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EFFECTS OF BRANCH BENDING ANGLE ON GROWTH AND FLOWERING OF WAX APPLE (*SYZYGIUM SAMARANGENSE*)

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Abstract

Wax apple or jambu madu as called by Malay, is a non-climacteric tropical fruit from the family Myrtaceae and scientifically named as *Syzygium samarangense*. It is native to Malaysia, Indonesia and Philippine. Jambu madu (wax apple) grows to a height of 5–15 m depending on the growing conditions. Manipulating the vegetative and reproductive growths is the goal of growers and researchers in agriculture for fruit trees. Bending effects of flowering and fruiting remains the controversial aspect of orchard. However, the optimum bending angle is yet to be elucidated. All the treatments represent different branch bending angle which was at 5° (control), 20°, 45°, 65° and 85°. The results revealed that 65° and 85° provide the best results in terms of enhancing flowering, fruit growth and quality of wax apple fruits. Bending increases the number, as well as the quality of fruit. This study concludes bending has a significant effect on the development and growth patterns of wax apple.

***Key words**:* branch bending, TSS, flowering, fruit growth, quality.

Introduction

Wax apple also known as jambu air madu, is a non-climacteric fruit from the tropical environment from the Myrtaceae family and scientifically called *Syzygium samarangense* (Al-Saif *et al.,* 2011). It is native to Malaysia, Indonesia and Philippine (Khandaker, 2012). In Malaysia, the fruits also known as jambu merah, jambu bar, jambu Melaka. jambu kling, and jambu kapal (Lim, 2012). The fruits are oblong shaped usually red, greenish-white, pink, light red or sometimes cream coloured, often crisp, with a subtly sweet taste and an aromatic flavor (Khandaker, 2012). Normally the Jambu madu red wax apple cultivar is the sweetest. The trees some time possess higher vegetative growth compared to reproductive growth and produced a smaller number of flowers (Al-Saif *et al.,* 2011). The climatic condition in Malaysian is suitable for fruiting and mass production of wax apple. It is harvested throughout the year in Malaysia. The potential and benefit of this wax apple are increasingly becoming popular in this region towards the farmers and subsequently increasing the country economy (Khandaker, 2012). Fruits of *S. samarangense* are eaten cooked as a sauce or raw with salt in Malaysia. All the fruits from the family are edible. The composition of the jambu air fruits; 90% water, 0.2 g fat, 0.7 g protein, 1.9 g fibre, 4.5 g carbohydrates, A 253 IU vitamin, traces of vitamin B1 and B2, C 8 mg vitamin, and 80 kJ/100 g of energy value (Wills *et al.,* 1986). Al-Saif *et al.,* (2011) also reported *S. samarangense* fruits as edible and has significant benefits for human health as potential sources of antioxidants.

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The process of cultural horticultural practices has documented ever since to affect the fruits quantitative and qualitative parameters through the application of plant growth regulators. Manipulating the vegetative and reproductive growths is the goal of growers and researchers in agriculture for fruit trees. In improving the yield of horticultural products, there are several agricultural techniques have been used. In other to produce fruits of quantitative and qualitative value in off season bending shoot is one of the only options (Guardiola, 1992; Sarkar *et al.,* 2005; Sherif, 2013). Bending of the branch leading to decreased in the formation of phloem and increased in wood tension branch. Thereby, leading to the slow passage of photosynthetic products from the bent branch of the shoots and the remaining parts of the plants. As a result of this, there is constant increases in the ratio of C:N and induction of flower and fruits set (Sherif, 2013). Reproductive buds that were dormant are activated into growth and developments through the process of bending in of plant part (Sherif, 2013). The bent branch produces more flowers and fruits when compared with the upright branch in the study plants (Ito *et al.,* 1999). The upright branches of wax apple plants produce a smaller number of flowers and fruits. Bud and premature fruit drop are very high from the upright branches due to the fewer photosynthates supply during growth and development (Fischer *et al.,* 2012).

