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*Full Length Research Paper*

# Photosynthetic yield, fruit ripening and quality characteristics of cultivars of *Syzygium samarangense*

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**This study was carried out to evaluate the photosynthetic yield, color development and quality characteristics of three cultivars of *Syzygium samarangense* at commercial farm of Banting, Selangor and functional food laboratories, University of Malaya, Kuala Lumpur. Various physiological and biochemical parameters were studied during two seasons of fruit growth from October, 2009 to August, 2010 with the 'Giant Green', 'Masam manis Pink' and 'Jambu madu Red' cultivars of *S. samarangense*. Results showed that the highest chlorophyll content, maximal and variable fluorescence (Fm and Fv) in mature leaves and photosynthetic yield (Fv/Fm) were found in 'Jambu madu Red' cultivar. Furthermore, this cultivar that had the medium time for fruit development also produced the highest amount of Juice content (ml/100 g). The highest, lower fluorescence (F0) in mature leaves, maximal fluorescence (Fm) and variable fluorescence (Fv) in new flush, the earliest peel color and the fruit maturity were observed in 'Masam manis pink' cultivar. The highest, lower fluorescence F0 in new flush and chlorophyll a, chlorophyll b and total chlorophyll were recorded in fruit of 'Giant Green' cultivar. Also, some other quality parameter like peel, pulp, biomass and juice color, aromatic flavor, texture and taste were taken into account to compare the quality in the cultivars of *S. samarangense*. This study also showed that the photosynthetic yield had a strong correlation with the fruit biomass among the three cultivars. In conclusion, Jambu madu Red' and 'Masam manis pink' 'cultivars are comparatively better than 'Giant Green' cultivar if cultivated under South Asian conditions.**

**Key words:** *Syzygium samarangense*, photosynthetic yield, ripening, quality, cultivars.

## INTRODUCTION

The wax jambu (*Syzygium samarangense)* is a non-climacteric tropical fruit, others names are wax apple, rose apple and java 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 smallholdings areas ranging from 1 to 5 ha with its hectarage estimated at about 2000 ha in 2005 (Shu et al., 2006). *Syzygium* is a genus of flowering plants that belongs to the family, Myrtaceae. The genus comprises about 1100 species (Little et al., 1989). High levels of diversity occur from Malaysia to northeastern Australia, where many species are very poorly known and many more have not been described taxonomically (Morton, 1987). Some of the edible species of *Syzygium spp* are planted throughout the tropics worldwide. In Malaysia, there are about three species which bear edible fruits, namely the water apple *(Syzygium aquem)*, Malay apple (*Syzygium malaccense*) and wax jambu (*S. samarangense*). The pink, red and green cultivars of wax jambu are popular in Malaysia and others South East

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**Abbreviations: F0,** Fluorescence; **Fm,** maximal fluorescence; **Fv,** variable fluorescence; **FDP,** fruit developmental period; **CRD,** completely randomized design; **LSD,** least significant difference.

Asian countries. The fruit is rounder and more oblong in shape, also having a drier flesh than the wax jambu. Wax jambu commonly flower early or late in the dry season; the flowers appear to be self-compatible and the fruit ripens 40 to 50 days after anthesis.

