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## Effect of gibberellic acid on the growth and biochemical content of water apple fruit

ABM Sharif Hossain<sup>1,3</sup>, Adel M Alsaif<sup>2</sup>, Rosna Mat Taha<sup>1</sup>

<sup>1</sup> Biotechnology Program, Institute of Biological Sciences, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia

<sup>2</sup> Plant Production Dept., College of Agriculture and Food Science, King Saud University, KSA, Saudi Arabia

<sup>3</sup> Department of Biology, Faculty of Science, University of Hail, KSA, Saudi Arabia

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### Abstract

The experiment was conducted to investigate the effect of GA<sub>3</sub> on the growth and development of water apple fruits (*Syzygium samarangense*). Three concentrations of GA<sub>3</sub> at 30, 60, 90 mg/L and water control were applied using swabbing technique. However, 60 mg/LGA<sub>3</sub> increased the number of buds and fruit setting compared to other treatments. It also decreased the premature fruit dropping. It was found that the application of GA<sub>3</sub> at 60mg/L increased fruit length and diameter. In addition to that fruit growth, maturity development and per fruit weight were higher at GA<sub>3</sub> at 60mg/L compared to other concentrations and water control. With regard to fruit quality, the application of GA<sub>3</sub> at 60mg/L increased TSS, inverted sugar, fructose and total flavonoid contents in the fruit compared to the other concentrations and water control. Besides, anthocyanin content and total phenol were higher in GA<sub>3</sub> treated fruits than water control. From this study it can be concluded that swabbing 60mg/L GA<sub>3</sub> was showed better results than other concentrations and water control. Finally it is recommended that swabbing technique is the best for saving environmental pollution and effective for low cost.

**Keywords:** water apple, gibberellin, growth, maturity development, sugars

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### Introduction

Water apple (*Syzygium samarangense*) is a common fruit in Malaysia as well as other Asian countries. The fruit is widely cultivated and grown throughout Malaysia mainly as small scale gardener ranging from 1 to 5 ha with its hectare average estimated at 1,500 ha in 2005 (Zen-hong shu *et al.*, 2006). Fruit development and repining have been considered as the most important phenomena in agriculture and fruit production. Idea to develop fruit growth was very old and increase of yield or weight using horticultural practices were reported by many researches. Some of the old used techniques were the pruning, hormone application by spray of trees increased fruit growth and development (Savage and Cowart, 1942; Elfving and Forshey, 1976). Phytohormone is a natural compound synthesized by plant cell with a very low concentration, then translocated to another plant tissue where it causes physiology responses (Romanov, 2002; Gaspar *et al.*, 2003; Galston *et al.*, 1980; Salisbury and Ross, 1992). Phytohormones contribute in a large range of phenomena that occur during the growth, and the development of plants (Taiz and Zeiger, 1998).

Spraying of plant growth hormone or chemicals is a traditional method. Nowadays Environmental Scientists do not suggest for using this technique too because of the pollution of the air in the environment, water and human health and also not cost effective (Miller, 2004; Tashkent, 1998). Dipping technique has been developed for the fruit growth and quality development instead of spray method due to not affecting environment and cost effective and can control the liquid effluent much easier (Probert, 2009). Asano *et al.* (2001) used dipping methods instead of spray and found better effects in grape fruit

An innovative technique swabbing method has been developed because of using small quantity to get more output compared to

spray and dipping methods. Swabbing method does not create any droplet and spray dirft which caused by spray and dipping method also. Hossain *et al.* (2007) developed swabbing technique and resulted excessive flowering in peach plants. They also reported that swabbing method enhanced early flowering (blooming) by dwarfing plant growth while ABA (abscisic acid) was applied to the bark in peach plant.

The size of the fruit can be affected by certain horticultural cultural practices, such as application of plant growth hormones. Gibberellic acid (GAs) has been shown to increase fruit set and growth in apples, pears (Weaver, 1972,). A spray of GA<sub>3</sub> at 50 mg/l using 5 weeks AFB reduced fruit dropped in 'Huaizhi' (Ji *et al.*, 1992), and a spray of GA<sub>3</sub> at 50–100 mg/l at full bloom also enhanced fruit retention and fruit size in 'Early seedless' and 'Calcuttia' litchiin India (Singh and Lal, 1980). It has been reported that the spraying of auxins prevented the senescence of fruits presumably by maintaining the cell turgidity at the zone of abscission, which prevents the synthesis of hydrolytic enzymes, such as cellulase, which hydrolyze cell walls (Onguso *et al.* 2004). The deep-red colored fruits are popular, factors influencing red color has become important for investigators. The red color in wax apples (water apple) is believed to be influenced by several factors such as; leaf: fruit ratio (Wang, 1991), sugars, position of fruits on the tree, fruit development stages, light and temperature (Shu *et al.*, 2001).

