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Tree Physiology, Fruit Growth and Nutrient Elements of Wax Apple (*Syzygium Samarangense*) as Affected by Branch Bending Angle

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Abstract: This study was conducted to evaluate the potential effects of branch bending angle on the plant physiological characteristics, mineral nutrients accumulation and fruit quality of wax apple. Different treatments with five replicates each by Randomized Complete Block Design (RCBD) layouts were arranged in this study. All the treatments represent different branch angles which were at 5˚ (control), 20˚, 45˚, 65˚ and 85˚ from vertical axis. Leaf chlorophyll content (SPAD chlorophyll index) was significantly affected by different bending treatments at a budding stage, flowering, fruit development and after harvesting of wax apple. Total soluble solids (TSS) content in the leaves of bent branches increased significantly at before bud development, flowering, fruit ripening and after harvesting stages of wax apple trees. During fruit development and maturation stages, leaf TSS content was decreased in all bent branches. The results showed that 20˚ to 65˚ angle bent branches increase weight and firmness of fruit, fruit diameter and produced dark-coloured fruit compared to control. The results showed that 65˚ bent branches give the highest potassium (K^+) and magnesium (Mg^{2+}) content in the fruits. Higher sodium (Na^+), iron (Fe^{2+}) and calcium (Ca^{2+}) content in fruits were found in 20˚ bent branches. There was a positive correlation between fruit TSS with Mg^{2+} (r = 0.70), with Na^+ (r = 0.67) and with Ca^{2+} (0.57) content in the bent branches of wax apple. Fruit TSS content also positively correlated with firmness and peel colour of wax apple fruits. The number of fruit, fruit weight and fruit diameter of wax apple also positively correlated (weak) with leaves TSS content. It can be concluded that 20˚ to 65˚ branch bending angle are promising for enhancing plant physiology, fruit growth and quality of wax apple fruits.

Keyword: Wax apple, Branch bending angle, Chlorophyll, fruit, Mineral element, Quality.

Introduction

The wax apple is a recurrent tropical fruit of *Myrtaceae* family botanically known as *Syzygium samarangense* (Morton, 1987). Wax apple is mainly cultivated on a small scale in Malaysia (Zen-hong *et al.*, 2006). This type of fruit crop is cultivated in South East Asian countries Thailand, Indonesia, and Taiwan inclusive. The species presumably is a true indigene of Malaysia and other South-East Asian countries (Nakasone & Paull, 1998). The fruit has become gradually popular in the tropical region where it can fetch price up to 3 USD per Kg and has the potential to bring benefits to local farmers (Khandaker *et al.*, 2012b). The fruits are pear-shaped, juicy, refreshing, with an imperceptibly sweet taste and also having an aromatic taste. Glossy indeed wax-like and the dry flesh is the quality of *Syzygium samarangense* compared to other species of Syzygium.

The wax apple fruits in Malaysia are eaten as raw with salt or some time cooked as a sauce. Ninety percent or more including peel and pulp of the wax apple fruit are edible. Shu *et al.* (2007) reported that the wax apple fruits are a rich source of phenols, flavonoids, and several antioxidant compounds. The wax apple fruit also has been used in traditional medicine for a variety of illnesses and conditions, despite use as food. Moneruzzaman *et al.* (2011) stated that the wax apple fruit has great benefits for human health due to its rich source of polyphenolic antioxidants. They also reported that the wax apple fruits can be used as a treatment of high blood pressure and several inflammatory conditions including sore throat. The wax apple fruit also can be used as an antimicrobial agent, astringent, antiscorbutic, diuretic, and carminative are addition beneficial qualities of the fruit. Thus, wax apple in Malaysia has the potential to bring great benefit to home-grown farmers and for the country's economy. Branch or shoot bending has proved the most successful method to control growth, development and fruit quality in an orchard (Aly *et al.*, 2012). Thus, the research can assist to develop wax apple as well as other tropical fruit industries.

Shoot bending is one of the ways to produce better quality fruits in the offseason (Sarkar *et al.*, 2005). Dormant reproductive buds are triggered into growth by the bending process. It was reported earlier that the upright branch produces fewer flowers and fruits than the bent branch of Japanese pear (Ito *et al.*, 1999). Bud and premature fruit drop are very high from the upright branches due to the fewer photosynthates supply during growth and development. Vegetative branch (narrow-angle branch) favored vegetative growth and create a negative impact on tree productivity of wax apple. Vertical vegetative growth favored by apical dominance negatively regulates flowering and fruiting in many trees. Narrow branch angle one of the main reasons for low productivity and poor fruit quality of fruit trees. Shoot bending techniques may reduce the shoot growth, increase the leaf TSS content and enhance the flowering of wax apple fruit trees. Considering the above facts an experiment was carried out to study the effects of branch bending on the plant physiology and fruit quality of wax apple. To the best of our knowledge, there is no literature on wax apple regarding the effects of bending angle on tree physiology and wax apple fruit quality improvement. This study investigated the effects of branch bending angle on tree physiology, fruit growth, development and quality of wax apple (*Syzygium samarangense*).

Materials & Methods

Plant material

In this research seven seven years of wax apple trees were used for the treatment application. The mini orchard of wax apple trees was located near the block D of Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia.