Fruit is a berry, pear shaped, broadly pyriform, crowned by the fleshy calyx with incurved lobes, 3.5-5.5 × 4.5-5.5 cm, light red to white; fruit flesh is white spongy, juicy, aromatic, sweet-sour in taste. Seeds 0 to 2, mostly suppressed globose up to 8 mm in diameter (Morton, 1987). The waxy fruit is pear shaped and the color of the fruit is usually pink, light-red, red, sometimes green or cream-colored (Morton, 1987). The size, shape and color of fruit are usually distinct characteristics for different cultivars in the same species (Galan, 1989). Only few cultivars of wax apple are available, which are exotic and perpetuated through vegetative methods of propagation (Morton, 1987). Measurement of the chlorophyll a fluorescence is a quick, precise and non-destructive technique, widely used in investigating damage/repair caused in the photosynthesis plant system by various types of stresses (Govindjee, 1995). The different cultivar produces fruits varying from pink to deep red, depending on environmental and cultural conditions. Fruit color is influenced by many factors, such as light, temperature, position on the tree, growing stage, and leaf: fruit ratio (Shu et al., 2001). It has been reported that different cultivars of wax jambu are different in their morphological and physiological characteristics depending on the genetic behavior, location and climatic conditions, yet this has to be documented. Currently very little information is available in the literature on photosynthetic yield, color development and quality characteristics of three cultivars of *S.samarangense*. Hence, this study is aimed to evaluate the photosynthetic character, color development and quality as well as the physiological and biochemical characteristics of the three cultivars of *S. samarangense*. It is also useful to assess the quality and the relationship between the photosynthetic yield and the fruit biomass of the three cultivars under South East Asian region.

## MATERIALS AND METHODS

The present study was carried out during the year of 2009 to 2010 to point out the photosynthetic characteristics, color development and quality compare of three cultivars of wax jambu (*S.samarangense*) namely 'Giant Green', 'Masam manis Pink' and 'Jambu madu Red' available at commercial farm of Banting, Selangor, Malaysia. Five trees of each cultivar (about 13 years old), were selected from a commercial farm in Banting, 2° 30 N, 112° 30 E and 1°28 N, 111° 20 E at an elevation of about 45 m from sea level. The area under study has a hot and humid tropical climate. The soil in orchard is peat with a mean pH of around 4.6 (Ismail et al., 1995). The experimental trees received similar horticultural management, and observations were recorded on the photosynthetic characteristics, fruit development and pigmentation characteristics of each cultivar as mentioned below. Chlorophyll content in leaves was determined using a Minolta SPAD meter. SPAD meter were calibrated before taking the readings. A single leaf was attached with the SPAD meter for chlorophyll readings. The SPAD value of the leaves was determined at the immediately after anthesis. Ten readings were taking per treatment. Chlorophyll fluorescence was measured by Hansatech Plant Efficiency Analyzer. It was represented by lower F0, Fm and Fv. Photosynthetic yield (Fv/Fm) also evaluated at 28°C and time rage was 10 $\mu s^{-3}$. Fruit development of each cultivar was monitored weekly. Flowers from each cultivar were tagged when available from 15 February to 17 May 2000. In total, 150 randomly chosen, open flowers were tagged (50 'Giant Green, 50 'Masam manis Pink', and 50 'Jambu madu Red'). The number of flowers tagged ranged between 1 and 10 for each cultivar on a particular date. On each tag, the date and flower position (1, 2, or 3°) was recorded. Then, as fruit approached horticultural maturity, they were observed every day and the dates on which they reached full maturity (that is, full color) were recorded.

This data was used to calculate fruit developmental period (FDP). Fruit were harvested after reaching full maturity. 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 as percentage of color cover. The chlorophyll content of both leaf and fruit was determined by methods described in Hendry and Price (1993). The peel, pulp, juice and biomass color was determined using a standard color chart (Minolta, Osaka, Japan). The $K^+$ content of the fruit juice was determined by using a Cardy Potassium meter. After extraction of fruit juice, 3 to 5 drops of fruit juice were placed on to the calibration sensor pad of Cardy Potassium Meter, Model-2400, USA. The reading in ppm was taken from the display pad after it stabilized of 20 s. Firmness was measured by deformation, under constant load of 400 g, with a penetrometer (Durapat et al., 1986). A sensorial analysis of taste and aromatic flavor was carried out at the laboratory among the ripen fruits of the three cultivars. We have employed a triangle test in which the tasters were asked to state whether one of the samples differs from the other two presented. The experimental design was Completely Randomized Design (CRD) comprised of three cultivars with ten independent observations. Only quantitative data were analyzed statistically using Fisher's analysis of variance techniques. One way ANOVA was applied to evaluate the significant difference in the parameters studied within the different cultivars. Least significant difference (Fisher's protected LSD) was calculated, following significant F-test ($p=0.05$).

