

# Response of Wax Apple Cultivars by Applied GA3 and 2,4-D on Fruit Growth and Fruit Quality

Minh Tuan, Nguyen, and Chung-Ruey Yen

**Abstract**—The experiment was performed to evaluate the effect of GA3, 2,4-D on fruit growth and fruit quality of wax apple. The experiment consisted of Red A, Monulla, Atu, Red B cultivars. GA3 and 2,4-D were applied at the small bud and petal fall stage. Physiological, biochemical characters of fruit were recorded. The result showed application of GA3, 2,4-D greatly response in increasing fruit set for all treatment as compared to control. Fruit weight, fruit size were increased at 10 ppm 2,4-D in 'Red A', 'Red B', however it was also enhancing at 10 ppm GA3 in 'Monulla', 'Atu'. For 'Monulla', 'Atu' fruit crack reduced by 10 ppm 2,4-D application, but 'Red B', 'Red A' gave least fruit crack at 10 and 30 ppm GA3, respectively. 'Monulla', 'Atu' and 'Red B' resulted in response well to 10 ppm GA3 on improving TSS, whereas application of 30 ppm GA3 greatly enhancing TSS in 'Red A'. For 'Atu' titratable acidity markedly reduced by 10 ppm GA3 application, but spraying with 30 ppm GA3 greatly response in reducing titratable acidity in 'Red A', 'Red B' and 'Monulla'. It was concluded that GA3, 2,4-D can be an effective tool to enhancing fruit set, fruit growth as well as improving fruit quality of wax apple.

**Keywords**—Wax apple, GA3, 2,4-D, fruit growth, fruit quality.  
Abbreviations: **GA3**, gibberellic acid; **2,4-D**, 2,4-dichlorophenoxyacetic acid.

## I. INTRODUCTION

WAX apple is a member of the Myrtaceae and is botanically identified as *Syzygium samarangense* Merr.&Perry. The origin of wax apple species belongs to Malaysia and other south-east Asian countries [24]. It is an economically important fruit crop in Taiwan [35], and in neighboring countries such Thailand, Indonesia and Malaysia [40]. The fruits are generally pear-shaped about 3.4-5 cm long, 4.5-5.4 cm wide. The flesh white, spongy, dry to juicy, low acid and aromatic favor [24]. The skin colour can be green to deep-red depending upon cultivars [27]. Moreover, the fruits can be used for several inflammatory conditions, including sore throat, high blood pressure, ringworm, and as an antimicrobial, antiscorbutic, carminative, diuretic, and astringent [31].

Plant growth regulators (PGRs) have become an important component of agrotechnical procedures for most of the cultivated plants and especially for fruit plants [23]. According to [25] growth regulators may provide the means of bringing about required growth responses as there is abundant data indicating that their use can increase the yield of product per

unit of time and land. The use of plant growth regulators compounds (auxins, cytokinins and gibberellins) is becoming popular to ensure efficient production [17]. There are many reports which indicate that application of PGRs enhanced plant growth and crop yield [42], [26]. The discovery of gibberellic acid (GA3) and their ability to induce pollination-independent fruit development (parthenocarpy) in several plant species [41], increases stem length, the number of flower per plant and induces fruit setting [4]. GA3 is also known for its capacity to increase source activity and redistribute carbohydrate, resulting in increased sink strength of developing fruit, either through increased cell division or enhanced cell size [18]. Moreover, gibberellins are used to control the fruit drop and to improve the quality of fruit in citrus [2]. Similarly found that 2,4-D use to improve fruit size [3], enhanced fruit set and development in apple [12] increased total sugar content in mango [6] vitamin C, reduced fruit drop in citrus [11], decreased acidity percentage in Satsuma mandarin fruit [43].

Additionally the information about response of wax apple cultivars by applied plant growth regulators to control fruit drop, improve fruit quality as well as fruit set so far lacking. The aim of this study was to evaluate fruit growth and fruit quality of four wax apple cultivars in response to GA3 and 2,4-D under field conditions.

## II. MATERIALS AND METHOD

### A. Plant Materials and Experiment Treatments

The experiment was carried out at Tropical fruit orchard, National Pingtung University of Science and Technology from March to June 2012. Four wax apple cultivars include Red A, Monulla, Atu and Red B were chosen for the experiment. There are four blocks and each block is one cultivar. Twenty trees (five trees per block) were used in the experiment, 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 4 treatments including control, GA3 10 ppm, GA3 30 ppm and 2,4-D 10 ppm. The experiment design was in Randomized Complete Block Design with five replicated and a single 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 drippoff.

### 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.

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Bud dropping percentage was calculated according to the following formula:

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

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:

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

Fruit growth (length and wide) 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 by counted.