Branch bending

The healthy and disease-free lateral branches of wax apple trees have been selected for branch bending with proper care according to the methods described by Mamun *et al*. (2013). All the experimental shoots were bent at 5˚ (used as a control), 20˚, 45˚, 65˚ and 85˚ angle from vertical by using protractor ruler from the vertical axis of the plant with the help of a piece of rope and supporting sticks (Fig. 1). Before branch bending, all the leaves were kept to continue its photosynthesis, respiration and other physiological processes of the tree. Water shoots (0˚ angle) which are vigorous, upright, and leafy branches, produce no

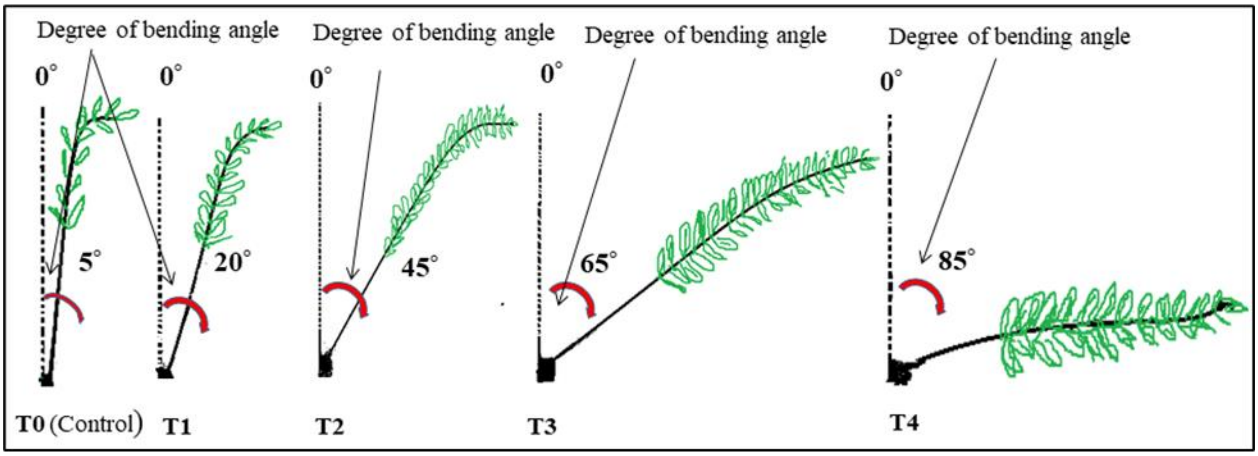

Fig. (1): Schematic diagram of different branch bending angle of wax apple trees employed in this current study.

flowers and fruits. That's why, in this study, we considered 5˚ bending branches as a control. Zhang *et al.* (2015) in their study also used 70˚ to 110˚ bending angle for the physiological study of the Gala Apple tree and the lowest bending 70˚ considered as a control.

Measurement of Morphological parameters

Chlorophyll and leaf TSS content

The chlorophyll content in the leaves was measured by using SPAD-502 portable chlorophyll meter (Minolta Japan) as suggested by Ling (2011). Before using this meter, it was calibrated to take accurate readings. The measurements were taken by a meter that was simply clamped over leafy tissue. Meter will show an indexed chlorophyll content reading in less than two seconds. The leaf TSS content was evaluated with a hand refractometer (Atago 8469, Atago Co. LTD, Japan) at 25°C and expressed % Brix.

Fruit weight and diameter

Fruit weight was recorded by weighing with an electronic valance the total number of fruits per treatment at the time of harvesting. The fruit diameter of wax apple was measured with the help of vernier caliper.

Fruit firmness

A digital hand-held penetrometer meter (Model KM-1, Fujiwara, Japan) was used to determine the fruit firmness of wax apple. A puncture was made in the fruit, depth of penetration should be consistent with the emblazoned line on the tip. The reading was recorded to the nearest 0.5 lb or 0.25 kg.

Fruit peel colour

The peel colour was evaluated by CR-400 Chroma Meter (Minolta Chroma Meter CR 400, Osaka, Japan). The colour was indicated by L* for lightness, a* for redness-greenness and b* for yellowness-blueness. The hue angle by h* determines the red, yellow, green, blue, purple or intermediate colours between adjacent pairs of the basic colours. Then, referred to chromaticity coordinates table by using the measurement got to indicate the colour. Sample means were calculated and the colour was expressed in L*, a*, b* Hunter parameter, using the following formula (L* × a*)/b*.

Mineral nutrient elements

Determination of mineral elements of Na^{+}, K^{+}, Fe^{2+}, Mg^{2+}, Ca^{2+} and P by inductively coupled plasma optical emission spectrometry (ICP-OES). The process of digestion and filter of the samples was done before being determined by ICP-OES. Sample preparation started by weight 0.3 g of the solid sample into a porcelain crucible. The crucibles were transferred into the furnace and heated up to 500˚C for two hours. The crucibles with ash were removed from muffle furnace, letting it cooled and followed by the addition of 3 mL of diluted 1:1 HNO_3. The samples were dried on a hot plate at 100˚ C to 120˚C until dried completely. The crucibles were then placed back to the furnace at 500˚C for another one hour. The crucibles were removed from the furnace. After cooled, 10 ml of HCL was added. The samples were then transferred into a 50 ml volumetric flask and deionized water was added to make the volume and mixed. All solutions preparation was done erstwhile to the analysis. A sample probe rinses solution of 1% ultrapure HNO_3, an internal standard solution of 10 ppm Sc in 1% ultrapure HNO_3, a calibration blank and calibration standard for a three-point calibration and a calibration check the blank solution. The calibration verification solution was made from stock solutions independent of the calibration standard stock solutions. Solid samples that had been digested were diluted 1:5 with RO water.

Experimental Design and statistical analysis

This experimental design was Randomized Complete Block Design (RCBD) with five replications. All five treatments (branch bending angle) consist of five replicates. The data obtained from the experiment were analyzed using SPSS 20 software. A one-way repeated Analysis of Variance (ANOVA) was chosen because only one factor that we wanted to test which is the different bending angle of wax apple at (5˚, 20˚, 45˚, 65˚ and 85˚) and to evaluate the significant differences in the examined parameters studied. Means comparisons were performed with Tukey’s HSD-test significance at $p<0.05$ (Sajili *et al*., 2020).

Results & Discussion

Chlorophyll content (SPAD chlorophyll index)

Chlorophyll content measurement shows that the branch bending angle has no significant effect on the leaf chlorophyll content before the bud development stage. However, it could depict that the chlorophyll content at the lowest bending angle 5˚ was lower than the other treatments. The lowest chlorophyll value 39.1 (SPAD chlorophyll index) was recorded in the 5˚ bent branch, whereas the highest chlorophyll content recoded in a 20˚ bent branch with a value of 46.6 (SPAD chlorophyll index). This indicates that the chlorophyll content is slightly increasing with the increase of branch bending angle as shown in fig. (2).

