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Full Length Research Paper

An evaluation of the nutritional quality evaluation of three cultivars of *Syzygium samarangense* under Malaysian conditions

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A study was carried out to selected physiological and biochemical characteristics of *Syzygium samarangense* for their physiological and biochemical characteristics at Functional Food Laboratory, University of Malaya, Kuala Lumpur. Various physiological and biochemical parameters were monitored during two seasons of fruit growth between October, 2009 to August, 2010 with the 'Giant green', 'Masam manis pink' and 'Jambu madu red' cultivars of *S. samarangense.* Ripened fruits of the different cultivars were collected from the experimental field of Banting, Selangor and analyzed for selected physiological parameters namely chlorophyll fluorescence, quantum yield, fruit weight, total yield, number of seed per fruit, seed weight and dry matter content and some biochemical parameters that is, juice content, pH, total soluble solids (TSS), glucose, fructose, inverted sugar, ethanol, total flavonoids, phenols and anthocyanins content. It was observed that highest chlorophyll fluorescence, maximum quantum yield (0.79), fruit weight, seed number (4) and seed weight per fruit (4.56 g) were in the 'Giant Green' cultivar while total yield, glucose (9.83%), fructose (9.9%), inverted sugar (9.57%), ethanol (20.5%), flavonoids (914.1 mg/100g) and phenols (326.67 mg GAE/100g) were in the 'Masam manis pink' cultivar, and the highest juice content (76.33 ml), highest total soluble solids (8.76ºBrix) and anthocyanins (2.78 mg/L) were in the 'Jambu madu Red' cultivar. From this study, it can be concluded that 'Masam manis pink' and 'Jambu madu red' cultivar are comparatively better than 'Giant green' cultivar under South Asian conditions.

Key words: *Syzygium samarangense*, nutritive value, cultivar, Malaysia.

INTRODUCTION

The wax jambu (*Syzygium samarangense)* is a non-climacteric tropical fruit, other names are wax apple, rose apple, java apple and water apple. The color of the fruit is usually pink, light-red, red, green, sometimes greenish-white, or cream-colored (Morton, 1987). The species presumably originated in Malaysia and other south-east Asian countries. It is widely cultivated and grown throughout Malaysia and in neighboring countries such Thailand, Indonesia and Taiwan. Currently in Malaysia it is cultivated mainly as smallholding areas ranging from 1 to 5 ha with its total planted area estimated at about 2000 ha in 2005 (Shu et al., 2006). In Malaysia, there is a great scope to developed wax jambu fruit industry and possible to earn fuse amount of foreign capital by exporting to the other countries.

Fruits are pear shaped, often juicy, with a subtle sweet taste and aromatic flavor. In Malaysia, the fruits of jambu air are eaten raw with salt or cooked as a sauce. Ninety per cent or more of the fruit is edible. In Malaysia, there are about three species which bear edible fruits, namely the water apple *(Syzygium aquem)*, Malay apple (*Syzygium malaccense*) and wax jambu (*Syzygium samaragense*). The pink, red and green cultivars of wax jambu are popular in Malaysia and other South East Asian countries. Wax Jambu fruit is rounder and oblong in shape. It has a drier flesh compare to the other spp of *Syzygium*. It has been found that wax jambu has a very low respiration rate of 10 to 20 mg CO_2/kg h at 20°C, although they are highly perishable fruits (Akamine and Goo, 1979). The compositions of wax jambu per 100 g edible portion are: water which is more than 90%, protein