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 °Brix. Titratable acidity (TA) was determined using the method described by [8]. The results were expressed as percentage of citric acid. The pH of the wax apple juice was recorded using a pH meter (Hanna pH 211, Italy)

### C. Statistical Analysis

The data obtained from the study were analyzed using SAS 9.1 statistical software for each cultivar separately. The least significant difference was calculated following a significance F-test (at  $p \leq 0.05$ )

## III. RESULTS

### A. Number of Bud and Bud Drop

The number of buds per branch for all treatment in this study is presented in Table I. For 'Red A' cultivar spraying with 10 ppm 2,4-D exhibited the maximum (50.2) number of buds/branch, whereas the lowest values was found in untreated control with 40.8 number of buds/branch. The same was also observed concerning the number of buds/branch of 'Monulla' cultivar. In term, the highest values (73.40 number of buds/branch) was obtained at 10ppm 2,4-D application, while the control gave the lowest values of 57.4 number of buds/branch (Table I). However, spraying with 10ppm GA3 produced the maximum (86.6) number of buds/branch, followed by 10ppm 2,4-D application, which was recorded in 'Atu' cultivar. The minimum number of buds/branch (65.8)

was found in the untreated control (Table I). For 'Red B' cultivar the highest buds number/branch (65.6) was observed at 10 ppm GA3 application, followed by 30 ppm GA3 and 10 ppm 2,4-D application with values (53.0 and 51.2 buds number/branch, respectively), whereas the control treatment had the lowest value of 42.6 buds number/branch (Table I).

TABLE I  
EFFECT OF GA3 AND 2,4-D ON NUMBER OF BUD, BUD DROP, FRUIT SET AND FRUIT DROP OF WAX APPLE

Treatment	Number of bud/branch	Bud drop (%)	Fruit set (%)	Fruit drop (%)
<b>Red A</b>				
Control	40.80 <sup>a</sup>	62.72 <sup>a</sup>	37.45 <sup>b</sup>	53.33 <sup>a</sup>
GA3 10 ppm	49.20 <sup>a</sup>	37.78 <sup>b</sup>	70.83 <sup>a</sup>	29.83 <sup>b</sup>
GA3 30ppm	48.00 <sup>a</sup>	35.68 <sup>b</sup>	67.41 <sup>a</sup>	30.95 <sup>b</sup>
2,4-D 10ppm	50.20 <sup>a</sup>	25.12 <sup>b</sup>	53.75 <sup>ab</sup>	26.83 <sup>b</sup>
<b>Monulla</b>				
Control	57.40 <sup>a</sup>	51.62 <sup>a</sup>	22.11 <sup>b</sup>	54.86 <sup>a</sup>
GA3 10 ppm	68.20 <sup>a</sup>	25.24 <sup>b</sup>	43.88 <sup>a</sup>	34.85 <sup>b</sup>
GA3 30ppm	66.60 <sup>a</sup>	32.22 <sup>ab</sup>	46.02 <sup>a</sup>	25.24 <sup>b</sup>
2,4-D 10ppm	73.40 <sup>a</sup>	43.70 <sup>ab</sup>	41.25 <sup>a</sup>	36.44 <sup>b</sup>
<b>Atu</b>				
Control	65.80 <sup>a</sup>	62.98 <sup>a</sup>	35.55 <sup>b</sup>	57.41 <sup>a</sup>
GA3 10 ppm	86.60 <sup>a</sup>	40.52 <sup>b</sup>	48.02 <sup>a</sup>	30.42 <sup>b</sup>
GA3 30ppm	68.00 <sup>a</sup>	36.60 <sup>b</sup>	54.52 <sup>a</sup>	27.02 <sup>b</sup>
2,4-D 10ppm	71.40 <sup>a</sup>	36.54 <sup>b</sup>	47.57 <sup>a</sup>	20.79 <sup>b</sup>
<b>Red B</b>				
Control	42.60 <sup>a</sup>	47.96 <sup>a</sup>	29.23 <sup>b</sup>	59.63 <sup>a</sup>
GA3 10 ppm	65.60 <sup>a</sup>	37.80 <sup>ab</sup>	60.27 <sup>a</sup>	24.45 <sup>b</sup>
GA3 30ppm	53.00 <sup>a</sup>	27.34 <sup>b</sup>	62.63 <sup>a</sup>	22.88 <sup>b</sup>
2,4-D 10ppm	51.20 <sup>a</sup>	30.92 <sup>b</sup>	63.56 <sup>a</sup>	25.28 <sup>b</sup>

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

As can be seen from Table I, the lowest bud drop of 25.12% was recorded at 10 ppm 2,4-D application, whereas the highest bud drop of 62.72% was obtained in untreated control. It is also clear from the results that spraying at 10ppm and 30ppm GA3 concentration showed the lower bud drop as compared to control treatment. This results was achieved in 'Red A' cultivars with the significantly difference at ( $p \leq 0.05$ ). For 'Monulla' cultivar, spraying with 10ppm GA3 gave the lowest bud drop with values of 25.24%, while the control treatment produced the highest bud drop (51.62%). Moreover, spraying with 30 ppm GA3 and 10 ppm 2,4-D had lower bud drop (32.22% and 43.70%, respectively) in comparison with control, although the difference was not statistically (Table I). In the case of 'Atu' cultivar, spraying with 10ppm 2,4-D produced the minimum bud drop (36.54%), followed by 30 ppm and 10ppm GA3 application with values of 36.6% and 40.52%, respectively. The highest bud drop (62.98%) was found in untreated control (Table I). However, 'Red B' cultivar with 30ppm GA3 application showed the lowest bud drop (27.34%), whereas the maximum (47.96%) bud drop was observed in control treatment (Table I).

### B. Fruit Set and Fruit Drop

The results summarize in Table I showed that there was greatly effect of GA3 and 2,4-D application on percentage of fruit set among treatment. For 'Red A' cultivar, spraying with 10 ppm GA3 had the maximum fruit set (70.83%), followed by 30 ppm GA3 applications with value of 67.41% fruit set.

