H. Tani, H. Nakajima, M. Mori, A. Itai, E. Sakuno, "Biologically active gibberellins and abscisic acid in fruit of two late-maturing Japanese pear cultivars with contrasting fruit size," J.