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0.7 g, fat 0.2 g, carbohydrates 4.5 g, fibre 1.9 g, vitamin A 253 IU, vitamin B1 and B2 traces, vitamin C 8 mg, energy value 80 kJ/100 g (Wills et al., 1986). Fruit growth and development are associated in the morphological, anatomical and physiological changes (El-Otmani et al., 1987). Fruit maturation is associated with changes in rind texture, juice composition and taste (El-Otmani et al., 191). Fruit quality is highly influenced by environmental characteristics, climate (Inglese et al., 2002) and orchard management and may change from year to year (Mokoboki et al. 2009). Felker et al. (2002) reported that major variation in fruit quality is not related to environment or edaphic factors but rather ascribed to genetic factors, and the majority of variation for fruit quality seems to be due to random error. Color is probably the most important quality factor used by consumers for wax apple (Shu et al., 2001). They also reported that the cultivars of *S. samarangense* produces fruits varying from pink to deep red, depending on light, temperature, position on the tree, growing stage, leaf: fruit ratio. Chang et al. (2003) stated that Sucrose, glucose and fructose are important quality parameters that influence the anthocyanin biosynthesis in wax apple fruits. The flowers, which contain tannins, desmethoxy-matteucinol, 5-O-methyl-40-desmethoxymatteucinol, oleanic acid, and b-sitosterol, are used in Taiwan to treat fever and halt diarrhea (Morton, 1987). In addition to their use as food; many of these fruits have been used in divergent traditional medical practices for a variety of illnesses and conditions. Ethanolic leaf extract of wax jambu exhibited immunostimulant activity (Srivastava et al., 1995), the hexane extract was found to relax the hyper motility of the gut (Ghayur et al., 2006), while the alcoholic extract of the stem bark showed antibacterial activity (Chattopadhayay et al., 1998).The fruit pulp of pink cultivar of *S. Samarangense* is a rich source of phenolics content, flavonoids and several antioxidant compounds (Simirgiotis et al., 2007). They also reported that edible fruits of *S. samarangense* represent potential benefits for human health because they are rich source of polyphenolic antioxidants.

For the commercial grower and for a person who wants to grow the wax jambu in home garden, it is very important to have information on the differences in fruit quality among the cultivars of *S. samarangense.* Since no report has been published as to the nutritional quality on the cultivars of *S. samarangense,* this project aims to evaluate the nutritional quality of different cultivars of *S. samarangense* as well as the physiological and biochemical characteristics of the three cultivars of *S. samarangense* for assessing their quality.

MATERIALS AND METHODS

Experimental site

The experiments were carried out in an orchard located at a commercial farm in Banting, 2° 30'N, 112° 30'E and 1°28'N, 111° 20'E at an elevation of about 147 ft above sea level. The area under study has a hot and humid tropical climate. The soil in the orchards is peat with a mean pH of around 4.6 (Ismail et al., 1994). Experiments were conducted between 2009 to 2010. The first season of experiments were carried out from October 2009 to February 2010, and second seasons from April to August 2010.

Treatment application

Twelve years old wax jambu were selected for the study. The trees were planted in a 14.5 ×14.5 ft hexagonal pattern and received the same horticultural management. Three wax jambu cultivars namely; 'Giant green', 'Masam manis pink' and 'Jambu madu red' were used in the study (Figure 1). Five trees per cultivar were used in the experiments for each season. Sixty uniform branches (four branches per tree) of about the same length, and diameter, and approximately the same number of leaves from fifteen trees were selected for the experiments. The experiments consist of 3 treatments (cultivar), with twenty replications and a single uniform branch was taken as an experimental unit. The selected uniform branches were tagged properly at the beginning of flower opening until fruit maturation. The experiments were arranged in a complete randomized design.

Measurement of physiological parameters

Leaves of selected uniformed branches were used for chlorophyll fluorescence and quantum yield measurement at 1.00 pm fully sunshine condition at fruit developmental stage. Chlorophyll fluorescence was measured by Plant Efficiency Analyzer (Hansatech Instrument Ltd., England). A single leaf was attached to the leaf clip and kept in the dark for 30 min to maintain dark adaptation. The fluorescence signal was measured for 3 s and the fluorescence yield observed where, Fo = lower fluorescence, Fm = higher fluorescence, Fv = relative variable fluorescence (Fm-Fo) and Fv/Fm =photosynthetic yield or quantum yield. Temperature = 28°C. Time range = 10 µs to 3 s.