Gibberellic acid (GAS) has been shown to increase fruit set and growth in clementine orange Van Rensburg *et al.* (1996). Choi *et al.* (2002) reported that spraying GA<sub>3</sub> increased the fruit size and firmness in cherry fruits. In addition to this El-Sese (2005) working on Balady mandarin trees reported that treatment with GA<sub>3</sub> increased the yield of fruits. GA<sub>3</sub> increased fruit firmness,

soluble solids and fruit weight (Basak, *et al.* 1998). Every year a lot of water apple fruit is being dropped in Malaysia. That is also one kind of issue to reduce the dropping fruit. The phenolic content of edible fruits are useful since the role of these factors play in health and disease chemoprevention have been widely reported. The leaves of *S. samarangense* have shown the presence of ellagitannins, proanthocyanidins (Nonaka *et al.* 1992), flavanones, flavonol glycosides, anthocyanidins (Kuo *et al.*, 2004), triterpenoids, chalcones (Srivastava *et al.*, 1995), and volatile terpenoids (Wong & Lai, 1996).

Very little scientific information is available and known about the growth and development of water apple fruit. A search in the Thomson-Reuters and Scopus database revealed only a few articles reporting on its chemical constituents as cited above. The following objectives were undertaken:

1. To investigate the effectiveness of swabbing method using plant growth regulator.
2. To investigate the various physical & biochemical characteristics of the fruits
3. To develop larger fruits with better taste and good color using GA3

## Materials and Methods

### Site

This study was carried out during two successive seasons (2010 and 2011) in a private orchard located at a commercial farm in Banting, Malaysia, 20 30N, 1120 30E and 1028 N, 1110 20 E at an elevation of about 147 ft from sea level.

### Plant materials:

Twelve years old water apple trees (wax jambu) were selected for the study. The trees were spaced at 20.25 m<sup>2</sup> (square pattern). Tree to tree distance was 4.5 m and row to row distance was 4.5 m. 12 trees were used in the study. Three trees were used for each treatment. Five branches from each tree were used for each unit. All the insects and diseases infected branches were removed before the experiment launched. Sixty uniform branches of the same length, diameter and number of leaves were maintained from the twelve trees for the experiment.

### Tree Management and Intercultural Operation

Field was maintained properly and irrigation was done when necessary. Pesticides were applied once at growing season. Weeding was done at one month interval. Plant hormone was applied in the sunny day. Fertilizer was applied at the rate of 15-15-15% (N-P-K) yearly (Hossain *et al.*, 2004).

### Design of Experiments

The experiment consists of 4 treatments including control (with fifteen replications). Five uniformed branches were taken as an experimental unit. The five selected uniform branches n swabbed with 30, 60 and 90 mg/L GA3 and water (control) in three plants. Five branches were considered as replication per tree, total 60 branches. 15 fruits were selected in each branch to make swabbing instate of spray. Total number of fruit was 15×15=225 per treatments [n= (10×15) for fruit and n=15 for branch]. The design used in the experiment was Completely Randomized Design (CRD). The swabbing method was applied to the branches once a week starting from bud formation stage to flower opening stage (blooming) and continued until fruit set stage. It was stopped at the beginning of fruit growth stage.

## Swabbing Technique

The best quality fruits can be produced through the management of nutrients, water, canopy and more precisely by use of plant growth regulators. To achieve the best results, stage and optimum concentrations of bioregulators are very important. The lack or overdose can causes no effect or adverse effect, respectively on the vine health and the berry quality. Therefore, it is advisable to use the bioregulators judiciously in fruit culture.

Usually the application phytohormone was made by the old method. It consists of the spray method of the solution of PBRs. In this work we have applied a new technique called swabbing (Figure 1). This method consists to swab PBRs with wetting cotton and forceps without any contamination of fruits. Spray method was hazard to the environment, affects other trees and other branches and it uses a lot of chemicals. Whereas, swabbing technique doesn't affect the environment, it gives a local application and uses fewer chemicals. This method was applied successfully followed by Hossain *et al.* (2007), where aqueous solutions of growth iregulator were applied by swabbing two-to-three times with cotton wool held with forceps.