Fig. (2) shows leaf chlorophyll content during flower bud development, bending angle 5˚, 45˚ and 65˚, respectively, has no significant effect but in comparison with control the bending angle 20˚ and 85˚, produced a significant effect. The lowest leaf chlorophyll content was recorded in bending angle 5˚ with a value of 39.8 (SPAD chlorophyll index), whereas, chlorophyll content was highest in 85˚ bent branches of wax apple trees. During flowering, and fruit development and maturation stages, the leaf chlorophyll content was affected significantly among the different bent branches. Like as before, the straight upright branch (5˚ angles) produced the lowest amount of chlorophyll with a value of 42 and 42 (SPAD chlorophyll index) at flowering, and fruit development and maturation stages. It was also observed that leaf chlorophyll content was increased with branch bending angles. Bending angles during the fruit ripening stage have no significant effects on chlorophyll content as shown in fig. (2). Bending angle 45˚

has the highest mean chlorophyll value (46.53 SPAD chlorophyll index) which is statistically insignificant when compared with that of

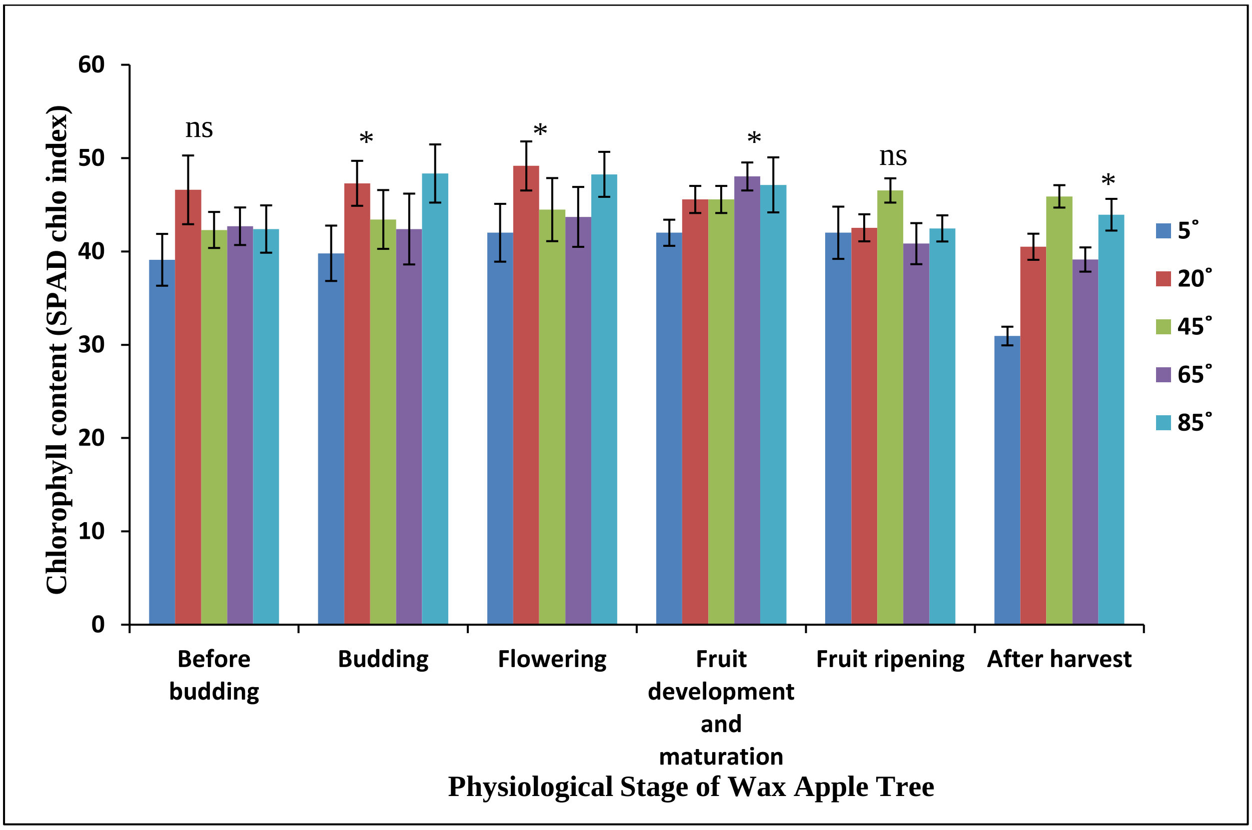

Fig. (2): The effect of branch bending angle on chlorophyll content of different physiological stages of wax apple tree. Error bars indicate ± S. E. Mean values presented with "*" are significantly different at $p < 0.05$. ns denotes non-significant.

bending angle 5˚ (42.80 chlorophyll index). Based on Figure 2, the result for chlorophyll content after harvesting stage shows the highest reading at 45˚angle with a mean value of 45.9 (SPAD chlorophyll index) followed by an 85˚ angle with a value of 43.93 (SPAD chlorophyll index).

The lowest reading of the chlorophyll content came from the control at 5˚ angle bent branch with 30.93 (SPAD chlorophyll index). After fruit harvesting, the chlorophyll content was affected significantly with the branch bending angle and chlorophyll content increased with bending angles (Fig. 2). Maimaiti *et al.* (2013) reported that branch bending significantly increased the leaf chlorophyll content of young "Fuji" apple tree and this was in concord with the results obtained in this study. Shoot bending may affect leaf photosynthesis via changes in leaf exposure to sunlight, and variations in the source-sink ration of leaf characteristics (Li & Lakso, 2004; Cheng *et al.*, 2008). Han *et al.* (2007) reported that bending inhibit shoot growth and promotes flowering. They also stated that branch bending in apple trees from 55˚ to 110˚ increased leaf thickness, stomatal conductance, and photosynthetic rate. Growth manipulation techniques may protect the chloroplast ultrastructure and improved chlorophyll content in the leaves (Nurnaeimah *et al.*, 2020; Rosnah *et al.*, 2020). Photosynthesis depends on chlorophyll and its content which may vary with plant to plant and exposure to light in the plant which is proportional to the rate of photosynthesis of plant.