Measurement of biochemical parameters

Fruits of different cultivars were randomly harvested from the selected outside branches at fully ripening stage during the first and second seasons from the experimental trees at the orchard. Fruits maturation was closely monitored and was determined in the field using the standard color chart of USDA (1991) depending on external color of wax jambu fruits. Harvesting was carried out early in the morning and manually with care to minimize mechanical injury. Fully ripened fruits were kept in a deep freeze at 4ºC and 80 to 90% RH for biochemical analysis. Eighty fruits were taken randomly from each cultivar.

Average fruit weight, seed weight and number of seed were determined by weighing and counting the number of seed per fruits. Total yield were determined by counting the total number of fruits per tree. Fruit dry biomass of pulp was determined by weighing pulp mass at 0% moisture. Fruit juice was extracted in a beaker to get average juice volume (ml)/ fruit.

Total soluble solids (TSS) was evaluated at 25°C with an Atago 8469 hand refractometer (Atago Co. LTD., Tokyo, Japan) and expressed as °Brix. Similarly glucose, fructose, inverted sugar and ethanol were evaluated at 25°C with Atago 8469 hand refractometer for glucose, fructose, inverted sugar and ethanol (Atago Co. LTD., Tokyo, Japan) and expressed as percentage. The pH was measured using a microprocessor pH meter (Hanna Instrument). The total phenolic content of wax jambu fruits were determined by using the Folin-Ciocalteu assay of Singleton and

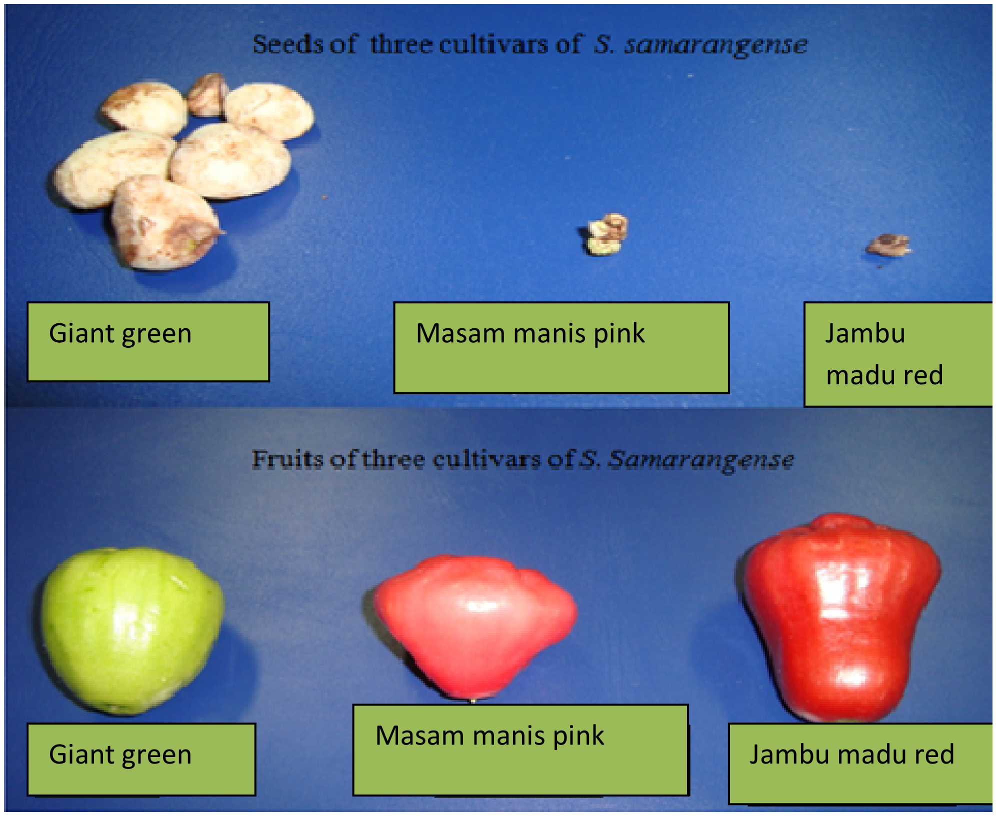

Figure 1. Photographs showing fruits and seeds of three cultivars of *S.samarangense*.