Bud stage initia

Bud stage final

**Fig 1:** Swabbing, by cotton applied, at bud flower and flower blooming stage of water apple, by GA3.

## Measurement of physiological parameter

### Total number of bud

The total number of buds was determined when bud size was 0.8-1.0 mm. Number of buds grown in 60 cm selected branch were counted before the opening of the flower bud.

### Bud dropping (%)

Percentage bud drop was calculated by dividing the total number of buds before anthesis minus the number of buds at anthesis with the total number of buds before anthesis.

### Initiation of flower

Flower initiation was reported at the beginning of the experimental and counted the flower initiation at 60 cm of the selected branches.

### Blooming percentage

Blooming percentage were calculated by the bloomed bud divided by total number of buds then multiply the result by hundred.

### Fruit setting (%)

Percentage fruit setting were calculated from tagged branches of the experimental trees immediatly after anthesis. The number of

flowers bud and total number of fruit set were counted before and after anthesis. Fruit set percentages were calculated using the following formula

$$\text{Fruit setting (\%)} = \frac{\text{Total number of fruit set}}{\text{Total number of flower bud}} \times 100$$

### **Fruit dropping (%)**

Fruit dropping percentage was determined from tagged branches on the experimental tree by counting the number of initial fruit and the total number of fruit immediately after anthesis. 35 days of anthesis fruit drop percentage was calculated using the following formula:

$$\text{Fruit dropping (\%)} = \frac{\text{Number of fruits at final harvest}}{\text{Total number of initial fruit}} \times 100$$

### **Fruit length, diameter and fruit growth**

Fruit length, fruit diameter, fruit growth was measured weekly with digital caliper (Japan, Model). For fruit growth measurement 10 fruits per selected branch were tagged after anthesis until the fruit harvested. Final length and diameter were measured immediately after harvest.

### **Fruit maturity (By observing color development)**

The surface color of each tagged fruit was determined at three different points of the fruit using a standard color chart (Minolta, Osaka, Japan) and expressed the percentage of maturity (peel color).

### **Fruit volume**

Fruits were kept in the scaled glass water for 2 minutes, after that volume was measured by this visual observation of water level in the scaled glass.

$$\text{Volume} = \text{Initial level of water} - \text{Final level of water}$$

Juice volume (ml)

Volume was measured by this visual observation of juice level in the scaled glass.

### **Chlorophyll content (Represented by SPAD unit)**

Chlorophyll content in leaves of treatment branches was determined using a Minolta SPAD meter and measured usually after 1.5 month of treatment application. SPAD value of the leaves were expressed the chlorophyll content.

### **Fruit Yield**

Yield per treatment was recorded by weighing the total number of fruits per treatment at the time of harvesting.

### **Fruit harvesting**

Fruits were harvested at different periods (1st experiment, August- 2010; 2nd experiment, December-2010; 3rd experiment, April-2011).

### **Measurement of biochemical parameters**

#### **Fruit grinding (Collection of fruit juice)**

Three fruit were selected randomly from each branch. Total of  $3 \times 15 = 45$  fruits were ground separately for each treatments. Total of 180 fruits ( $4 \times 45$ ) were used for 4 treatments. Fruit was cut into pieces and blender machine was used for grinding. The juice was

centrifuged and supernatant (Clear juice) was collected and it was placed in airtight glass bottles, stored in an ice filled cooler and transported to the laboratory to keep at cold temperature ( $4 \pm 1$  °C) for biochemical analysis.

#### **Total soluble solid (TSS) content**

Total soluble solids (TSS) content in the fruits were evaluated at 25°C with abbe Refractometer. TSS were expressed with % Brix. A hand-held refractometer (Atago ATC-1, 32-10 Honcho, Itabashi-ku, Tokyo 173- 001, Japan) was used from 2010 and a digital refractometer (Atago PR-101) was used for TSS determinations. A few drops of juice were kept on the refractometer prism surface (Figure 7) and reading was collected from skin pad.

#### **Fructose and inverted sugar**

Centrifuged clear juices of fresh harvested Water apple were used for fructose and inverted sugar determination. Fructose and inverted sugar were evaluated at 25°C with Atago 8469 digital handled refractometer (Atago Co. LTD., Tokyo, Japan) and expressed as percentage.

#### **pH of fruit juice: Sample Preparation**

Immediately after harvest, fruit were clean, washed and dried of surface water with fan. Then the fruit are blended and fruit juices are kept in glass bottle. All fruit juice samples were first allowed to equilibrate to room temperature (25°C) before pH determination. pH was measured using a Microprocessor pH meter (Hanna Instrument). Before measurement of pH the Microprocessor pH meter was calibrate properly.