Vegetative branch (narrow-angle branch) favored vegetative growth and create a negative impact on tree productivity of wax apple (Narayanasamy, 2013). 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 (Dhillon & Thakur, 2014). Hence, based on the above literature, the following study was carried out to examine the effect of branch bending in wax apple under field condition. To the best of our knowledge, there is no literature on wax apple regarding the effects of bending angle on wax apple quality. This study investigated the effects of branch bending angle on growth and flowering of wax apple (*Syzygium samarangense*). It is proposed that the bending process can induce more flowering and increasing leaf TSS content to produce quality fruit.

Materials and Methods

Plant material

Six-years-old apple wax plants were selected for the examination of bending effect on flowering and fruit growth of wax apple. The mini plant orchard was located near the D block of Universiti Sultan Zainal Abidin, Besut Campus, Besut, Terengganu, Malaysia.

Shoot bending

Branches that are free from any diseases and healthy lateral branches were used for branch bending with proper handling according to Mamun *et al.,* (2013). All the experimental shoots were bent at 5° (used as a control), 20°, 45°, 65° and 85° angle by using protractor ruler from the vertical axis of the plant with the aid of an rope. Prior to shooting bending all the leaves were kept continuing its photosynthesis and respiration as well as for other physiological processes.

Treatment Setting

The experiments consist of five treatments of different degree of bending as 5° under Treatment 1 as the control, treatment 2 with 20° angle, treatment 3 with 45°angle, treatment 4 with 65° angle and lastly treatment 5 with 85°angle from vertical axix. Each treatment consists of 5 replicates or 25 branches of wax apple plants. Five plants have been used in this experiment. The experiment consisted of five treatments including the control, in five replicates.

Experimental Design

This experimental design was Randomized Complete Block Design (RCBD) with five replications. All five treatments (branch bending angle) consist of five replicates. 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°).

Measurement of morphological parameters

The parameters that have been taken according to the phase include the number of leaves, number of flower buds, number of flower and number of fruits was counted manually. Fruit growth which includes fruit length, fruit diameter, fruit firmness and the peel color of the fruit itself was measured. Fruit firmness and fruit peel color were measured after the fruit has been harvested.

Physiological parameters

1. Chlorophyll content

The chlorophyll content in the leaves was measured by using SPAD-502 portable chlorophyll meter (Minolta Japan). Handheld SPAD-502 meter device was used for accurate, rapid and non-destructive measurement of chlorophyll content of the leaf. SPAD-502 device meter produces measurements with SPAD values that are proportional to the number of chlorophyll contents present in leaf (Ling *et al.,* 2011). Before using this meter, it was calibrated to take accurate readings. Leaf tissue was clamped using SPAD-502 meter to take the measurement. Meter showed an indexed content of chlorophyll within seconds.

2. Leaf and fruit total soluble solids (TSS)

The TSS content of leaf and fruit was evaluated by using Hanna HI96801 Digital Refractometer and wax expressed as percentage Brix (% Brix). The leaves samples and fruits were collected for each treatment. Then, the extraction was made from the samples. It was calibrated with some drops of distilled water. Two drops of leaf extract and fruit extract were placed to the refractometer sensor. The readings showed in percentage and the data were recorded.

3. Fruit firmness

Fruit firmness was evaluated by using Effegi penetrometer. A puncture was made in the fruit, Depth of penetration should be consistent to the inscribed line on the tip. The reading was recorded to the nearest 0.5 lb or 0.25 kg.

4. Fruit colour

The peel colour was evaluated by CR-400 Chroma Meter (Minolta Chroma Meter CR 400, Osaka, Japan). It is a portable handheld device for measurement. Designed to evaluate the colour of the object with minimal color variation and smoother surface conditions. 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 (Khandaker, 2012).