Table1. Chlorophyll fluorescence and quantum yield of cultivars of *S. samarangense* grown in Malaysian condition.

Cultivar	F0	Fm	Fv	Fv/Fm
‘Giant green	911±32b (ns)	4002±234a*	3090±56a*	0.77±0.02a (ns)
Masam manis pink	1013±61a (ns)	3840±123a*	2827±153b*	0.74±0.04a (ns)
‘Jambu madu red	849±28b (ns)	3486±260a*	2636±280b*	0.75±0.02a (ns)

Means (±S.E) within the same column followed by the same letter, do not differ significantly according to LSD test at ά=0.01 ns, non-significant * Significant at 0.05 levels, ** Significant at 0.01 levels.

Rossi (1965). The total flavonoid content was measured by the aluminum chloride colorimetric assay using catechin as standard (Zhishen et al., 1999). Total anthocyanin contents of the hydrophilic extracts were measured by the pH-differential method using cyanidin-3-glucoside as standard as described by Rodriguez-Saona et al. (1999).

Statistical analysis

The experimental design was a completely randomized design (CRD) with twenty replicates. Uniform branches of about the same length, and diameter and approximately the same number of leaves were selected for the experiments units. The data from the two seasons were pooled 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).

RESULTS AND DISCUSSION

Chlorophyll fluorescence and quantum yield

Chlorophyll fluorescence has become one of the most powerful and widely used techniques available to plant physiologist and ecophysiologist. Chlorophyll fluorescence gives information about the state of photosystem II (PSII) in the chloroplasts thylakoid membranes. Measurements of chlorophyll fluorescence are linearly correlated with the functionality of PSII, where Fo and Fm are the chlorophyll fluorescence yields corresponding to open and closed PSII reaction centres, respectively (Ilias et al., 2007). Chlorophyll fluorescence was different in cultivars of *S. samarangense* (Table 1).

Our results showed that the cultivar of wax jambu

Table 2. Physiological characteristics of cultivars of *Syzygium samarangense* grown in Malaysian condition.

Cultivar	Yield (NO. of fruits/tree)	Average fruit weight (g)	No. of seed /fruit	Seed weight/fruit (g)	Weight of DM (g)
'Giant green	650±55b**	89±4a (ns)	6±2a (ns)	4.41±0.01a**	07.56±0.94*
Masam manis pink	950±70a**	78±3a (ns)	2±1b (ns)	0.02±0.00b**	10.84±1.67*
'Jambu madu red	890±65a**	85±3a (ns)	2±1b (ns)	0.04±0.00b**	10.37±0.51*

Means (±S.E) within the same column followed by the same letter, do not differ significantly according to LSD test at ά=0.01 ns, non-significant * Significant at 0.05 levels, ** Significant at 0.01 levels.

played a significant role in chlorophyll fluorescence. Chlorophyll fluorescence intensity had a fluctuating trend in all cultivars. The highest maximum fluorescence (Fm) was observed in 'Giant green' cultivar followed by 'Masam manis pink' with a value of 4002 and 3840, whereas leaves of 'Jambu madu red' cultivar produced the lowest (3486) Fm value. Lower fluorescence (Fo) was not significantly different among the cultivars (Table 1).

Similarly, relative variable fluorescence (Fv) was highest in 'Giant green' cultivar followed by 'Jambu madu red' whereas, 'Masam manis pink' performed least relative variable fluorescence (Table1). From the results shown in Table 1, it can be seen that optimum quantum yield (Fv/Fm) was not statistically significant among the cultivars of *S. samarangense* (Table 1). Chlorophyll fluorescence represents the plant tissue condition status, the photosynthetic efficiency in leaves and screening of plants for tolerance to environmental stresses. Biber et al. (2004) reported that if photosynthetic yield or quantum yield ranged from 0.65 to 0.78 then the plant is healthy but when the Fv/Fm value below o.5 then the plant under severe stress or dying.