#### **Statistical Analysis**

The data were plotted and analyzed using MSTAT statistical software. One way ANOVA was applied to evaluate the significant difference in the parameters studied in the different treatments. Least significant difference (Fisher's protected LSD) was calculated, following significant F-test ( $p=0.05$ ). Standard error (SE) was measured by Excel.

#### **Results**

GA3 at different concentrations has affected the bud and fruit dropping as well as fruit setting over the control. Fruits setting percent was observed to be 30% in water control, while it was 70% and 68% in 60 ppm and 90 ppm GA3, respectively. In the case of fruit dropping, the percent of fruit dropping per branch was 38% and 37% in water control and in 30 ppm GA3, respectively. The most significant difference was observed when the branch was treated with the 60 ppm GA3 and 90 ppm GA3. In this case, fruit dropping was higher in each concentration (Table 1). In addition, GA3 (30, 60 and 90 ppm) has increased the average fruit length and diameter. Plant in which GA3 (60 ppm) applied, produced maximum sized fruit (43.37 mm diameter) with maximum total (70.30 mm) fruit length. Although plants, in which GA3 (90 ppm) applied and produced fruit of second largest size (41.85 mm diameter) with the total fruit length (64.3 mm/fruit). Whereas, water swabbing produced lowest sized fruit (39.04 mm) with minimum fruit length (60.39 mm).

Fruit weight is the most important for fruit size, on which fruit value (price) is dependent. As shown in Table 2, gibberellic acid (GA3) treated fruits were larger than untreated fruits (in fruit

weight), but the differences were more significant in 60 ppm than other concentrations. The most important benefits of GA3 are a reliable increase of fruit size of about 10%. Increased firmness is a more consistent response to GA3 and there are always change in fruit yield parameters. There were also significant differences among the treatments in fruit juice. Fruit yield (weight and volume) were significantly affected by the treatment with 60 ppm GA3. The fruits treated with 30 ppm GA3, were a little bit lower in weight and volume than 60 and 90 ppm GA3. On average treated fruits contained more juice content than untreated fruits. The highest juice content was 72.3 ml/100g of fruit in 60 ppm GA3 treated fruits.

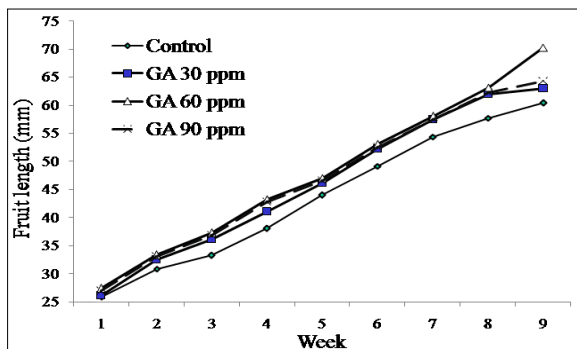


Fig 2: Fruit growth (Length)/week as influenced by different concentration of GA3

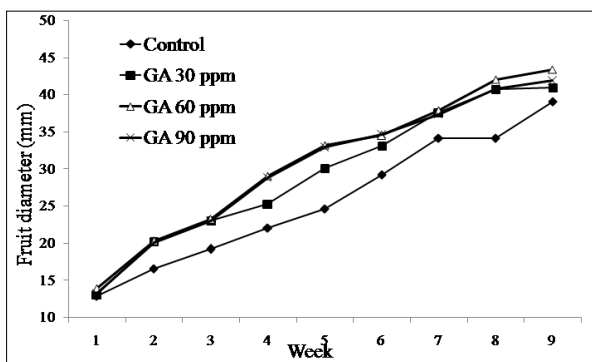


Fig 3: Fruit growth (Diameter)/week as influenced by different concentration of GA3

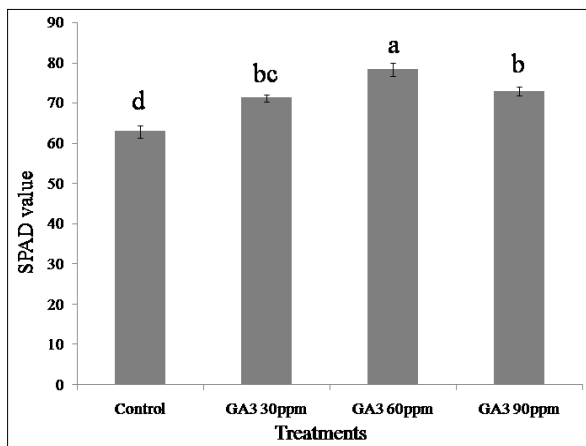


Fig 4: The leaf chlorophyll or SPAD value of leaves in different treated branches