However, application of 10 ppm 2,4-D showed slightly increased fruit set as compared to untreated control, although there were not significantly different. The minimum fruit set (37.45%) was recorded in control treatment. However, application of 30 ppm GA3 produced the maximum fruit set (46.02%) in 'Monulla' and (54.52%) in 'Atu' cultivar. The control treatment showed the lowest fruit set with values of 22.11% and 35.55%, respectively (Table I). For 'Red B' cultivar, the highest fruit set (63.56%) was obtained at 10 ppm 2,4-D application, whereas the lowest fruit set was found in untreated control. Moreover, spraying 10 ppm and 30 ppm GA3 also had the higher fruit set compared to control treatment, which was significantly different (Table I).

As shown in Table I, there was significantly decreased fruit drop in all treatment as compared to untreated control. Spraying with 10 ppm 2,4-D produced the lowest fruit drop 26.83% in 'Red A' and 20.79% 'Atu' cultivar, whereas the maximum fruit drop was recorded (53.33% and 57.41%, respectively) from control treatment. Moreover, spraying with 10 ppm and 30 ppm GA3 also had significantly reduced fruit drop as compared to untreated control. However, for 'Monulla' cultivar the minimum fruit drop (25.24%) was observed with 30 ppm GA3 application, followed by 10 ppm GA3 and 10 ppm 2,4-D with values of (34.85% and 36.44%, respectively), while the highest fruit drop (54.86%) was recorded in untreated control (Table I). For 'Red B' cultivar, spraying 30 ppm GA3 also produced the lowest fruit drop (22.88%), whereas the control treatment exhibited the highest fruit drop with value of 59.63% (Table I).

### C. Fruit Growth (Length and Diameter)

As shown in Fig. 1 and 2, spraying with GA3 and 2,4-D has significant effect on fruit growth rate of wax apple, with regard to fruit length and diameter. At the 7th week of observation, application of 10 ppm 2,4-D gave the highest fruit length growth rate 6.44 cm in 'Red B' and 8.10 cm in 'Red A' cultivar, whereas the lowest fruit growth rate was found in untreated control with value of 5.61 cm and 7.26 cm respectively (Fig. 1a and d). For 'Monulla' cultivar, spraying with 30 ppm GA3 had a maximum (4.86 cm) fruit length growth rate, while the minimum (4.07 cm) fruit length growth rate was recorded in control treatment (Fig. 1b). Moreover, in the case of 'Atu' cultivar application of 10 ppm GA3 showed the highest fruit growth length rate (5.14 cm), but the control treatment showed the least fruit length growth rate with value of 4.45 cm (Fig. 1c).

Similarly, maximum fruit diameter growth rate 4.38 cm in 'Red B' and 5.53 cm in 'Red A' cultivar, while the control had the lowest fruit growth rate with values of 3.66 cm and 4.87 cm, respectively (Fig. 2 a and d). However, application of 10 ppm GA3 gave the highest fruit growth rate 5.37 cm and 5.50 cm in 'Monulla' and 'Atu' cultivar, respectively. The lowest fruit growth rate (4.79 cm and 4.97 cm, respectively) was found in untreated control (Fig. 2b and c).

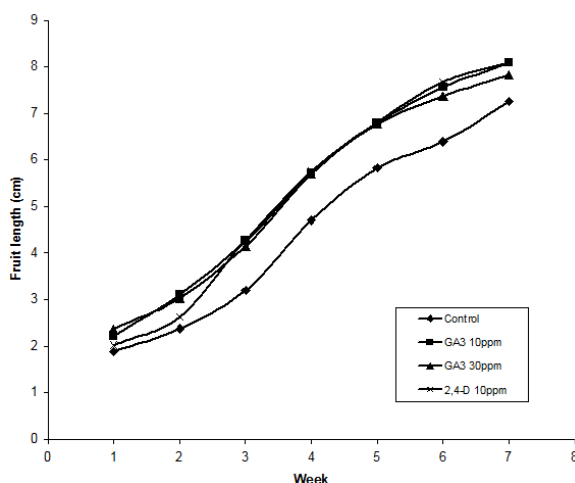


Fig. 1a Effect of GA3 and 2,4-D on fruit growth (length/week) in Red A cultivar

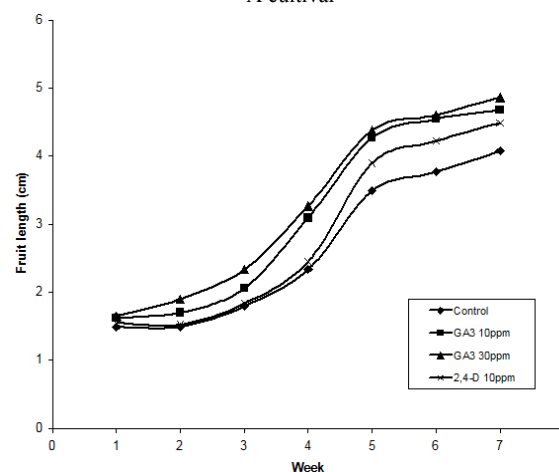


Fig. 1b Effect of GA3 and 2,4-D on fruit growth (length/week) in Monulla cultivar