Yield (number of fruits) and average fruit weight (g)

Results showed that 'Masam manis pink' and 'Jambu madu red' cultivar produced the highest number of fruits than the 'Giant green' cultivar (Table 2). The total yield (950 fruits/tree) was highest in the 'Masam manis pink' cultivar followed by 'Jambu madu red' cultivar with a fruit number of 890 per tree, whereas minimum yield (650 fruit/ tree) was recorded in 'Giant green' cultivar (Table 2). It was found to be statistically significant (P>0.01) among the different cultivars. Our results were found to be in agreement with that of Shu et al. (1998) who observed that trees of *S. samarangense* yielded more or less 700 fruits and fruit weight varies with the cultivars. Chiu (2003) reported that wax apple (pink) is a heavy producer on well fertilized good soils and can produce more than 200 clusters per trees, with 4 to 5 fruits in a cluster when mature. They also reported that average fruit weight of 'Masam manis Pink' variety is about 100 g. As shown in Table 2, cultivars of wax jambu did not show significant differences (P>0.05) in average fruit weight.

Seed number and seed weight per fruit

Fruits of 'Giant green' cultivar produced highest number of seed/ fruit amounting to about 6 seeds per fruit (Figure 1). This was followed by the remaining two with a seed number of 2. 'Giant green' cultivar produced significantly (P>0.01) difference from 'Masam manis pink' and 'Jambu madu red' (Table 2).This results are supported by the observations of Shu et al. (1998), who reported that seed number per fruit in 'Giant green' cultivar was significantly higher than the 'Masam manis pink' and 'Jambu madu red' cultivar. The total seed weight per fruit was almost 150 times higher in the 'Giant green' cultivars compared to the 'Jambu madu red' and 'Masam manis pink'. The highest (4.41 g) seed weight was recorded in 'Giant green' cultivar followed by 'Jambu madu red' and 'Masam manis pink' with a weight of 0.04 and 0.02 g respectively (Table 2). It was found to be statistically significant (P>0.01) between 'Giant green' and 'Jambu madu red' the different cultivars. Another study suggested that green cultivar contain highest seed number and seed weight compare to others (Shu et al., 1998). 'Giant green' cultivar had a large number of seeds and maybe most of the photosynthates goes to the seeds.

Dry matter content in fruits

Shu et al. (2007) reported that fruit mass ranges from 7 to 25 g to the jumbu size of 100 g per fruit. From the results, it can be revealed that fruits dry matter significantly differ between cultivars of *S. samarangense.* 'Masam manis pink' cultivar posted the highest amount of fruits dry matter (10.84 g) followed by 'Jambu madu red' cultivar with a value of 10.33 g, whilst, 'Giant green'

Table3. Biochemical characteristics of different cultivars of *Syzygium samarangense* grown in Malaysian condition.

Cultivar	Juice/ 100g (ml)	pH	TSS(%Brix)	Glucose (%)	Fructose (%)	Inverted sugar (%)	Ethanol (%)
'Giant green	44.00±3.46b*	3.24±0.02a*	8.36±0.23a (ns)	8.90±0.38b*	8.9±0.08b*	8.7±0.24b*	18.83±0.33a (ns)
Masam manis pink	68.33±8.19a*	2.89±0.04b*	8.43±1.18a (ns)	9.83±1.29a*	9.9±1.36a*	9.6±1.43a*	20.50±4.72a (ns)
'Jambu madu red	76.33±8.25a*	3.65±0.06a*	8.76±0.17a (ns)	9.61±0.43a*	9.6±0.28a*	9.3±0.31a*	19.33±0.86a(ns)

Means (±S.E) within the same column followed by the same letter, do not differ significantly according to LSD test at ά=0.01 ns, non-significant * Significant at 0.05 levels, ** Significant at 0.01 levels.

cultivar produced the lowest amount (7.56 g) of fruit dry matter (Table 2). Our results are in agreement with the results of Chiu (2003). They reported that the fruit weight (dry mass) was relatively high in pink and red cultivar.