## RESULTS AND DISCUSSION

### Leaf chlorophyll content

Plant structure and chlorophyll content strongly affect rates of photosynthesis (Eitel et al., 2009). The Chlorophyll a and b content of the new flush and mature leaves was determined using a Minolta SPAD meter. The results showed that the chlorophyll content in mature leaves were not statistically significant among the cultivars (Figure 1). In new leaves chlorophyll content (SPAD value) also did not varied significantly among the three cultivars of *S. samarangense.* The range of $Chl_{ab}$ values was comparable to those shown in other studies that examined the $Chl_{ab}$ of broadleaf specie (Richardson et al., 2002).

### Potassium content in leaf

Potassium (K) increases the photosynthetic rates of crop

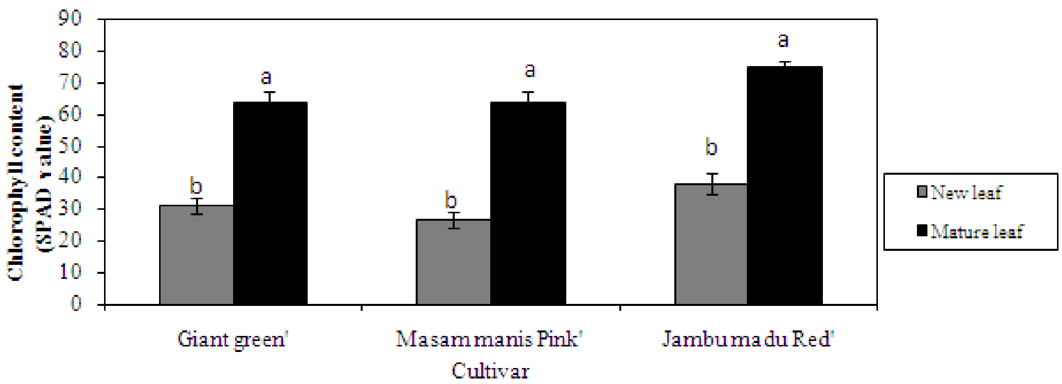


**Figure 1.** Chlorophyll content in new and mature leaves of three cultivars of *S. samarangense.*

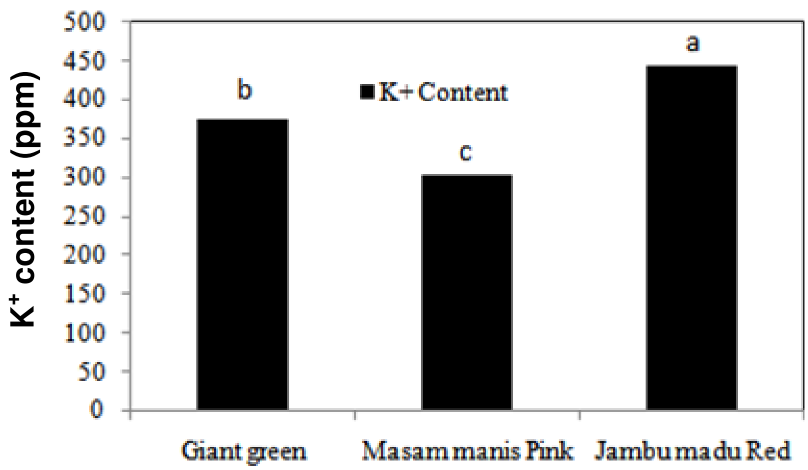


**Figure 2.** Potassium content in new flush of different cultivars of *Syzygium samarangense.*

leaves, $CO_2$ assimilation rate and facilitating carbon movement (Sangakkara et al., 2000). The high concentration of $K^+$ is thought to be essential for normal protein synthesis. The physiological role of K during the fruit formation, fruit setting and maturation periods is mainly expressed in carbohydrate metabolism and translocation of metabolites from leaves and other vegetative organs to developing bolls. Pettigrew (1999) stated that the elevated carbohydrate concentrations remaining in source tissue, such as leaves, appear to be part of the overall effect of K deficiency in reducing the amount of photosynthate available for reproductive sinks and thereby producing changes in yield and quality seen in cotton. Notable improvements in fruit yield and quality resulting from K input were reported by Gormus (2002), Aneela et al. (2003), Pervez et al. (2004) and Pettigrew et al. (2005). These may be reflected in distinct changes in seed weight and quality. Cultivars of *S. samarangense* produced significant differences in the case of $K^+$ content in leaves (Figure 2). Results showed that the highest $K^+$ content of leaves (495 ppm) was recorded in 'Jambu madu Red' cultivar followed by 'Giant Green' and 'Masam manis Pink' cultivars with a potassium content of 477 and 463 ppm. The potassium content in the leaves of Wax jambu cultivars might be genetically regulated. Level of potassium was considered higher, when most plants on potassium levels were in the range of 100 to +400 ppm. In agriculture, some cultivars are more efficient at K uptake due to genetic variations, and often these plants have increased disease resistance (Datnoff, 2007). Potassium has also been implicated to have a role in the thickening of cell walls (Datnoff, 2007).