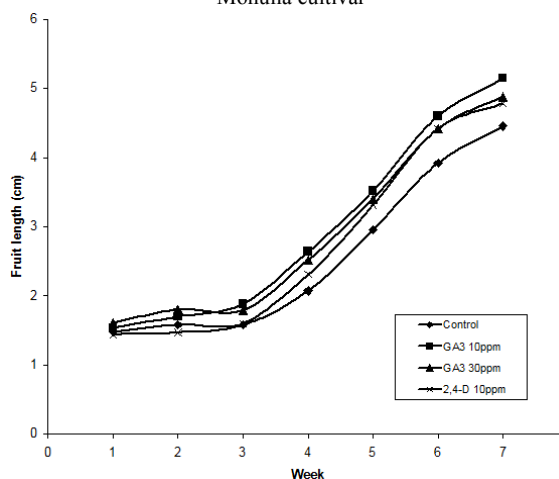


Fig. 1c Effect of GA3 and 2,4-D on fruit growth (length/week) in Atu cultivar

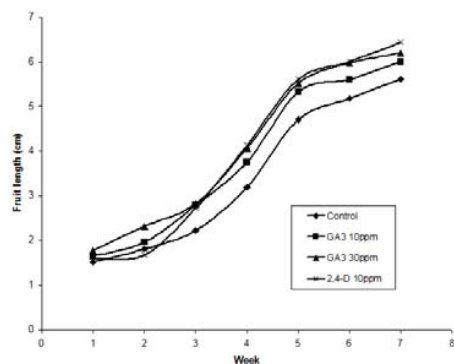


Fig. 1d Effect of GA3 and 2,4-D on fruit growth (length/week) in Red B cultivar

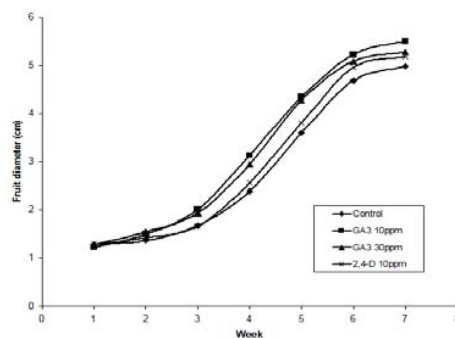


Fig. 2c Effect of GA3 and 2,4-D on fruit growth (diameter/week) in Atu cultivar

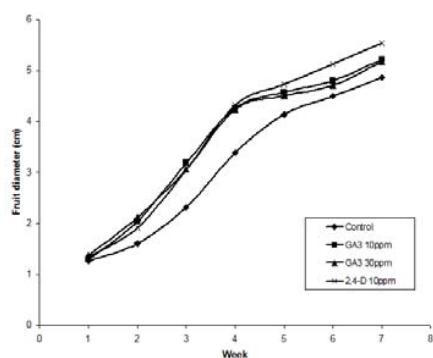


Fig. 2a Effect of GA3 and 2,4-D on fruit growth (diameter/week) in Red A cultivar

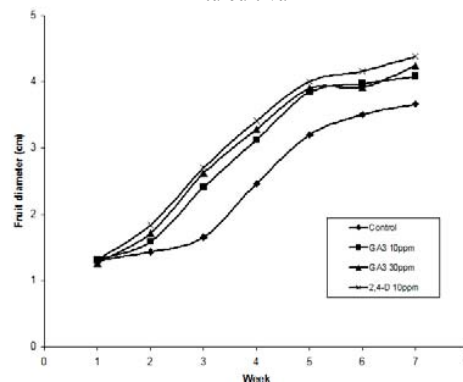


Fig. 2d Effect of GA3 and 2,4-D on fruit growth (diameter/week) in Red B cultivar

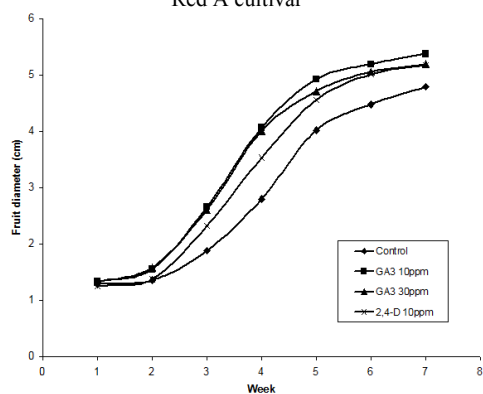


Fig. 2b Effect of GA3 and 2,4-D on fruit growth (diameter/week) in Monulla cultivar

*D.Effect of GA3 and 2,4-D on Fruit Quality Parameters*TABLE II  
EFFECT OF GA3 AND 2,4-D ON FRUIT CHARACTER OF WAX APPLE<sup>1</sup>