Table 1: Effects of different concentration of GA3 on growth parameters, bud and fruits setting. Values are means ± S.E. (Different alphabets mark significant differences, P < 0.05)

Treatments	Number of bud	Bud dropping (%)	Fruit setting (%)	Fruit Dropping (%)
Control	57.3±0.33d	31±0.57c	30±0.57d	38.6±0.33c
GA3 30	64±0.57b	27.3±0.33cd	33.6±0.33c	37.3±0.33cd
GA3 60	67.3±0.33a	41±0.57a	70±0.57a	49±0.57a
GA3 90	61±0.57bc	37.6±0.66b	68±0.57ab	46±0.57b

Table 2: Effect of GA3 on fruit yield contributing factors and fruit juice in water apple fruit. Values are means ± S.E. (Different alphabets mark significant differences, P < 0.05)

Treatments	Yield/branch g/branch	Fruit weight g/fruit	Fruit volume ml/fruit	Juice content ml/100g fruit
Control	510.3±1.4d	48±0.57d	49±0.57cd	63±0.57d
GA3 30	529±2c	54±0.57c	52±0.57c	66±0.57bc
GA3 60	808±6.1a	69±0.57a	70.3±0.88a	72.3±0.88a
GA3 90	781±3.7b	61±0.57b	62±1.15b	66.6±2.84b

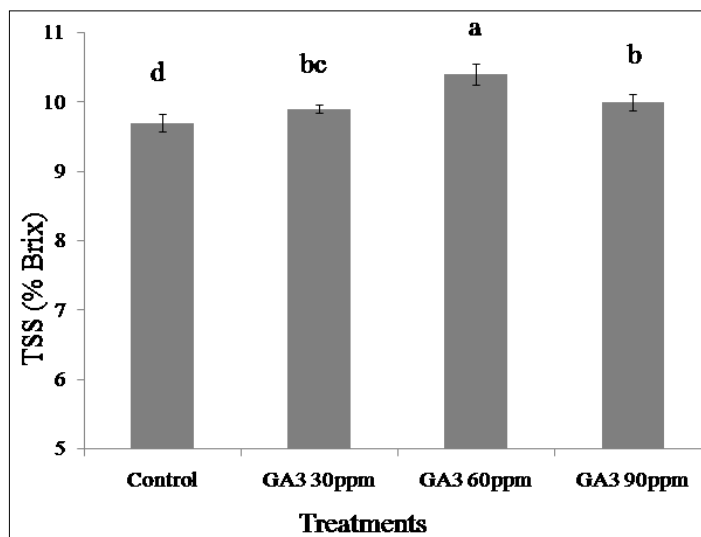


Fig 5: Effect of different treatments of GA3 on Total soluble solids (TSS) content of water apple fruit

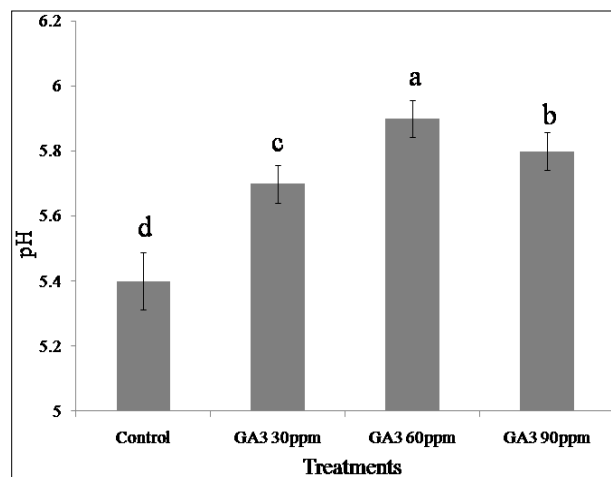
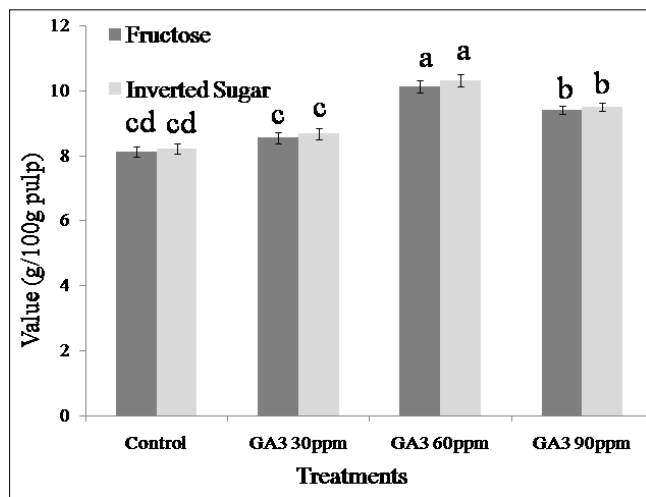
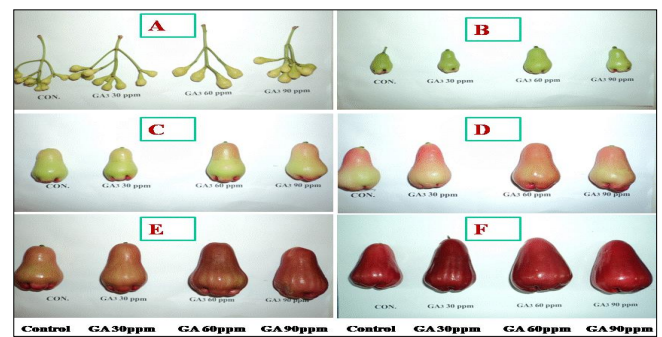