## Chlorophyll fluorescence of new and mature leaf

The 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 photo system II. Chlorophyll fluorescence varied at different cultivar and age of leaves (Table 1). The chlorophyll

**Table 1.** Chlorophyll fluorescence of new (NL) and mature leaves (ML) and total chlorophyll of three cultivars of *S. samarangense.*

| Cultivars | F0 | | NL | | Fv | | Chlorophyll (Fruit) |
|---|---|---|---|---|---|---|---|
| | NL | ML | NL | ML | NL | ML | |
| 'Giant green' | 1112±67 | 865±36 | 3937±74 | 3446±178 | 2817±59 | 2882±198 | 3.43±0.18[a] |
| 'Masam manis Pink' | 958±25 | 922±23 | 4068±81 | 3664±229 | 3150±67 | 2754±216 | 0.31±0.09[c] |
| 'Jambu madu Red' | 880±35 | 866±17 | 3823±130 | 3890±198 | 2945±123 | 3025±195 | 1.33±0.09[b] |
| | ns | ns | ns | ns | ns | 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 FO: lower fluorescence, Fm: maximum fluorescence, Fv: variable fluorescence.

fluorescence intensity was found fluctuated in all cultivars. The highest (3890) Fm in mature leaves was recorded in 'Jambu madu Red' followed by 'Masam manis Pink' with a value of 3664, whilst, 'Giant Green' Cultivar produced the lowest (3446) Fm value. The highest (922) lower fluorescence was recorded in 'Masam manis Pink' cultivar followed by 'Jambu madu Red' and 'Giant Green' cultivar with a value of 866 and 865. Fv was highest in 'Jambu madu Red' cultivar followed by 'Giant Green' and 'Masam manis Pink' cultivars (Table 1). In case of new flush, 'Masam manis pink' cultivar had the highest Fm and Fv compare to the 'Jambu madu red' and 'Giant Green' cultivars. New flush of 'Giant Green' cultivar produced the maximum lower F0 than 'Masam manis Pink' and 'Jambu madu Red' cultivars (Table 1), although their differences were not statistically significant. Difference in chlorophyll fluorescence was attributed to difference in stomata density. In a comparative investigation of ginkgo trees across a climatic gradient in China, it was found that ginkgo sun leaves possess a higher stomata density than shade leaves (Sun et al., 2003). Also in beech, a tree that exhibits the strongest high irradiance adaptation response of its leaves and chloroplasts, the stomata density of sun leaves amounts to ca. 210 stomata mm−2 leaf area as compared to only 144 in shade leaves (Lichtenthaler et al., 2004). A higher stomata conductance, together with a higher stomata density, seems to be a typical characteristic of sun leaves and one prerequisite for their higher PN rates (Boardman, 1977; Lichtenthaler et al., 2004)