Treatment	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Flesh thickness (mm)	Fruit crack/clu ster	TSS (°Brix)	TA (%)	pH
<b>Red A cultivar</b>								
Control	74.34 <sup>c</sup>	72.13 <sup>b</sup>	50.67 <sup>c</sup>	15.24 <sup>c</sup>	2.07 <sup>a</sup>	8.71 <sup>b</sup>	0.55 <sup>a</sup>	4.32 <sup>c</sup>
GA3 10 ppm	85.64 <sup>b</sup>	83.22 <sup>a</sup>	57.35 <sup>ab</sup>	16.87 <sup>ab</sup>	1.07 <sup>b</sup>	10.69 <sup>a</sup>	0.37 <sup>b</sup>	5.42 <sup>a</sup>
GA3 30ppm	78.00 <sup>c</sup>	78.27 <sup>a</sup>	55.02 <sup>b</sup>	15.61 <sup>bc</sup>	0.67 <sup>b</sup>	11.68 <sup>a</sup>	0.36 <sup>b</sup>	5.24 <sup>a</sup>
2,4-D 10ppm	94.19 <sup>a</sup>	83.39 <sup>a</sup>	59.28 <sup>a</sup>	17.49 <sup>a</sup>	1.13 <sup>b</sup>	12.14 <sup>a</sup>	0.39 <sup>b</sup>	4.77 <sup>b</sup>
<b>Monulla cultivar</b>								
Control	52.09 <sup>c</sup>	44.04 <sup>c</sup>	50.01 <sup>c</sup>	13.72 <sup>b</sup>	2.40 <sup>a</sup>	8.51 <sup>b</sup>	0.61 <sup>a</sup>	3.75 <sup>b</sup>
GA3 10 ppm	63.49 <sup>a</sup>	48.42 <sup>a</sup>	54.12 <sup>a</sup>	16.15 <sup>a</sup>	0.87 <sup>b</sup>	11.45 <sup>a</sup>	0.42 <sup>b</sup>	4.73 <sup>a</sup>
GA3 30ppm	62.19 <sup>a</sup>	49.16 <sup>a</sup>	52.34 <sup>b</sup>	16.13 <sup>a</sup>	0.73 <sup>b</sup>	11.32 <sup>a</sup>	0.39 <sup>b</sup>	4.87 <sup>a</sup>
2,4-D 10ppm	57.11 <sup>b</sup>	45.77 <sup>b</sup>	52.49 <sup>ab</sup>	15.25 <sup>a</sup>	0.60 <sup>b</sup>	10.86 <sup>a</sup>	0.43 <sup>b</sup>	4.75 <sup>a</sup>
<b>Atu cultivar</b>								
Control	68.10 <sup>c</sup>	48.21 <sup>b</sup>	53.90 <sup>c</sup>	14.07 <sup>c</sup>	2.60 <sup>a</sup>	6.68 <sup>c</sup>	0.78 <sup>a</sup>	3.23 <sup>b</sup>
GA3 10 ppm	83.69 <sup>a</sup>	55.87 <sup>a</sup>	59.27 <sup>a</sup>	16.66 <sup>ab</sup>	1.13 <sup>b</sup>	10.89 <sup>a</sup>	0.50 <sup>b</sup>	4.24 <sup>a</sup>
GA3 30ppm	81.24 <sup>ab</sup>	54.39 <sup>a</sup>	60.03 <sup>a</sup>	16.99 <sup>a</sup>	1.27 <sup>b</sup>	9.61 <sup>ab</sup>	0.60 <sup>b</sup>	4.32 <sup>a</sup>
2,4-D 10ppm	73.21 <sup>bc</sup>	53.61 <sup>a</sup>	55.75 <sup>b</sup>	15.58 <sup>b</sup>	0.60 <sup>b</sup>	8.33 <sup>b</sup>	0.58 <sup>b</sup>	4.54 <sup>a</sup>
<b>Red B cultivar</b>								
Control	31.26 <sup>c</sup>	58.76 <sup>c</sup>	39.82 <sup>c</sup>	8.58 <sup>c</sup>	0.73 <sup>a</sup>	9.93 <sup>c</sup>	0.76 <sup>a</sup>	3.79 <sup>b</sup>
GA3 10 ppm	33.39 <sup>bc</sup>	61.77 <sup>bc</sup>	41.29 <sup>bc</sup>	9.62 <sup>b</sup>	0.13 <sup>b</sup>	13.87 <sup>a</sup>	0.50 <sup>b</sup>	4.93 <sup>a</sup>
GA3 30ppm	35.89 <sup>b</sup>	65.73 <sup>ab</sup>	41.71 <sup>b</sup>	9.81 <sup>b</sup>	0.27 <sup>b</sup>	12.13 <sup>b</sup>	0.35 <sup>b</sup>	4.79 <sup>a</sup>
2,4-D 10ppm	45.32 <sup>a</sup>	69.19 <sup>a</sup>	45.19 <sup>a</sup>	11.04 <sup>a</sup>	0.26 <sup>b</sup>	13.78 <sup>a</sup>	0.51 <sup>b</sup>	5.02 <sup>a</sup>

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

### 1. Fruit Weight

Data in Table II indicated that fruit weight of wax apple cultivar among treatments significantly increase as compared to untreated control. For 'Red A' cultivar the highest fruit weight (94.19 g) was obtained at 10 ppm 2,4-D application, followed by 10ppm GA3, whereas the control treatment produced the lowest values (74.34g). However, spraying with 30 ppm GA3 slightly increase fruit weight, even though the effect was not significantly difference. In the same table data showed that application of 10 ppm 2,4-D also significantly increase fruit weight as compared to untreated control, which was recorded in 'Red B' cultivar. Furthermore, spraying with 10 ppm GA3 produced the maximum fruit weight with values of 63.49g in 'Monulla' cultivar and 83.69 g in 'Atu' cultivar, whereas the lowest fruit weight 52.09g and 68.10 g, respectively was recorded in control treatment (Table II). Moreover, spraying with 10 ppm 2,4-D also gave the higher fruit weight as compared to untreated control in the case of 'Monulla' cultivar, however no significant increased fruit

weight with 10 ppm 2,4-D application in 'Atu' cultivar (Table II)