Leaf TSS content at different physiological stage

Based on fig. (3), the result for leaf total soluble solids (TSS) before the bud development stage was showed the highest reading at a 65˚ angle with a value of 1.15 % Brix followed by at 5˚ angle with a value of 1.075 % Brix. The lowest reading of the leaf TSS content came from the 20˚ angle with a value of 0.9 % Brix. The means differences of the leaf TSS content before bud development was showed a significant difference at $p < 0.05$ level. The result for leaf total soluble solids (TSS) during bud development and flowering stages were showed a non-significant difference at $p < 0.05$ level among the different bent branches of wax apple trees (Fig. 3). At fruit development and maybe the branch bending technique increases the amount of leaf chlorophyll content

maturation stages, the leaf TSS content in all bent branches reduced drastically compared to other physiological stages of wax apple trees.

Based on fig. (3), the leaf total soluble solids (TSS) during fruit development and maturation stages was affected significantly by branch bending treatments. The highest reading at 20˚ angle with a mean value of 0.32 % Brix followed by others angle as well as control. The lowest leaf TSS content was recorded in 85˚ bending branches.

The leaf total soluble solid (TSS) during the fruit ripening stage was showed the highest reading at 65˚ angle with a mean value of 1.49 % Brix followed by at 20˚ angle with a value of 1.40 % Brix. The lowest reading of the chlorophyll content came from the at 5˚ angle with a value of 0.89 % Brix.

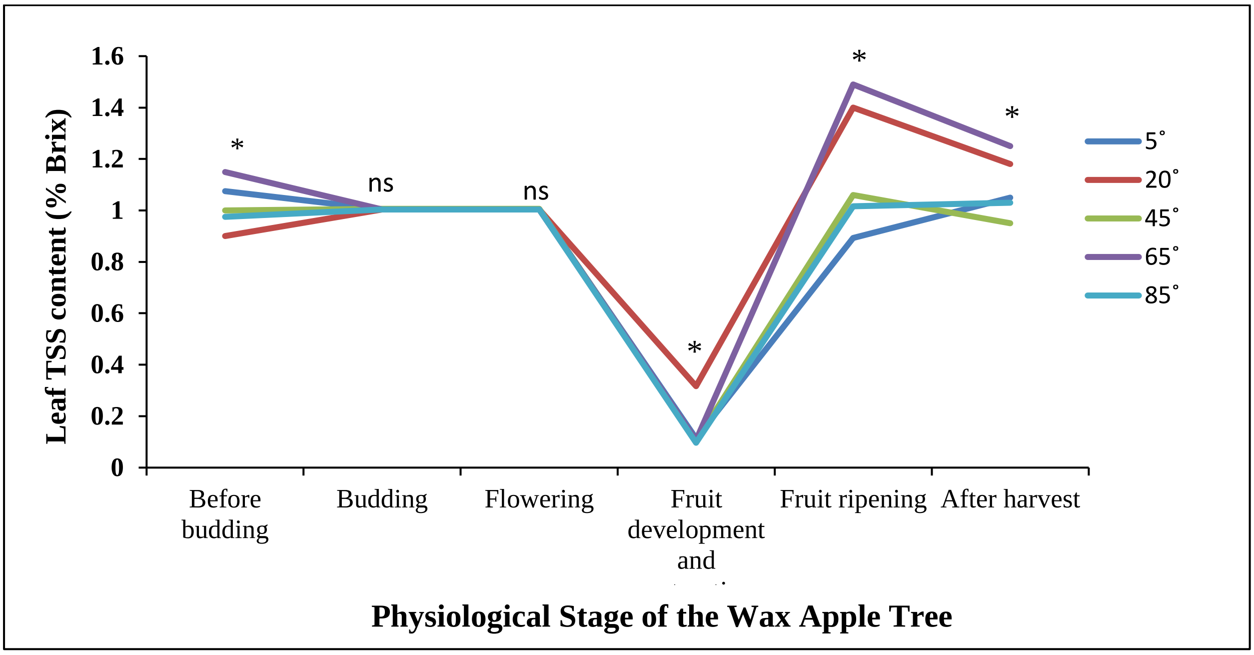

Fig. (3): Effects of different branch bending angle of leaf TSS content of wax apple trees at different physiological stage. Mean values presented with "*" are significantly different at p < 0.05. ns denotes non-significant.

During the fruit ripening stage, the leaf TSS content among the different bent branches was showed a significant difference at $p > 0.05$ level. After the fruit harvesting stage, the highest amount of leaf TSS content was recorded in 65˚ angle bent branch with a value of 1.25 % Brix followed by 20˚ bent branch. The lowest leaf TSS content was found in the 45˚ angle bent branch. At the vegetative stage (after fruit harvesting), the leaf TSS content was also affected significantly among the bent branches (Fig. 3). Carbon partitioning involves the transport of assimilates from source organs and their distribution to various sinks. The shoot structure and architecture influence on assimilates partitioning in various sink organs. Shoots tips and young leaves are stronger sinks then flowers and young fruits. In this study, branch bending techniques affect the leaf TSS content at different physiological stages of wax apple trees. The leaf TSS content at fruit development and maturation stages was very low compared to other physiological stages may be due to developmental fruits act as a stronger sink.