## Photosynthetic or quantum yield

Cultivars of *S. samarangense* had a significant effect on photosynthetic yield or optimum quantum yield. 'Jambu madu Red' and 'Masam manis Pink' cultivar yielded significant difference from 'Giant Green' cultivar on photosynthetic yield in new flash. Results showed that highest (0.78) photosynthetic yield (Fv/Fm) in new flush was in 'Masam manis Pink' cultivar followed by 'Jambu madu Red' cultivar with a value of (0.77), whereas, 'Giant Green' had the least (0.73) photosynthetic yield (Figure 3). Photosynthetic yield in mature leaves was also varied significantly among the cultivars. As it is shown in Figure 3b, the highest (0.80) photosynthetic yield is observed in 'Jambu madu Red' cultivar followed by 'Giant Green' cultivar with a value of (0.79), whereas, the least (0.72) photosynthetic yield was in 'Masam manis Pink' cultivar. The differences among the cultivar may be genetically makeup. Values of quantum yield of this work were similar with those reported by Gulmira et al. (2007).

## Total chlorophyll content

It is well documented in the literature that during ripening, the skin of fruits changes from green to a different brighter color. The most obvious change which take place is the degradation of chlorophyll and is accompanied by the synthesis of other pigments usually either anthocyanin or carotenods. In this study the chlorophyll in the peel of the fruits was measured at the fully ripening stage. It was observed that the chlorophyll loss gradually took place at color turning stage of the fruits. This results reported that 'Giant Green' cultivar showed a significant difference from 'Jambu madu Red' and 'Masam manis Pink' cultivars. The highest (3.43 mg/l) chlorophyll content in fruit peel was recorded in 'Giant Green' cultivar followed by 'Jambu madu Red' cultivar with a chlorophyll content of 1.33 mg/l, whilst the lowest chlorophyll content (0.31 mg/l) was recorded in 'Masam manis Pink' Cultivar (Table 1).

## Fruit ripening after anthesis

The fruit cultivars have a different number of days from bloom to maturity (Westwood, 1978). It was reported that the FDP for 'McIntosh' apple ranges from 125 to 145 days, while the FDP for 'Golden Delicious' apple ranges from 140 to 160 days. the variation of the fruit in FDP, also depends on the air temperatures. Westwood (1978) also reported that Pears, apples and peaches grown at relatively high temperatures during cell division (the