Fig 6: Effect of different treatments of GA3 on acidity or pH content of water apple fruit juice



**Fig 7:** Effect of different GA3 treatments on fructose and inverted sugar content



**Fig 8:** Developmental stages of water apple fruits in (A) Initial budding, (B) Green stage- 0-7 days, (C) light Green stage- 4-7 days, (D) Light red 14-28 days, (E) Red 28-35 days and (F) Deep red or harvesting stage 35-45 days.

## Discussion

The discussions on some physiological aspects of hormonal application on water apple fruits are presented. Still research about water apple fruit was only focused on physiological aspects, mainly on yield and fruit setting and dropping studies. This research is focused on offering a wide view about physiological parameter as well as chemical analysis and the effects related to plant hormone. A new hormone application method (Swabbing technique) has been introduced under natural sunlight growing condition.

The transition from vegetative to reproductive growth is a critical event in the life cycle of plants. Plant hormones play an integral role in controlling the growth, development, metabolism and morphogenesis of higher plants (Claus, 2008) [7]. Auxins, gibberellins, cytokinins, ethylene and abscisic acid are well known plant hormones. However, growth hormones especially GA3 differ from others considerably in their mode of actions (Goro *et al.*, 2001; Andrea *et al.*, 2004) [12, 2]. Fruit set is a phenomenon induced by pollination and fertilization or chemical treatment which culminates in the initiation of growth in fruit tissues. Fruit development begins with the initiation of growth and continues through maturity. During water apple bud to fruits setting, GA3 was found to be essential for the development of fruits and in the mobilization of nutrients to the developing organs of bud (Claus, 2008, Saifuddin *et al.*, 2009; Moneruzzaman *et al.*, 2011) [7, 27, 23]. High concentration of GAs showed a positive role on flower formation in olive during induction and initiation period. In addition, the application of gibberellic acid (GA3) has the potential to control growth and flowering and induce earliness of meristem. Enhancement of synthesis of chlorophyll pigment by GA3 concentration had previously been reported and it has been suggested that the enhanced synthesis was attributed to the increased cytokinin activity in rose and bougainvillea plants (Angeles *et al.*, 2008; Saifuddin *et al.*, 2009) [27]. Thus finding of the present study agrees with the reports on the enhancement of the photosynthetic pigments by GA3 hormones (Moneruzzaman *et al.*, 2011) [23]. In strawberry, GA3 application increased petiole length and leaf area. It reduced the time needed for inflorescence emergence, accelerated flowering and therefore, increased the number of flower buds and open flowers in most growing conditions (Khan and Chaudhry, 2006; Sharma and Room, 2009) [21, 31]. In the case of the tropical reason, high temperatures and humidity inhibit pollen development and result in failure of fruit setting and

Results shown in Fig.3 illustrated that the total soluble solids (TSS) in fruit juice of water apple was significantly increased by GA3 treatments. GA3 at 30 and 90 ppm concentrations decreased TSS in fruit juice as compared to the control. The pH or acidity was also significantly affected by treatments. The lowest fruit pH value in fruit juice was recorded in control of compared to all GA3 concentrations. Percentages of fructose and inverted sugars in fruit juice decreased significantly by the higher concentration (90 ppm) of GA3 compared with the water control and low concentration of GA3 in present experiment (Fig. 4 and Fig. 5). In addition, the highest contents of fructose and inverted sugars in fruit juice were exhibited in 60 ppm of GA3.