### 2. Fruit Length

As shown in Table II, the highest value (83.39 mm) was obtained with 10ppm 2,4-D application, followed by 10 and 30 ppm GA3 application with value (83.22 mm and 78.27 mm, respectively), compared to lowest value of 72.13 mm was found in untreated control in the case of 'Red A' cultivar (Table II). For 'Monulla' cultivar, maximum fruit length (49.16mm) was recorded in 30 ppm GA3 sprays, whereas the control treatment produced the minimum fruit length (44.04 cm). However, the highest fruit length (55.87 mm) was obtained in 10 ppm GA3, followed by 30 ppm GA3 and 10 ppm 2,4-D application, but lowest fruit length (48.21 mm) was observed in untreated control, which was achieved in the case of 'Atu' cultivar (Table II). Moreover, spraying with 10 ppm 2,4-D also gave the highest value of 69.19 mm, whereas the control treatment produced the lowest fruit length (58.76 mm) in 'Red B' cultivar.

### 3. Fruit Diameter

As can be seen from Table II, application of 10 ppm 2,4-D in 'Red A' cultivar produced the maximum fruit diameter with value of 59.28 mm, whereas the lowest fruit diameter (50.67 mm) was found in control treatment. For 'Red B' cultivar, spraying with 10 ppm 2,4-D also produced the maximum value (45.19 mm), while minimum of fruit diameter (39.82 mm) was obtained in control. Moreover, spraying with 10 ppm GA3 gave the highest value (54.12 mm) compared with control treatment (50.01mm), which was found in the case of 'Monulla' cultivar (Table II). However, for 'Atu' cultivar application of 30 ppm GA3 exhibited the maximum fruit diameter (60.03mm), but control treatment showed the lowest value of 53.90 mm (Table II).

### 4. Flesh Thickness

From the data presented in Table II resulted that the maximum flesh thickness (17.49 mm) in 'Red A' and (11.04 mm) in 'Red B' were observed with application of 10 ppm 2,4-D, whereas the minimum flesh thickness (15.24 mm and 8.58 mm) was found in untreated control, respectively (Table II). However, application of 10ppm GA3 in 'Monulla' cultivar produced the highest value of 16.15 mm, while the control treatment exhibited the lowest value of 13.72mm (Table II). Moreover, for 'Atu' cultivar spraying with 30 ppm GA3 gave the highest flesh thickness (16.99 mm) as compared to untreated control, which was gave the lowest value of 14.07 mm (Table II).

### 5. Fruit Crack

Results in Table II showed that application of 30 ppm GA3 gave the lowest value (0.67 fruit crack/cluster), whereas the highest (2.07 fruit crack/cluster) was recorded in control treatment, which was obtained in 'Red A' cultivar. However, spraying with 10 ppm 2,4-D produced the minimum (0.60 fruit crack/cluster) in 'Monulla' and 'Atu' cultivar, while the control treatment showed the highest value of 2.40 and 2.60 fruit crack/cluster, respectively. For 'Red B' cultivar, with 10 ppm GA3 application had the lowest value of 0.13 fruit crack/cluster. The highest fruit crack/cluster (0.73) was found in control treatment (Table II).

### 6. Total Soluble Solids

As can be seen from the Table II, there was significantly affected by application of 2,4-D and GA3 on TSS among treatments as compared with control. For 'Red A' cultivar, the highest value of 12.14°Brix was obtained in 10 ppm 2,4-D application, whereas the lowest value of 8.71°Brix was found in control treatment. However, spraying with 10 ppm GA3 produced the highest TSS with value of 11.45°Brix in 'Monulla' and 10.89°Brix 'Atu', whereas the minimum TSS (8.51 and 6.68°Brix, respectively) were recorded in control treatment (Table II). Moreover, application of 10 ppm GA3 also produced the maximum value (13.87°Brix), while the control exhibited the lowest value of 9.93°Brix in the case of 'Red B' cultivar (Table II).

### 7. Titratable Acidity and pH

Data in Table II showed that the lowest values of TA 0.35% in 'Red B', 0.36% in 'Red A', and 0.39% 'Monulla' was recorded in 30 ppm GA3 application, whereas the control gave the highest value of 0.76%, 0.55% and 0.61%, respectively. However, for 'Atu' cultivar spraying with 10 ppm GA3 showed the minimum value of 0.50%, while the maximum value (0.78%) was found in untreated control (Table II).

As showed in Table II, spraying with 10 ppm GA3 produced the highest value of 5.42, whereas the control treatment gave the lowest value of 4.32 in 'Red A' cultivar. Moreover, sprays of 30 ppm GA3 recorded the maximum value of 4.87, while the minimum value of 3.75 was obtained in untreated control, which was found in the case of 'Monulla' cultivar (Table II). However, application of 10 ppm 2,4-D had the maximum value 4.54 in 'Atu' and 5.02 in 'Red B' cultivar, whereas the minimum was recorded in control treatment with value of 3.23 and 3.79, respectively (Table II).