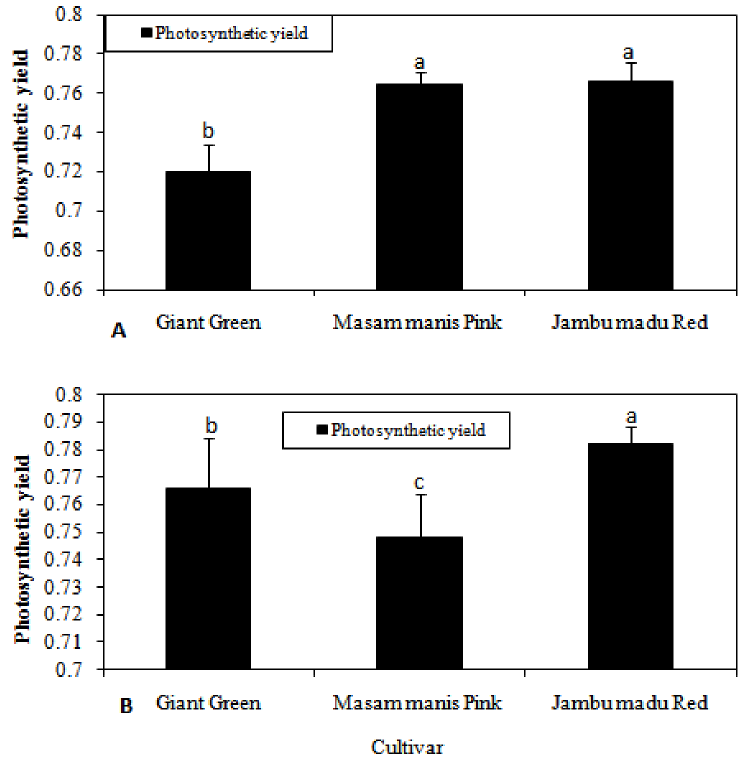


**Figure 3.** Photosynthetic yield: (A) new flush and (B) Mature leaves of three cultivars of *Syzygium samarangense.*

first 4 to 8 weeks after bloom, depending on species) mature in fewer days than those grown at lower post-bloom temperatures. The fruit developmental period after anthesis varied significantly with different cultivars of *S. samarangense*. Results showed that 'Masam manis pink' cultivar had the earliest fruit maturity approximately 38 days after anthesis followed by 'Jambu madu Red' cultivar with nearly 45 days (Figure 4). On the other hand, 'Giant Green' cultivar had late maturity. It takes longer period of about 50 days after anthesis. Our findings supported by the results of Morton (1987) who reported that the average period from anthesis to berry maturity is about 35 to 50 days in cultivars of wax jambu (Figure 4).

## Peel, pulp and Juice color

One of the most conspicuous characteristics to consumers of Wax jambu is the external color that is also considered as an important varietal character. Fruit peel, pulp and juice color are important not only for consumer acceptability but also in association with aroma, flavor and health benefits (Burger et al., 2006). Variability with respect to fruit peel, pulp and juice color also recorded. 'Giant Green' cultivar had light green to green peel color, 'Masam manis Pink' cultivar had pink to crimson and the 'Jambu madu Pink' cultivar had light red to dark red peel Table 2. Cultivars of *S. samarangense* produced different color of fruit pulp. Greenish white pulp color was observed in 'Giant Green' cultivar and 'Jambu madu Red' cultivars**,** whereas, pinkish white and reddish white pulp was recorded in 'Masam manis Pink' (Table 2). These variations are due to the genetic characters. The fruits peel and the juice color is a genetic character for each cultivar, species and variety. It was observed that 'Giant Green' cultivar had green color juice. Light pink and light red color juice were observed in 'Masam manis pink' and 'Jambu madu Red' cultivars. Our results confirmed by the findings of Kumar et al. (1998) who reported that the color of the fruits varies depending on the cultivars and it is also influenced by the growing conditions and the cultural practices.

## Volume of fruit juice and biomass color

Fruit juice is an important character in fruit processing industry. The juice quality characteristics vary with cultivar, fertilization, frequency of irrigation, date of harvest, age of tree, tree spacing, position of fruit tree, climactic condition and the places of growing. There were significant variations in juice content of different cultivars. The highest amount of juice (76.33 ml) was recorded in 'Jambu madu Red' cultivar, followed by 'Masam manis Pink' with a juice content of 68 ml, whereas, 'Giant color. The data observed for fruit pulp color are shown in


**Figure 4.** Photograph showing color development of different cultivars of *Syzygium samarangense.*

**Table 2.** Fruit characteristics of cultivars of *S. samarangense* during two seasons in 2009 and 2010. All the data represent in the table were pooled for two years.

| Name of cultivars | Peel color | Pulp color | Juice (ml)/100 | Juice content | Biomass flavor | Aromatic | Texture | Taste |
|---|---|---|---|---|---|---|---|---|
| 'Giant Green' | Green | Greenish white | Green | 44±3.5b | Green | High | Crispy | Less sweet |
| 'Masam manis Pink' | Pink | Pinkish white | Pink | 68±8.2a | Pink | Less | Spongy | Sweet-Sour |
| 'Jambu madu Red' | Red | Redishwhite | Red | 76±8.3a | Red | Less | Spongy | Sweet |
| | -- | -- | -- | ** | -- | -- | -- | -- |

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.