5. Mineral element

Determination of mineral element of K by inductively coupled plasma optical emission spectrometry (ICP-OES). The process of digestion and filter of the samples were done before being determined by ICP-OES. Sample preparation started by weight 0.3g of the solid sample into a porcelain crucible. The crucibles were transferred into the furnace and heat up to 500° C and the temperature was kept for two hours. The crucibles with ash were removed from muffle furnace, letting it cool and added with 3 ml of diluted 1:1 HNO_3. The sample was dried on a hot plate at 100 to 120°C until dried completely. The crucibles were put back into the furnace at 500°C for another one hour. The crucibles were removed from the furnace. After cooled, 10 ml of HCl were added. The sample then transferred into 50 ml volumetric flask and added with deionized water to the volume and mixed. Solutions were prepared prior to the analysis, 1% ultrapure HNO_3 solutions was used in probe rinsing the sample, 10 ppm Sc in 1% ultrapure was used as standard internal solution of HNO_3, blank calibration and standard calibration for a three-point calibration and a calibration blank check solution was made. Verification of calibration solutions was made from the stock solutions. Solid samples that had been digested diluted 1:5 with RO water.

Statistical Analysis

The data obtained from the experiment were analyzed by using SPSS Statistics version 14 software. A one way repeated analysis of variance (ANOVA) was applied to evaluate significant differences in the studied parameters in different treatments. Means comparisons were performed with Duncan test significance at $p<0.05$.

Results

Number of Leaves

Based on Fig. 1, the number of leaves before bud development was showed the highest reading at a 45° angle with mean 104.5 ± 4.87 followed by a 65° angle with 97.75 ± 3.54. The lowest reading of the leaves number came from the control of 5° angle with 57.5 ± 3.43. The means differences of the leaves number before bud development was showed a non-significant different at $p > 0.05$ level (Fig. 1).

Number of flower bud

The number of buds is the major external factor consider to be significant in determination of fruit developments, as the total number of flower buds influences greatly the production of fruit. With an increasing the bending angle, it showed increasing the number of buds. (Fig. 2) shows the effect of branch bending angle on the number of a flower bud. The result showed the highest reading at 65° followed by at 45° angle. The lowest number of buds came from the 20° angle. The best result showed that 65° angle gave the highest number of buds.

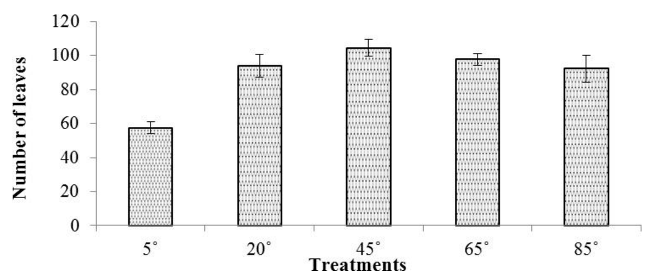

Fig. 1: The effect of branch bending angle on number of leaves before bud development.

Number of fruits

The number of fruits is important in determining fruit growth. (Fig. 3) shows the highest reading at 45° angle followed by a 65°and 5° angle. The lowest number of fruits came from the 85° angle. The best result showed

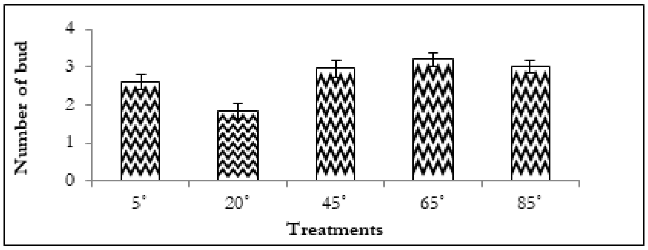

Fig. 2: The effect of branch bending angle on number of flower bud.

that 45° gave the highest number of fruits.