## IV. DISCUSSION

The data presented in Table I indicated that there were various responses among treatments with GA3 and 2,4-D at different concentration, although the difference was not statistically significant ( $p \leq 0.05$ ). The best result for 'Red A' and 'Monulla' cultivar was obtained with spraying 2,4-D 10 ppm. However, the high number of bud/branch was resulted in 'Atu', and 'Red B' cultivars at 10 ppm GA3 application as compared to control treatment. From the results shown in Table I, it can be seen that wax apple cultivar played a difference role in bud number, which is in accordance with the finding of [24].

In fruit production initial bud drop is a serious problem. Resference [2] indicated that endogenous hormones and their balance play a modulating role in the mobilization of nutrients to the developing organs and can influence the bud longevity in 'PERA' oranges. In the current study, bud drop among treatment was markedly reduced by application GA3 and 2,4-D in comparison with control. Spraying with 10 ppm 2,4-D had a positive effect on reduced bud drop in 'Red A' and 'Atu' cultivar, with significant response (Table I). Furthermore, the data in Table I showed that application of 10 ppm GA3 exhibited the least bud drop, but had a non significantly response in decreasing bud drop at 30 ppm GA3 and 10 ppm 2,4-D sprayed comparison with the control treatment in the case of 'Monulla'. Moreover, the clearly reduced bud drop was influenced by GA3 30ppm and 2,4-D 10 ppm sprays in 'Red B' cultivar (Table I). It seems that the lowest incidence of bud drop in the GA3 and 2,4-D application is an indication of more buds and better quality.

According to [7] plant growth regulators are used extensively in horticulture to enhance plant growth and improve fruit number, fruit set and size. The data in Table I shows that all wax apple cultivars using different plant growth regulator (GA3 and 2,4-D) significantly increased fruit set. In our study, the highest fruit set as was observed in 10 ppm GA3 application, indicated that the application of 10 ppm GA3 was

suitable to increased fruit set in 'Red A' cultivar. The data further suggests that application of 30 ppm GA3 resulted in a significant maximum fruit set as compared to untreated control in 'Monulla' and 'Atu' cultivar (Table I). It seems that GA intensifies an organ ability to function as a nutrient sink, it also increases the biosynthesis of IAA in plant tissues which delays the formation of the separation layer therefore enhancing fruit retention. This results are in accordance with the findings of Sasaki et al [34] who indicated that gibberellic acid (GA3) at low concentration was reported to promote fruit setting in tomato. On the other hand, spraying with 10 ppm 2,4-D greatly increased fruit set as compared to untreated control in 'Red B' cultivar. This implied that 'Red B' cultivar have been shown to respond well to application of 2,4-D in enhancing fruit set (Table I). This results are in agreement with Miguel et al [21] who found that fruit set was improved by application of 2,4-D in watermelon.

Resference [11] indicated that 2,4-D is regarded as one of the most effective ones in preventing fruit drop in citrus. Moreover, GA3 can also be utilized to prevent fruit drop in citrus [20]. As shown in Table I, the highest fruit drop was found in control treatment for all wax apple cultivars. This drop causes competition among fruitlets for carbohydrates, water, and hormones [22]. However, application of GA3 and 2,4-D have been shown greatly response to controlling fruit drop among the treatment. In contract, spraying with 10 ppm 2,4-D gave the highest response in reducing fruit drop, which was achieved in 'Red A' and 'Atu' cultivars. Similar results were reported by [1]. Moreover, with 30 ppm GA3 application indicated that this treatment was the most response in decreasing fruit drop in the case of 'Monulla' and 'Red B' cultivars (Table I). This result are in agreement with Almedia et al [2] who started that application of GA3 some other plant growth regulators significantly reduced the preharvest fruit drop in citrus species. Similar results were reported by [14] as they sprayed "Anna" apple trees with GA3 at petal fall stage.

In fruit growing, gibberellic acids are effective in maintaining cell expansion [13], [29] and thus have been used to enhance fruit growth in a wide variety of species such as Japanese pear [45], litchi [10] and grape [9]. Therefore in the study, application of GA3 and 2,4-D gave the faster fruit growth rate as compared to untreated control (Fig 1 and 2). On the basis of these results, it can be seen that GA3 and 2,4-D promote growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell water potential, resulting in the entry of water into the cell and causing elongation. Therefore, spraying GA3 and 2,4-D greatly response in accelerating fruit growth rate (length and diameter) in comparison with untreated control (Fig 1 and 2). These results are in agreement with Kondo & Mizuno [19] who found that gibberellins influence fruit development, especially at the younger stage of fruit. The same has been reported by Stern et al [36] who indicated that application synthetis auxins in 'Bing' cherry had fruit grew at a faster rate than untreated control.

The previous results in Table II exhibited that application of GA3 and 2,4-D was significantly response in increasing fruit

weight among treatment and control. In addition, spraying with 10 ppm 2,4-D resulted in significantly fruit weight enhancement as compared to untreated control. in 'Red A' and 'Red B' cultivar. It consider that 10 ppm 2,4-D application greatly response in increasing fruit weight (Table II). The results were found to be in agreement with that of Saraswathi et al [33] who observed that growth regulators 2, 4-D and their combinations significantly influenced the fruit weight. However, application of GA3 10 ppm has been found to significantly enhance fruit weight compared to the control treatment in the case of 'Monulla' and 'Atu' cultivar (Table II). It seems that the role of GA3 was to multiply and to lengthen the meristem cells, which resulted in the increase of fruit weight. This is in agreement with El-Shaikh et al [15] who found that spraying "Costata" persimmon trees with GA3 significantly increased fruit weight.