Green' cultivar produced the least (44 ml) amount of fruit juice. From Table 2, it is revealed that the fruit biomass color also depend on the cultivars. 'Giant Green' cultivar had green fresh biomass, whereas, 'Masam manis Pink' and 'Jambu madu Red' had the pink and red biomass.

## Firmness, aromatic flavor and taste

A great importance is given to study the textural properties and aroma composition the fruits for varietal characterization and quality assessment. 'Giant Green' cultivar had the highest aromatic flavor, whereas, 'Masam manis Pink' and 'Jambu madu Red' cultivars had the least aromatic flavor. In case of fruit texture, 'Giant Green' cultivar had crispy in nature, while, 'Masam manis pink' and 'Jambu madu Red' were soft and spongy (Table 2), Cultivar has an important role in determining the taste, quality, yield and nutrient composition of fruits. Fruit taste is mainly determined by the concentration and the type of soluble solids and organic acids (Dirlewanger et al., 1999). From our evaluation, 'Jambu madu Red' cultivar had a relatively sweet taste and 'Masam manis Pink' cultivar had sweet-sour taste. On the other hand, 'Giant Green' cultivar had sweet taste but it bears also a nice aromatic flavor and a crispy fruit flesh. These results are supported with the findings of Byrne (2002), who reported that fruit taste varies with the cultivars.

## Correlation between photosynthetic yield and biomass

Accumulation of dry matter content in plants depends on photosynthetic yield or optimum quantum yield. Results showed that photosynthetic yield had a strong correlation

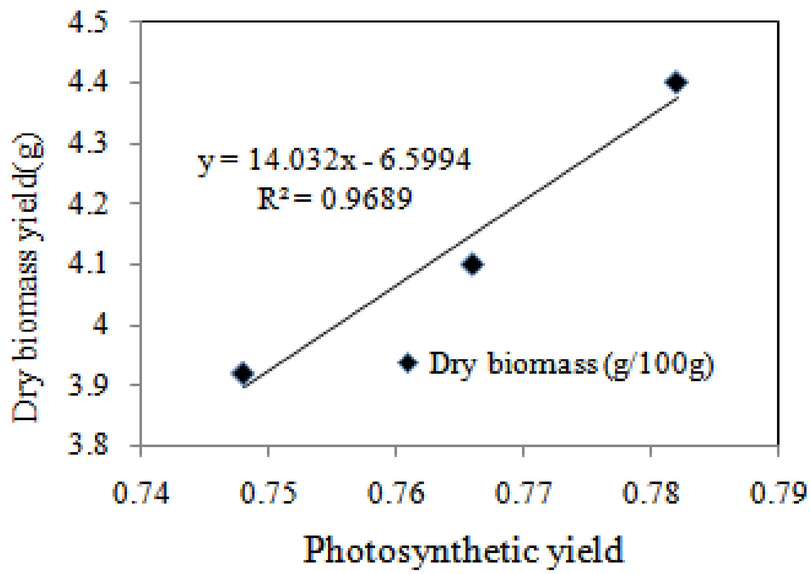


**Figure 5.** Correlation between photosynthetic yield and dry biomass of three cultivars of Syzygium samarangense.

($R^2$=0.96) with the fruit biomass among the cultivars of wax jambu. Highest photosynthetic yield and fruit biomass observed in 'Jambu madu Red' cultivar followed by 'Giant Green' cultivar, whilst 'Masam manis Pink' cultivar had the least photosynthetic yields and dry fruit biomass (Figure 5). The observations recorded in the present investigation suggested that the different cultivars varied markedly with respect to photosynthetic yield, fruit ripening and quality characteristics. These varieties appeared to be due to their genetic differences. From our observation, it can be summarized that 'Jambu madu Red' and 'Masam manis Pink' cultivars are comparatively better than green cultivar. Finally, it can be recommended that 'Jambu madu Red' cultivar is the best cultivars for cultivation of South Asian regions for better market value, yield and quality.

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