Juice, pH, TSS, soluble sugars and ethanol percentage in fruits

Fruit juice content, which is related to fruit size, is an extremely important parameter in industrial processing of fruits. Fruit size in turn depends on genetic characteristics and cultural practices. The highest amount of juice 76.33 ml was observed in 'Jambu madu red' cultivar fruits followed by 'Masam manis pink' with a juice percentage of 68.67 ml, whereas the lowest percentage of juice (44 ml) was recorded in the 'Giant green' cultivar (Table 3).

This data were statistically significant in 'Jambu madu red' and 'Masam manis pink' than the 'Giant green' (Table 3). Cultivars of *S. samarangense* produced the significant different (P>0.05) in case of pH in fruit juice (Table 3). Results showed that highest pH (3.65) in fruit juice was in 'Jambu madu red' followed by 'Giant green' with a pH content of 3.34 and least pH (2.89) was recorded in 'Masam manis pink' cultivar. Total soluble solids (TSS) of fruit is one of the parameters that strongly affect consumer acceptability of a variety. TSS content of fruit was not statistically different among the cultivars of wax jambu (Table 3). Shu et al. (2007) observed a greater range of TSS in pink cultivar from 5.5% to 8.25 ºBrix. From our previous study of GA3 effects on growth, yield and quality of Jambu air madu fruits, it can be seen that soluble solids content in 'Jambu madu Red' wide- ranging from 5.63 to 12.5% Brix.

Subsequent to the above experiments we determined the sugar content of the wax jambu fruits. As is well known during and after photosynthesis, sugars namely glucose and fructose, are exported from the source leaves to other plant parts. Sugar concentrations in the fruit increase as fruit gets mature with fructose and glucose being the main components. Sucrose has only 0.6% of fructose and rest 0.4% is glucose (Shu et al., 1998). In this study as shown in Table 3, the three cultivars differed significantly in their sugar content. The highest glucose content of 9.83% was recorded in 'Masam manis pink' cultivar fruits followed by 'Jambu madu red' cultivar which recorded glucose content of 9.1%, whereas 'Giant green' cultivar showed the lowest sugar content of 8.9%. Similarly, fructose and inverted sugar was also high in 'Masam manis pink' cultivar followed by 'Jambu madu red' cultivar, whereas the least amount of fructose and inverted sugar found in 'Giant green' cultivar. These results are in an agreement with the results of Shu et al. (1998) who observed that soluble sugar content was high in 'Masam manis pink' cultivar followed by 'Jambu madu red' cultivar, whereas, 'Giant green' cultivar contained the least amount of soluble sugar. The differences in percentage of ethanol in fruit juice among the cultivars were not statistically significant (Table 3).

Total flavonoids content

Many fruits and vegetables are highly rich in flavonoid content. Flavonoids are in vacuoles and, thus water soluble, and the major determinants of flower and fruit color in many plants (Raven et al., 1992). Flavonoids impart color and taste to flowers and fruits, and it is estimated that humans consume between a few hundred milligrams and one gram of flavonoid everyday (Pieta, 2000). Results showed that flavonoids content were significantly different between the 'Giant green' and other cultivars but no significant differences were shown between the 'Masam manis pink' and 'Jambu madu red' cultivars (Figure 2). 'Masam manis pink' cultivar fruits had the highest (14.1 mg/100g) flavonoids content followed by the 'Jambu madu red' cultivar which recorded values of 13.23 mg/100g, while the fruits of 'Giant green' cultivar produced the