Leaf and fruit TSS content

The ripening of fresh fruits is significantly resulted

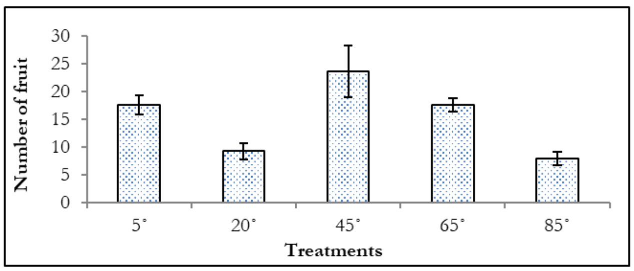

Fig. 3: The effect of branch bending angle on number of fruit.

from the amount of TSS in leaves of wax apple. (Fig. 4 (a)) shows leaf total soluble solid (TSS) during flowering and the highest reading are at 45° angle followed by at 65° angle. (Fig. 4 (b)) shows leaf total soluble solid (TSS) during fruit maturation which the highest reading at 5° angle followed by at 65° angle. (Fig. 4 (c)) shows the highest fruit TSS content of wax apple was recorded in 85° angled followed by 20° angle.

Chlorophyll contents

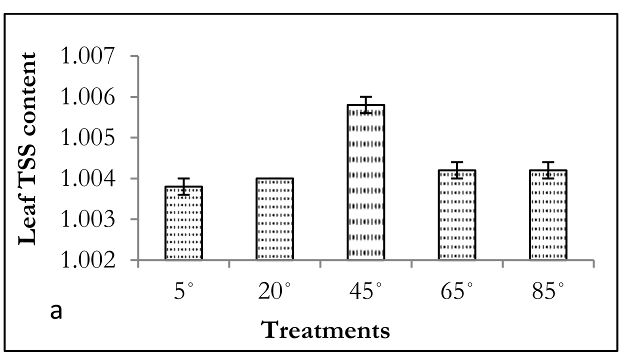

Fig. 4(a): The effect of branch bending angle on leaf TSS content during flowering.

Based on Fig. 5, the result for chlorophyll content showed the highest reading at 5° angle with mean 44.16. ± 2.07 followed by at 20° angle with 38.86 ± 3.99. The lowest reading of the chlorophyll content came from the

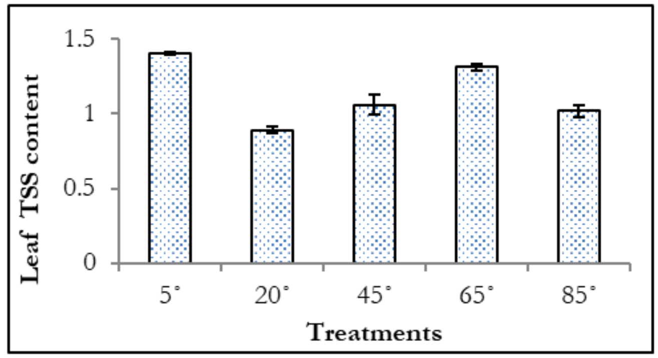

Fig. 4(b): The effect of branch bending angle on leaf TSS content during fruit maturation.

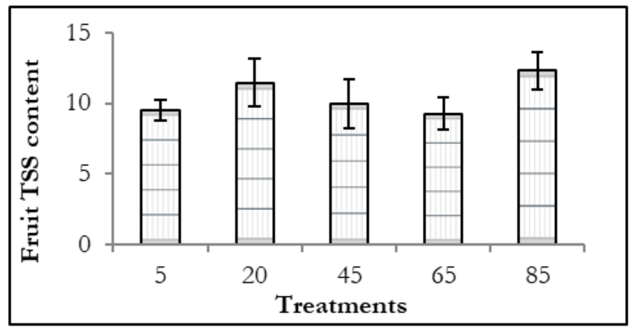

Fig. 4(c): The effect of branch bending angle on fruit TSS content of wax apple.

85° angle with 34.82 ± 2.12. The branch bending angle did not produce any positive effect on chlorophyll content as the gap reading has no significant difference.

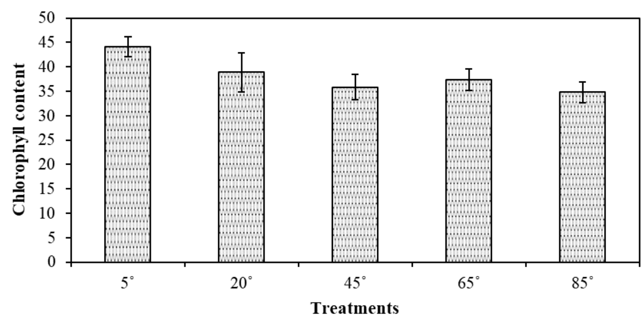

Fig. 5: The effect of branch bending angle on leaf chlorophyll content of wax apple.