The influence of treatments on maturity development was observed throughout the experiments. All concentrations were able to enhance the color associated component with respect to experimental periods. The most effective concentration to earlier maturity of water apple fruit was 60 ppm of GA3. In the case of flavonoid, lower content was observed in control, 30 and 90 ppm GA3 than 60 ppm GA3 concentration. However, the most effective concentration for flavonoid content was in the 60 ppm GA3. In contrast, the maximum anthocyanin content was observed in 60 ppm GA3 and the minimum was observed in water control (Table 3). The results showed that color, total flavonoid, total phenolic and anthocyanin compounds were significantly increased by GA3 treatment (Fig. 6 and Fig. 7). It was found that total phenolic content also followed the same trend as total flavonoid and anthocyanin content in case of all treatments. It was clear that 60 ppm GA3 had a positive effect on anthocyanin and maturity colour improvement compared to 30 and 90 ppm GA3. Fruit K<sup>+</sup> content was significantly increased by GA3 treatments, especially at 60 ppm (Fig. 8). However, no significant differences were found between K<sup>+</sup> content at 30 and 90. Thus, there were differences in sensitivity of fruits to GA3 at various fruit development stages. The photosynthetic pigment, chlorophyll (SPAD) showed a significant difference with respect to the applied hormone treatments. The accumulation of chlorophyll was significantly higher in plants which underwent in GA3 application than control (Fig. 9). The lowest amount of chlorophyll was observed in the control treatment. Hence, it was visualized that 60 ppm GA3 was the optimum rate for water apple leaves to maintain the highest chlorophyll content.

growth (Sato *et al.*, 2000, 2002) <sup>[29, 30]</sup>. Plant hormone, GA<sub>3</sub>, is well known plant growth regulators that can substitute for pollination and induce fruit setting and growth, and these are used for stabilizing fruit production in commercial growing. However, under high temperature and humidity conditions may not be supportive to induce a sufficient fruit setting (Sasaki *et al.*, 2005) <sup>[28]</sup>. Fruit setting and development are two developmental processes at the reproductive phase of a plant which are controlled by internal hormonal balance. Consequently both fruit setting and development could be regulated by external application of plant growth substance similar as flowering and sex expression. The role of endogenous GA<sub>3</sub> in seed and fruit development was reported also in tomato fruits (Oded and Uzi, 2003) <sup>[25]</sup>. More recent work has indicated that final fruit size, weight and length of treated GA<sub>3</sub> in water apple is higher than that of pollinated controls which is similar to this research findings (Fig. 11). The significant Increased of TSS and pH content of water apple fruits was observed in present study. In many reports, it was generalized that fruits were shown to have higher levels of soluble solids and sugar, but lower level of acid compared with non-treated fruits (Gelmesa *et al.*, 2010) <sup>[11]</sup>. As was discussed earlier in this discussion, successful induction of fruit set in response to application of exogenous growth regulators varies among different fruits. Many researchers reported that plant hormones exert their effect on fruit set by controlling the direction of transport of nutrients such as TSS, fructose and sugar content rather than by direct control of fruit setting process. According to the authors, the rate of assimilate export from the leaves; rate of import by fruits, and the fruit carbon metabolism are factors that finally influence the TSS, fructose and sugar of water apple fruit. The role of GA<sub>3</sub> in increasing TSS of various fruit was reported by many authors. For instance, Graham and Ballesteros (2006) <sup>[14]</sup> reported that GA<sub>3</sub> increased proteins, soluble carbohydrates, ascorbic acid, starch and carotene in the tomato. Higher sugar content in this and previous study (Jambo and tomato fruits) were obtained from plants treated with 50 ppm GA<sub>3</sub> (Kataoka *et al.*, 2009.) <sup>[20]</sup>. Hossain and Fusao (2008) <sup>[17]</sup> explanted a clear understand on the relationship in TSS and acid content in peach fruit having same experiment for six years. They reported that obviously when TSS is increased the acid value exponentially decreased. In general, TSS has been of major interest to the food processing industries that manufacture concentrated fruit products (Ram, 2005) <sup>[26]</sup> and for fresh market consumption (Ho, 1998). It is believed that increased TSS content of fruits could give more finished product per ton of raw tomato fruit and thus, require less energy to produce a certain quantity of concentrated product. Hence, the use of GA<sub>3</sub> application for fruit production is one option to improve TSS content of various fruit. Though fruits pH is dependent on several factors, including cultivar, maturity stage, cultural practices as well as growing location and seasonal variations (Gould, 1992) <sup>[13]</sup> but achievement of low fruit pH and high TSS value by swabbing 60 ppm GA<sub>3</sub> in our study could be a useful investigation. Comparable to the present result, significant increase of fructose and inverted sugar content in fruits due to application of PGRs was reported due to increased formation of fructose and sugar in the tissues (Graham and Ballesteros, 2006) <sup>[14]</sup>. Thakur *et al.* (1996) <sup>[32]</sup> indicated that acidity of tomato fruits was reduced when the whole plant was sprayed with GA<sub>3</sub>. On the other hand, increased pH value of fruit