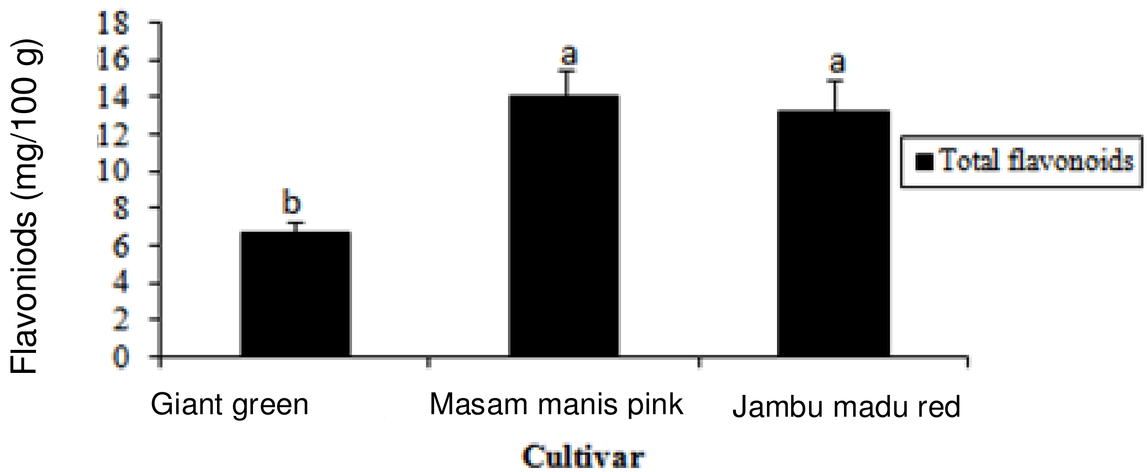

Figure 2. Total flavonouds content in cultivars of *s.samarangense.*Bars indicates ± S.E.

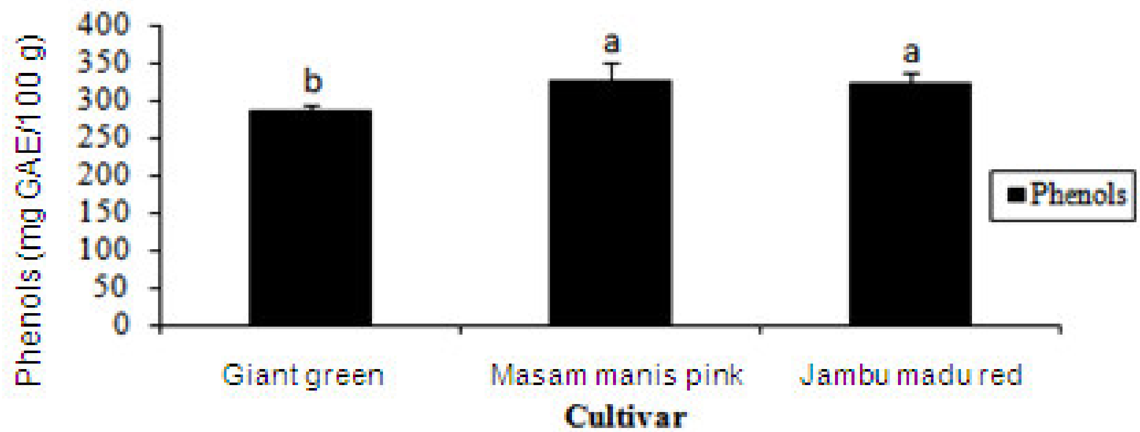

Figure 3. Total phenols content in cultivars of *s.samarangense.*Bars indicates ± S.E.

lowest (6.73 mg/100g) flavonoid content (Figure 2).

Total phenolics content

Fruits are rich source of phytochemicals such as phenolic compounds. Phenolic compounds are important because of their antioxidant properties. The antioxidant properties of phenolics is mainly due to their redox properties, which allow them to act as reducing agents, hydrogen donors, singlet oxygen quenchers and metal chelators (Rice-Evans et al.,1997). 'Masam manis pink' and 'Jambu madu red' cultivar produced significantly higher phenols than the 'Giant green' but they did not significantly differ themselves (Figure 3). 'Masam manis pink' cultivar branches produced phenols amounting to 327 mg GAE/100g and 'Jambu madu red' cultivar had a phenols content of 321 mg GAE/100g. 'Giant green' cultivar fruits showed the least amount of 285 mg GAE/100g phenols content (Figure 3).