Mineral elements of Potassium (K)

In this study, K content is the highest in wax apple fruits. Figure 6 shows the highest K content is recorded in 65° angled followed by the 45° angle.

Correlation leaf TSS content with different parameters

Table 1 shows the relationship between leaf TSS content with number of leaves, number of flowers, number of fruits, fruit TSS content and K element in wax apple fruit. The result of the regression equation showed

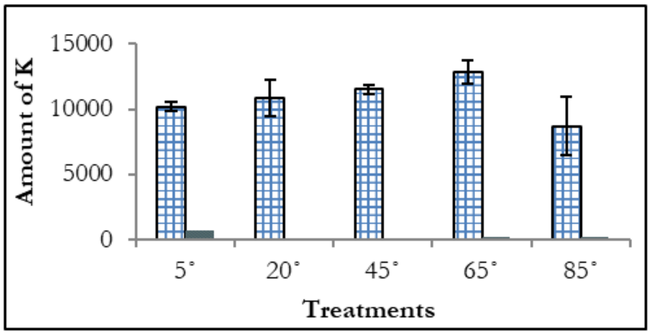

Fig. 6: The effect of branch bending angle on fruit K content of wax apple.

that the number of leaves, number of flower and number of fruits in the bended branch was positively correlated with leaf TSS content. This positive correlation suggests that leaf TSS content is an indicator towards fruit quality. High leaf TSS content gave better fruit quality. The results showed that 45° bending angle gave positively correlation between leaf TSS content with the number of leaves, number of flowers and number of fruits. Minerals element of potassium (K) show highest at 85° angle which give a positive correlation with the fruit growth.

Discussion

Fruits of wax apple are 3 – 6 cm wide 3.5 – 5.5 cm long and, pear shaped, about with 1–5 seeds or in rear cases without seed (Khandaker, 2012). The skin or peel is very thin and has an appearance of waxy glossy. Fruits are in pear-shaped, often juicy and come along with a subtly sweet taste and aromatic flavor. Bending in fruit management has been in practice for ages as the means of traditionally and culturally increasing quality and yields of the fruits (Zhang *et al.*, 2015). Bending leading to more shoots as a result of the reduction in the number of nodes and the length of internode. The need to manage excess growth of branch (vegetative) in order to increase fruiting and ûowering becomes paramount for economic importance, so as to reduce the cost of production (Aly *et al.*, 2016). Among the examined traditional orchard management methods in order to improved fruiting and growth, branch bending has proved to be the most successful among the cultural methods (Aly *et al.*, 2017).

For the control of excessive vegetative growth in fruits, branch bending remains the alternative to pruning for the management of vegetative growth leading to a reduction in budding of flower initiation, yield and fruits set (Costes *et al.*, 2006). High density orchard has long been using branch bending means as an alternative method for better quality (Lauri *et al.*, 2005). Previously it has been reported apple trees yield better fruits in terms of quality and number when regulated through bending (Aslantaº *et al.*, 2007). Increasing angle bending resulting to increase branching frequency and lateral flower number when compared to upright one (Han *et al.*, 2007). Flower initiation budding is a complex anatomical physiological process across which meristems situated on spurs or shoots form ûower budding. Flower induction in apple occurs early on the season, for about five to ten weeks after blooming full, and is regulated through the anatomical physiological process. The number of buds is significantly believed to be one of the external factors responsible in the determination of fruits growth, as the total number of flower buds greatly influences the production of fruit. With an increasing the bending angle, it showed increasing the number of buds. The following study finds increased in the number of budding with the increase in the angle of bending. In the same vain Zhang *et al.*, (2017), increase in the number of buds significantly in 'Fuji' apple with increasing bending angle from 70° to 110° and the results have proven at 65°. Original branching patterns changed through bending as a result of stimulating latent budding development; giving birth to laterals vegetative. Bending promoted the development of lateral shoots on the upper part of the shoot arched due to the increasing of zeatin cytokinin type in buds while reduced the growth of acrotonic lateral shoots. Similarly,

Table 1: Regression equation, correlation coefficients (r) and coefficient (R^2) of different parameters.