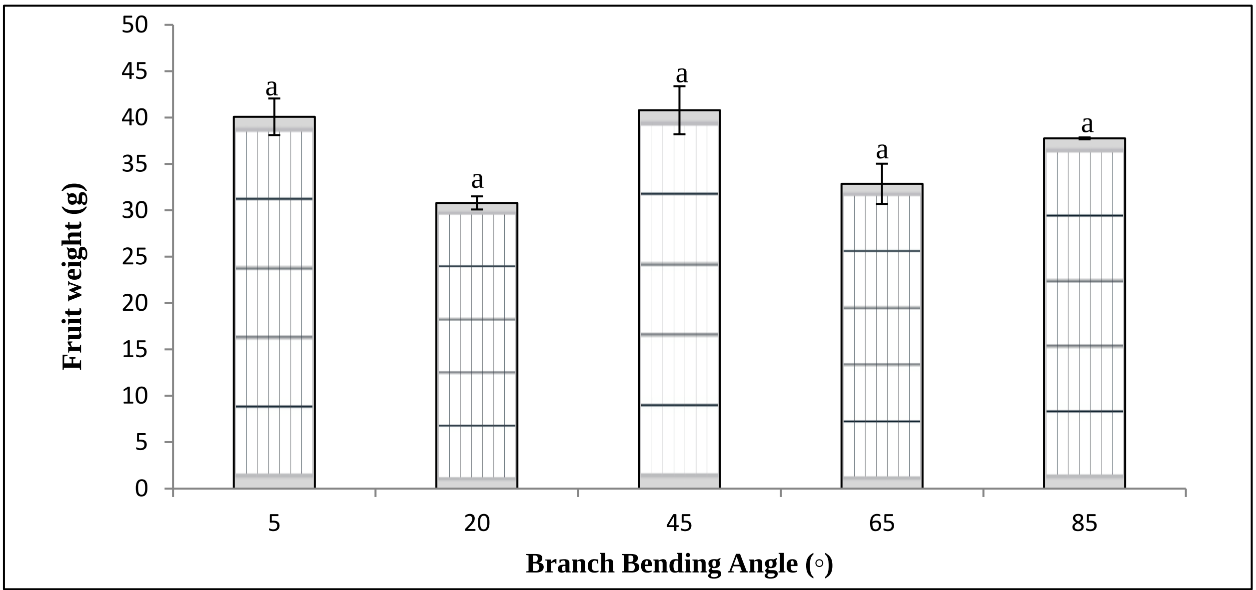

Fig. (4): The effect of branch bending angle on individual fruit weight of wax apple after harvesting. Error bars indicate ± S.E. Mean values presented with different alphabetic letters are significantly different at p < 0.05.

Based on Fig. (4), the highest individual fruit weight of wax apple was recorded in a 45˚ angle branch with a mean value of 40.79 g followed by the 85˚ angle with a fruit weight of 37.76 g. The lowest reading obtained from a 20˚ angle branch with a value of 30.8 g. The means differences of the individual fruit weight showed a non-significant difference at $p < 0.05$ level. It was also observed that bending techniques stimulates the flowering, increase the number of fruits and fruit TSS content of wax apple (data not shown). Our result buoyed by the findings of Sherif (2012), that bending significantly increased fruit weight (g) and size (cm^2) compared with control treatment. These results were also in according with Li-Tain *et al.* (1996) and Nasr *et al.* (2015), on pear, also for apple which shows that increase in bending angle is proportional to the weight of fruit. Like bending, girdling a growth manipulation technique that can affect the fruit quality of wax apple. Girdling on the branch before flowering enhances the flower development and increased the fruit quality of wax apple (Khandaker *et al*., 2011). Branch bending decreases the length of a shoot which leads to retardation of the upward and downward flow of phloem sap. In the bent branch, IAA and GA_3 content decrease, whereas, the concentration of ABA and cytokinin increases, thus stimulate flowering (Ito *et al*., 1999). Shoot bending reduced the basipetal transport of IAA and this could reduce IAA content in the lateral bud and promote flowering. Bagchi *et al.* (2008) reported that branch bending increase flowering and fruiting might be due to a higher C: N ratio. They also found that branch bending increased the accumulation of tryptophan and lipid in leaves and barks, these improved accumulations may help the plant to overcome the shock effect of bending. Samant *et al.* (2016) also reported that branch bending in guava increases the TSS and ascorbic acid content in fruits.

Fruit Firmness

Based on fig. (5), no statistically significant differences were recorded on comparing fruit firmness across the whole bending angles. At 20˚ bending angle, the highest fruit firmness (1.77 lb) was obtained and the lowest was at 5˚ angle with a value of 1.03 (lb). Nasr *et al.* (2015) reported that the decrease of fruit firmness recorded might be due to an increase of light penetration which led to increasing in IAA content in the cell.

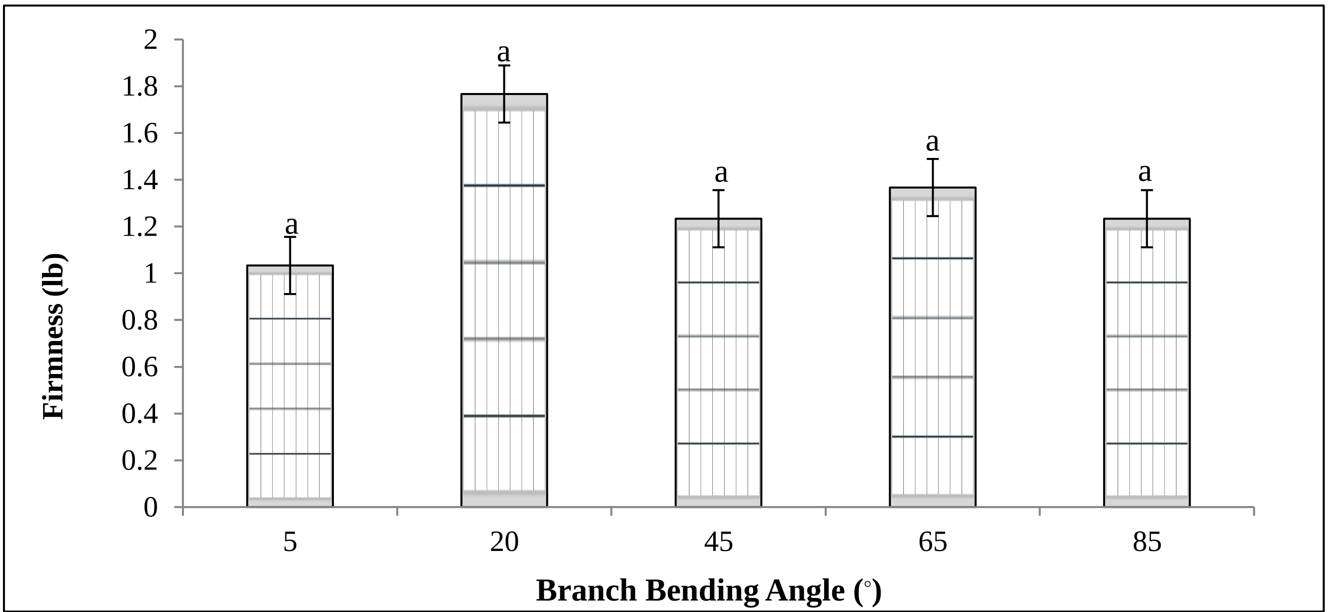

Fig. (5): The influence of branch bending angle on the fruit firmness of wax apple. Error bars indicate ± S.E. Mean values presented with different alphabetic letters are significantly different at $p < 0.05$.