Total anthocyanin content

Color is probably the most important factor that attracts consumers for wax apple (Shu et al., 2001). Xue (2005) reported that reverse-HPLC analysis revealed that there are four anthocyanins species, mainly cyanidin and peonidin, in the skin of wax apple fruits. During fruit development chlorophyll content start to decrease and anthocyanin increase gradually with the ripening. Fruit color of wax apple range from green to yellow green to pink to red and fully deep red. Anthocyanin pigments are responsible for the red, purple, and blue colors of many fruits, vegetables, cereal grains, and flowers and as a result, research on anthocyanin pigments has intensified recently because of their possible health benefits as dietary antioxidants (Ronald, 2001). Our results shown in Figure 4, show that anthocyanin content in fruit differs between cultivars. The highest amount (2.75 mg/L) of anthocyanin was observed in 'Jambu madu Red' cultivar fruits followed by 'Masam manis pink' cultivar with a

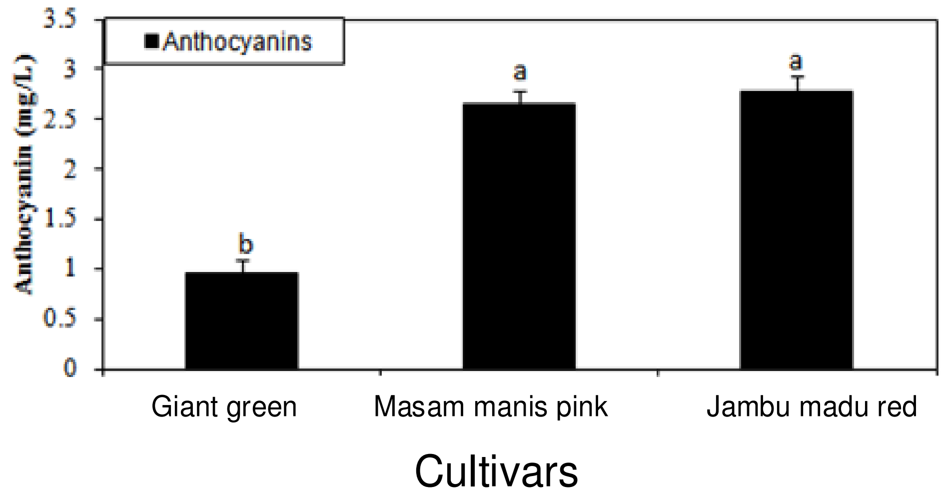

Figure 4. Total Anthocyanins content in cultivars of *s.samarangense.*Bars indicates ± S.E.

anthocyanins content of 2.67 mg/L, whereas, 'Giant green' cultivar fruits showed the least amount (0.95 mg/L) of anthocyanin content. These results concured with the findings of Shu et al. (2007). They reported that fruit color was influenced by many factors, such as light, temperature, position on the tree, growing season, leaf, fruit ratio and variety. 'Jambu madu Red' and 'Masam manis Pink' are nutritionally rich than 'Giant green'. Our results suggested that 'Masam manis pink' and 'Jambu madu red' cultivar is a very good source of flavonoids, phenols, anthocyanin and carotene; these compounds are known to have antioxidant properties and essential for health.

Conclusion

Based on physiological and biochemical analysis, 'Masam manis pink' and 'Jambu madu red' cultivars contain a larger amount of TSS, soluble sugars (glucose, fructose and inverted sugar), total flavonoids, phenols and anthocyanins content compared to the 'Giant green' cultivar. 'Masam manis pink' and 'Jambu madu red' cultivar also produced the largest yield (total number of fruits/ tree) and dry matter content in the fruits. However, 'Giant green' cultivar produced the highest chlorophyll fluorescence, quantum yield, seed number and weight. It can be concluded that 'Masam manis pink' and 'Jambu madu red' cultivars bear better nutritive value and can be recommended as the best wax jambu cultivars in Malaysia as well as South East Asian countries.

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