is a desirable quality and essential factor accounting for flavor. Thus processors typically add more sugar and fructose to juice to ensure high pH values. Thus, relationship between increased pH and increased sugar content is the desirable fruit quality parameter (Erdal *et al.*, 2007; Fontes *et al.*, 2000) <sup>[8, 9]</sup> to reduce the risk of microbial spoilage and requires moderate conditions for processing and enzyme inactivation.

Flavonoids are the most important plant pigments for flower and fruit coloration producing yellow or red/blue pigmentation in petals and fruits skin. An important role of flavonoids is to serve as visual signals for animals in attracting pollinators in flowers, and later for animals eating the fruits and thereby helping in seed dispersal. In fruits, flavonoids may contribute in a number of ways to fruit quality, for instance to traits such as color, flavor, and bitterness or texture (Amiot *et al.* 1997) <sup>[11]</sup>. The composition of flavonoids in different fruit species varies greatly. Anthocyanins are pigments that give most fruits their red, violet and blue color. In addition, environmental factors such as nutrients, temperature and light conditions can have an effect on flavonoid composition and on the final hue of the fruit. In addition, phenolic component, as well as other molecules, such as purines, has the ability to function as co-pigments. Also, the temperature and pH of the vacuolar solution may affect the final color (Brouillard & Dangles 1994) <sup>[4]</sup>. The change in color in these cultivar mutants might be due to mutations in structural or regulatory genes involved in anthocyanin biosynthesis (Fig. 10). Potassium (K<sup>+</sup>) is importance for its role of an activator of many enzymes and to regulate osmotic potential in cell (Bussakorn *et al.*, 2003). Known as a 'quality element', K<sup>+</sup> could increase fruit development of apple by enhancing synthesis and translocation of carbohydrates in plants (Han *et al.*, 1995), citrus (Chen *et al.*, 2000). Generally, application of plant hormones could increase both fruit setting rate and content of the soluble solids, sugars (Zhang *et al.*, 1998; Huang *et al.*, 2000; Gao *et al.*, 2001) <sup>[33, 19, 10]</sup>.

In this experiment following GA<sub>3</sub> application, however, it was found that fruit K<sup>+</sup> was significantly increased. Niu *et al.*, (2008) <sup>[24]</sup> reported that at early stage, it is required for sufficiently large molecular substrates like carbohydrates and fruit tissues such as peel and seeds to develop its normal cell division and cell enlargement. As fruit species with high demand for K<sup>+</sup>, nutrient contents in grape fruits have an important effect on their quality. Niu *et al.*, (2008) <sup>[24]</sup> reported that the application of GA<sub>3</sub> to grape fruits enhanced K<sup>+</sup> and fruit growth as well as the endogenous hormones (IAA) during fruit growth and development. This result was also attributed to growth acceleration by the GA hormone (Chen *et al.*, 2000; Ma and Liu, 1998; Huang *et al.*, 2002) <sup>[6, 33, 18]</sup> which enhanced both the enlargement of grape fruits and sink capacity of grape fluster to absorb water or nutrients, such as K<sup>+</sup>.

### Conclusion

It is believed that fructose, inverted sugar and K<sup>+</sup> were increased and related with fruit weight and size which were considered as affect the fruit setting and high growth rate as well as color content. It was determined that swabbing of GA<sub>3</sub> had a tendency to increase juice content per fruit by 15–17%. Higher concentration of GA<sub>3</sub> might be enhanced sugar translocation from fruits into other parts of plant. The decreased fructose, inverted sugar and K<sup>+</sup> accumulation are resulted in decreasing

both fruit weight and size. Fruit setting and development in water apple fruit could be regulated by the external application of GA<sub>3</sub>. Gibberellin acid (60 ppm GA<sub>3</sub>) improved the quality of water apple fruit by increasing length, and yield of the fruits as well as by increasing the content of total sugar inside fruits.

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