According to Kefford & Goldacre (1961) the cell wall plasticity has been shown to increase before and during auxin-induced cell elongation which might due to the rupture of Ca bond in the cell wall. Contrarily, Benitez *et al*. (1998) revealed that the fruit position was not been affected by the fruit firmness of pears and also been proven on apple by Sharma (2014). Fruit tissue firmness is an important aspect of fruit quality and it depends on the maturity stages of the fruits, location of the fruits in the tree canopy, growing condition and sunlight availability on the tree. Khandaker *et al.* (2012a) reported that the fruit firmness of wax apple significantly affected by the application of plant growth regulators. Li *et al.* (2006) reported that fruit firmness increased with shoot bending and fruit hardness reached the highest when the bending branch angle was 110 degrees. This may be due to the higher C: N ratio in the fruits of the bent branch.

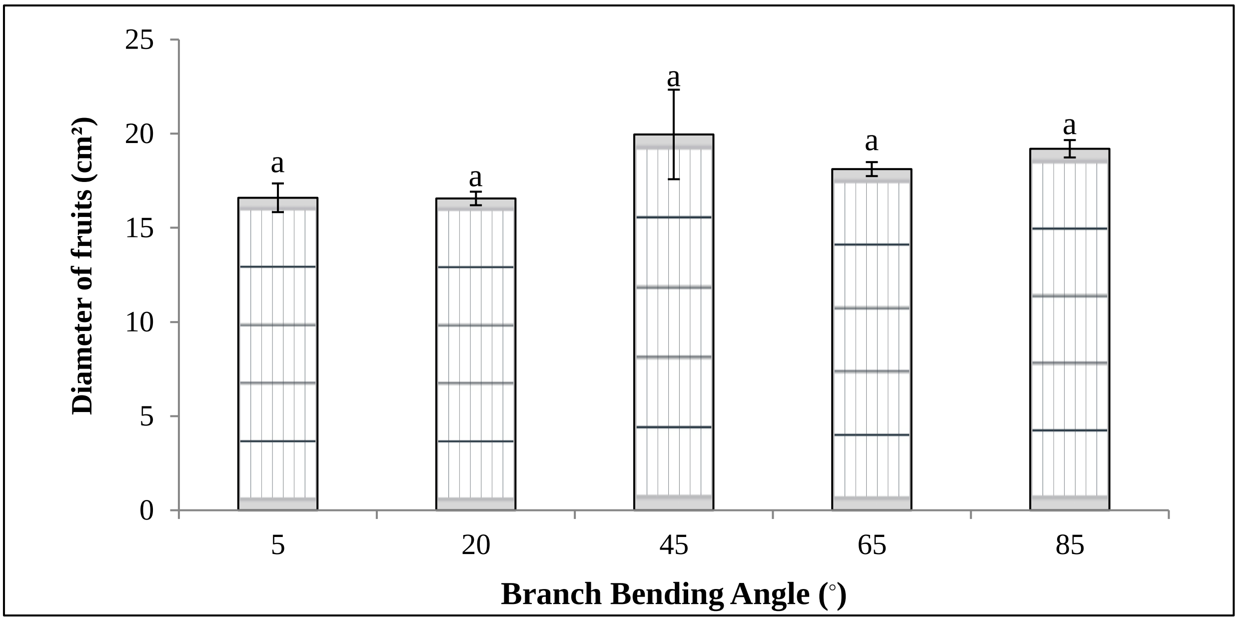

Fig. (6): The effect of branch bending angle on fruit diameter after harvesting of wax apple fruits. Error bars indicate ± S.E. Mean values presented with different alphabetic letters are significantly different at $p < 0.05$.

Fruit Diameter

Different bending angle treatment increase the fruit diameter of wax apple, however, their differences were not statistically significant (Fig. 6). The highest fruit diameter was recorded in a bending angle of 45˚ followed by that of 95˚, whereas, bending angle 5˚ has the lowest mean value (16.59) as shown in fig. (6). Our finding tally with the report of Sherif (2012), who stated that branch bending increased the fruit dimensions of pear. Similar positive effects of branch bending on fruit quality of pear reported by Li-Tain *et al.* (1996) and Nasr *et al.* (2015). Aly *et al.* (2012) also reported that shoot bending with GA_3 increases the leaf area, fruit set, number of fruits per tree, fruit weight, fruit diameter, TSS and total sugar content in pear fruits.

Table (1): Peel colour of wax apple fruits as affected by different branch bending angle.

Treatment (Bending angle)	Chroma value (C*)	Hue angle (h*)	Fruit peel colour (L* × a*)/b*.
5˚	21.04	62.39	Dull yellowish-red
20˚	19.80	52.09	Dull reddish yellow
45˚	23.33	55.92	Dull reddish yellow
65˚	20.35	55.81	Dull reddish yellow
85˚	23.98	55.71	Dull reddish yellow

Values are mean of three (3) replications.