Regression equation	Correlation (r)	Coefficients of Determination (r^2)
Leaf TSS content and number of leaves y= 7874x -7805.1	0.59*	0.348
Leaf TSS content and number of flower y= 844.09x- 841.72	0.83*	0.69
Leaf TSS content and number of fruit y= 39.574x- 13.723	0.74*	0.542
Leaf TSS content and fruit TSS content y= 0.1375x+ 1.2363	0.66*	0.438
Leaf TSS content and mineral element Potassium (K) y= (-0.0013)x + 4.0687	0.71*	0.501

shot bending has reported to increasing the number of budding in fruit plants. The number of fruits is important in determining fruit growth.

The present study shows the highest reading of the number of fruits was recorded at 45° angle of bending. Branch bending has been in practiced for decades in China and other developed countries to induce budding in flower in 'Fuji' apple and increased fruit set during their studies on pear (Wagenmakers *et al.,* 2000; Lauri & Lespinasse, 2001; Alméras *et al.,* 2004). In order to promote early fruiting in plants bending has been proposed as an alternative to pruning and controlling tree size (Tehrani *et al.*, 2011; Nadzirah *et al.*, 2013). Horticultural used bending orientation to reduce vegetative growth and increase the number of fruiting in plants (Lauri & Lespinasse, 2001). The ripening of fresh fruits is attributed to the TSS contents in a plant leaf. The following study established the mean differences of the leaf TSS content after harvesting shows a non-significant different. This shows a good sign which the amount of carbon: nitrogen is accumulate in a leaf because the fruit has been harvested. Lauri & Lespinasse (2001) reported TSS content in Fuji apple increased with branch bending angle and it was highest at 110°. This proven that the highest leaf TSS content producing the highest fruit TSS content. Thus, it contributes to the best quality of wax apple.

Sherif (2013) reported that an increase in TSS percentage was obtained by branch bending. Soluble solids increase could be attributed to the cell wall decomposition which leads to the released of water soluble components from the plants part. Also, due to the increase in water-soluble galacturonic acids from the degradation of pectic substances by polygalacturonase (PG). TSS increased attributed to the conversion of starch to sugars which gave the sweetness of the fruits and this also proven in this wax apple. In this study, K content is highest in wax apple fruits. The highest K content is recorded in 65° angled followed by the 45° angle. According to Moneruzzaman et al. (2015), the composition of the following elements Zn, Mn, Ca, Cu and Mg in jambu cultivars did not significantly vary among them. Contrary to the amount of Na, Fe and K in fruits of wax apple were significantly higher in red and pink cultivars. Cultivars of green species exhibited the lowest amounts of K, Fe and Na composition. As this study was regarding the red cultivars, the result was supported whereas K gave the highest reading in the wax apple fruit. Quite a number of studies have reported the significant effect of bending on the vegetative growth of plants resulting to flowering and large number of fruits. Similarly, the reduction in the number of nodes yields more fruiting in plants. The following study has established a bending position have significant effect on the number of buds, flowering, and fruits in wax apple (*Syzygium samarangense*).

Conclusion

The following study found that 65° and 85° branch bending angle provide the best results in terms of enhancing flowering, developments of fruit and quality of wax apple fruits. Bending increases the number, as well as the quality of wax apple fruit. This study found bending has a significant effect on the development and growth patterns of wax apple. We concluded that 65° and 85° branch bending angle are promising for enhancing flowering, fruit growth and quality of wax apple fruits. Finally, the study concluded that bending plant branch is more practical and has significant impacts on the quantitative and qualitative yield of wax apple.

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