Resference [28] indicated that the direct effect of gibberellic acid on stimulating cell division and cell enlargement and increasing fruit size in kinnow mandarin. From the data presented in Table II it is clear that spray of 30 ppm GA3 gave the highest values of fruit length as compared to the control in 'Monulla' cultivar, but with 10 ppm GA3 application showed the greatly increased fruit diameter, flesh thickness. However, for 'Atu' cultivar fruit length and fruit diameter were markedly increased in 10 ppm GA3 as compared to untreated control, whereas spraying with 30 ppm GA3 showed greatly response in improving flesh thickness (Table II). It consider that the increase in fruit size might be attributed to increase in cell division and cell elongation caused by auxins and GA3, which is in accordance with the findings of [30]. Similar results were reported by [44]. On the other hand, spraying with 10 ppm 2,4-D significantly increased fruit length, fruit diameter and flesh thickness as compared to control treatment in 'Red A' and 'Red B' cultivar (Table II). This is in accordance with the finding reported by Gemici et al [16] who indicated that application of 2,4-D increased fruit size in tomato. From the results, it consider that fruit size were significantly different due to the interaction effect of cultivar with 2,4-D and GA3, indicating differential response in increasing size of wax apple cultivars to 2,4-D and GA3 application (Table II).

Rain at harvest in many cherry production regions of the world is a serious problem and risk associated with fruit cracking and crop loss [38]. Gibberellic acid (GA3) sprays have been evaluated in many cherry growing regions to reduce the risk of crop loss by making fruit more resistant to cracking. In the current study, there was significant different effects of GA3 and 2,4-D on fruit crack among treatments and control (Table II). Application of 30 ppm GA3 showed markedly reduced fruit crack in 'Red A' cultivar, whereas in 'Red B' cultivar application of 10ppm GA3 also greatly decreased fruit crack as compared to untreated control (Table II). These results are in agreement with Usenik et al [39] who found GA3 to reduce fruit cracking in sweet cherry. On the other hand, spraying with 10 ppm 2,4-D significant response in decreasing fruit crack as compared to control treatment, which was achieved in 'Monulla' and 'Atu' cultivar (Table II).

It seem that wax apple cultivar were more sensitive to 2,4-D spray than GA3 and control treatment and resulted in less fruit crack in the case of 'Monulla' and 'Atu' cultivar.

TSS is considered an important quality parameter attribute for many fresh fruit during ripening. From the results in Table II, it is evident that application of 10 ppm 2,4-D significantly improved total soluble solid in 'Red A' cultivar as compared to untreated control. It seems that 2,4-D spray clearly response in increasing TSS (Table II), which is in accordance with the findings of [5]. However, TSS of fruit in 'Monulla', 'Atu' and 'Red B' cultivar significantly enhanced by spraying with 10 ppm GA3 compared with control treatment. It considered that spraying with 10 ppm GA3 had positive effects on improving TSS among treatment and the differences were statistically significant (Table II). These results agree with Sarker and Ghosh [32] who found that the spray application with GA3 on mango trees increased SSC and total sugars.

Reference [37] indicated that titratable acidity was significantly reduced with GA3 and auxin application in tomato. Therefore, the results in this research indicated that spraying with 30 ppm GA3 greatly response in reducing titratable acidity in 'Red A', 'Monnula' and 'Red B' cultivar as compared to untreated control. However, spraying with 30 ppm GA3 had a greater effect on reducing titratable acidity in comparison with control treatment, which was found in the case of 'Atu' cultivar (Table II). This is accordance with the finding reported by Xiao et al [43] who reported that by the application of 2,4-D, GA3 acidity percentage was significantly reduced. Moreover, spraying with 10 ppm 2,4-D also clearly reduce titratable acidity among treatment in comparison with control, this effects were significant different (Table II). From the result it can be seen that GA3 and 2,4-D application significantly reduced the titratable acidity content in wax apple fruits.

Finally, the data in Table (2) revealed that application of 10 ppm GA3 significantly improving pH in 'Red A' cultivar as compared to untreated control. However, spraying 30 ppm GA3 showed greatly response in increasing pH in 'Monulla' cultivar. On the other hand, for 'Atu' and 'Red B' cultivar application of 10ppm 2,4-D showed the markedly response to enhancing pH as compared to the control (Table II). This is in accordance with the finding reported by Thakur et al [37] who indicated that the acidity of tomato fruits was reduced when the plant was sprayed with GA3 and 2,4-D.

#### V. CONCLUSION

From the result it can be concluded that 'Monulla' and 'Atu' cultivar responded best to 10 ppm and 30 ppm GA3 in reducing bud drop, fruit crack and TA. Improvement of fruit set, fruit weight, fruit size as well as TSS. On the other hand, spraying with 10 ppm 2,4-D were the best and the most response in increasing fruit set, fruit character as well as improving fruit quality in the case of 'Red A' and 'Red B' cultivar. For all cultivar application of GA3 and 2,4-D greatly stimulated fruit growth. Therefore, we can be concluded that application of GA3 and 2,4-D at small bud and petal fall stage

markedly increasing fruit growth, improving fruit quality for all wax apple cultivar to meet commercial demands.

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