Peel colour of wax apple fruits

It is extensively recognized that the peeling red or other bright colours are an important factor for purchasing consideration of wax apple as well as many other fruits. The peel colour is an imperative feature for determining the appearance, maturity, and quality of fruits. The choices of consumers are impressively influenced by the peel colour, texture, and appearance of fruits. According to Supapvanich *et al.* (2011), the peel colour of wax apple fruits was present as lightness (L value), red to green (a value), red to purple colour (hue angle), 0˚ = red, yellow = 90˚, bluish-green = 180˚ and blue = 270˚ angle and colour intensity as chroma value. An increase in hue angle (h˚) value shows that the peel red colour of the wax apple fruit was getting lighter during ripening. The result showed the peel colour of the wax apple fruits was affected by branch bending treatments. Dull yellowish red colour fruits harvested from the lower angle branch (5˚), whereas, other angle treatments produced reddish-yellow fruits. It was observed that fruit peel colour increased with the branch bending angle due to the availability of light in the canopy. Zhang *et al.* (2008) reported that the development of red pigmentation in the peels of ripening wax apple fruits due to the massive accumulation of anthocyanin and degradation of chlorophyll pigment. In this study, the positive values of a* and b* were credited due to the presence of carotenoids or anthocyanin n the peel of fruits. The colour in the fruits also reflects the presence of certain biologically active phytochemical compounds and antioxidants that purportedly could promote good health. At the fully ripening stage of jambu madu cultivar of wax apple fruits contains a less amount of chlorophyll and a higher amount of anthocyanin (Moneruzzaman *et al.*, 2011; 2015). Khandaker *et al.* (2018) stated that the peel colour of fruits changes from green to red or other brighter colours during the ripening of fruits. Li *et al.* (2006) reported that shoot bending in apple trees increases the TSS content in apple. Fruit TSS content positively correlated with anthocyanin as well as other pigments of fruits and play a significant role in colour development during maturation and ripening of fruits. Artificial bending of shoots may have a positive qualitative and quantitative impact on flowering, fruit production, maturation and ripening (Liu & Chang, 2011).

Mineral nutrient elements in wax apple fruits

Based on table (2), the highest mineral elements in the wax apple fruit were potassium (K^+) and the highest amount was recorded in 65˚ bent branches with a value of 128 mg g^{-1} followed by the 45˚ angle with a value of 115 mg.g^{-1}, respectively. The lowest reading of the K^+ element was from the 85˚ angle with 87 mg. g^{-1}, however, the results were not statistically significant among the treatments.

Table (2): The effects of branch bending angle on mineral nutrient elements content in wax apple fruits

Bending angle	Na^+ (mg g^{-1})	K^+ (mg g^{-1})	Fe^{2+} (mg g^{-1})	Mg^{2+} (mg g^{-1})	Ca^{2+} (mg g^{-1})	P (mg g^{-1})
5˚	8.08±0.32a	101.75±3.58a	0.41±0.06a	6.56±0.17b	3.99±0.85a	5.20 ± 0.86a
20˚	8.70±0.33a	108.54±13.5a	0.48±0.07a	6.95±0.46b	4.10±0.22a	1.26 ± 0.19b
45˚	7.05±1.82a	115.01±3.28a	0.31±0.01ab	7.22±0.39a	2.66±0.34b	1.31 ± 0.35b
65˚	6.21±0.98a	128.16±9.14a	0.33±0.08ab	7.34±0.43a	2.45±0.34b	2.06 ± 0.10b
85˚	6.07±1.51a	87.01±22.7a	0.19±0.10b	7.62±1.35a	2.27±0.38b	1.48 ± 0.30b

Values (mean ± S. E.) for followed by the same letter were not significantly different at $p < 0.05$.

The results showed that the second-highest mineral content was Na^+, followed by Mg^{2+}, Ca^{2+} and P, respectively. The lowest amount of mineral content in fruit of wax apple was Fe^{2+}. It was found that Na content in wax apple fruits was decreased with increasing bending angle, although their differences were not significant (Table 2). The fruits from 20˚ bent branch yielded the highest amount Fe compared to other treatments and their differences were statistically significant. Mg content was highest at 85˚ and 65˚ angles branch with a value of 7.62 and 7.34 mg g^{-1}, respectively. The lowest amount of Mg recorded in the 5˚ angle branch (6.56 mg. g^{-1}), and their differences were statistically significant (Table 2).

The highest amount of Ca^{2+} content in wax apple fruits was recorded at 5˚ and 20˚ angled branches. The results showed that calcium content decrease with increasing bending angle and the effect of branch bending was statistically significant. The highest amount of P was recorded in the fruits of the 5˚ angle branch and it was significant than the other treatments. Different variety of wax apple contains an almost similar amount of Mn, Zn, Ca, Mg and Cu nutrient, but Fe, Na and K contents were higher in red and pink cultivar compared to green one (Moneruzzaman *et al*., 2015). They also stated that K content was highest among the minerals found in these fruits. Bending of a branch caused a rapid and significant expulsion of water from a sample which reduced the flower of water upstream (Lopez *et al.*, 2014). May be the bending of branches affects the xylem flow and accumulation of minerals in the plant parts.

Relationship between leaf and fruit TSS contents with different parameters

Based on table (3), a weak positive correlation between leaf TSS with leaf number before bud development (r = 0.23), with number of bud (r = 0.35), with number of fruit (r = 0.21), with fruit firmness (r = 0.21) and fruit TSS with fruit Fe content (r = 0.37) were observed in the bent branches. Similarly, a moderate positive correlation between leaf TSS with leaf number during fruit maturation (r = 0.49), and fruit TSS with Na content (r = 0.67) and with Ca^{2+} content (r= 0.57) were also observed. A high degree of positive correlation was observed between fruit TSS with fruit Mg content (r = 0.70) of bent branches. There was no positive correlation between the leaf TSS content with leaf number at bud and fruit development stage, with fruit weight and fruit diameter and fruit TSS with fruit P content of bent branches of wax apple.

This positive correlation suggests that leaf TSS content is also an indicator of fruit quality which related to other parameters such as the number of leaves, number of buds, number of fruits, fruit TSS content and mineral nutrients contained in fruits. Those represent that branch with high leaf TSS content produces fruit with better quality. Sherif *et al*. (2012) also reported that an increase in TSS percentage was obtained by branch bending. Equally, the sunlight distribution on the canopy of the trees influences the flowering, fruit set, fruit size, colour and total soluble solids content in the fruits (George *et al*., 1996). This is proven the results that 45˚ to 85˚ bending angle gave the highest number of flowers and fruit might be due to the penetration of sunlight. Rees *et al.* (1981) stated that increment of total soluble solids could be attributed to the decomposition of cell wall which causes a release of water-soluble components during maturity and ripening of fruits. The increase in TSS may be due to the increase in water-soluble galacturonic acids from the degradation of pectin substances by polygalacturonase enzyme (Reaves, 1959). The sweetness of guava fruit was due to its soluble solids content converting from starch to sugars during ripening of fruits (Sharaf & El-Saadany, 1987). This study presents the report of different branch bending angle effects on wax apple trees physiology and fruit development. The findings of this study have a significant impact on developing the fruit industry and can be used by others to provide a basis for future research on growth manipulation study and yield enhancement of other fruit trees.

Table (3): Regression equation, correlation coefficients (r) and coefficient of determination (R^2) among different parameters with leaf and fruit TSS content of wax apple.

Regression equation	Correlation (r)	Coefficients of determination (R^2)
Leaf TSS content with leaf number		
Before bud development (y = -44.116 x + 134.15)	0.23*	0.053
At bud development (y =2718.7 x 2602.5)	0.12	0.015
During fruit development (y = 96.25x + 87.125)	0.16	0.027
During fruit maturation (y = 99.681x - 37.043)	0.49*	0.243
Leaf TSS with flowering and fruit development		
TSS with bud number (y = 237.5x - 235.82)	0.35*	0.125
TSS with number of fruit (y = 47.5x + 38.75)	0.21*	0.045
TSS with fruit weight (y = -0.008 x + 2.9735)	0.13	0.017
TSS with fruit diameter (y = 0.0198x + 2.3173)	0.13	0.018
TSS with fruit firmness (y = 0.3206x + 2.2547)	0.32*	0.10
Fruit TSS with mineral nutrients content		
TSS with fruit sodium (Na) (y = 0.0161x + 1.51	0.67*	0.447
TSS with fruit ferum (Fe) (y = 0.0913x + 2.3611)	0.37*	0.136
TSS with fruit magnesium (Mg) (y = -0.024x + 4.3)	0.70*	0.495
TSS with fruit calcium (Ca) (y = 0.013x + 2.2496	0.57*	0.333
TSS with fruit phosphorus (P) y = 0.0017x + 2.6367	0.14	0.02

* denote positive correlation.

Conclusion

The main purpose of this study was to identify the best bending angle to enhance the fruit growth and developmental process within the wax apple trees. The application of branch bending angle, particularly bending angle with 20˚, 45 ˚ to 65˚, increased the leaf chlorophyll content, leaf TSS content, fruit growth, and fruit diameter of wax apple fruits. At the same time, fruit colour development and nutrient elements (potassium, magnesium, and calcium) content increased with the bending angle of wax apple trees. The correlation analysis showed that leaf TSS content positively correlated with the number of flower buds, number of fruits, and fruit firmness of bending branches. In addition, fruit minerals content positively correlated with fruit TSS content of wax apple fruits. As a result, it is concluded that 20˚ to 65˚ branch bending angle enhance the tree physiology, fruit formation, and growth, and accumulates mineral content in the fruits of wax apple. Our findings of this study have great significance to improve the yield and quality of tropical and subtropical fruits.

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ونمو الثمار و حالة العناصر الغذائية المتأثرة *Syzygium samarangense*فسلجة شجرة التفاح الشمعي بزاوية انحناءة الفروع

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المستخلص: نفذت الدراسة الحالية لتقييم تأثير زاوية انحناءة الفروع في الخصائص الفسيولوجية والحالة المعدنية ونوعية الثمار في شجرة التفاح الشمعي. طبقت عديد من المعاملات بمكررات خمسة وفقا لتصميم القطاعات تامة العشوائية RBCD، وتمثلت المعاملات معاملات تجريبية. بينت ° هي معاملة السيطرة، والزوايا العمودية 45 و 65 و 85° بزوايا مختلفة لانحناءة الفروع كانت فيها الزاوية 5 النتائج أن محتوى الأوراق من الكلوروفيل قد تأثر بصورة معنوية بالمعاملات المختلفة في مرحلة تكوين البراعم و التزهير وتطور الثمار وصلابتها حتى مرحلة قطف الثمار. كما ازدادت معدلات المواد الصلبة في الأوراق نتيجة المعاملات المختلفة قبل مرحلة تطور البراعم و التزهير ونضج الثمار وما بعد القطاف. وخلال مرحلة تطور الثمار ونضجها وجد إن معدلات المواد الصلبة الذائبة الكلية قد انخفضت بشكل معنوي في جميع المعاملات. كما بينت النتائج أن الزاويتين 20 و 65 ادتا الى زيادة وزن وقطر الثمار، وسببتا زيادة في اللون الاسود في الثمار قياسا بمعاملة المقارنة. فضلا عن زيادة معنوية في محتوي البوتاسيوم والمغنيسيوم في الثمار في معاملة الزاوية 20°الانحناء 65، وزيادة في محتوى الثمار من الصوديوم والكالسيوم في معاملة زاوية ، مع تأشير وجود ارتباط موجب بين معدلات المواد الصلبة الذائبة الكلية و محتوى الثمار من المغنيسيوم (0.57)، والكالسيوم (r = 0.67)، والصوديوم (r = 0.70) . كما كانت صفتي صلابة الثمار ولونها مرتبطتين بشكل معنوي مع المواد الصلبة الذائبة الكلية في شجرة التفاح الشمعي. وإن عدد الثمار ووزنها وقطرها قد ارتبطت بشكل موجب (ضعيف) مع محتوى الاوراق من المواد الصلبة الذائبة الكلية. من خلال النتائج المتقدمة من الممكن الاستنتاج أن زاوية ميل الفروع 25 و 65 ° كانتا الفضلى في زيادة مؤشرات النمو الفسيولوجية المهمة المدروسة لشجرة التفاح الشمعي.

الكلمات المفتاحية: شجرة التفاح الشمعي، زاوية ميل الفرع، الكلوروفيل، العناصر المعدنية، النوعية.