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Evaluation of yield and fruit quality traits of eight selected starfruit clones

(Penilaian hasil dan ciri kualiti buah untuk lapan klon belimbing terpilih)

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Key words: starfruit, *Averrhoa carambola* L., yield, fruit quality

Abstract

Eight selected Department of Agriculture-registered clones namely; B1, B2, B4, B6, B9, B11, B13 and B16 were evaluated and compared to B10 and B17 as check clones. The plants were planted in six single-tree plots in randomised complete block design. The evaluation was done on the plants at the age of five years after planting in Kluang, Johor. Yield traits were assessed based on fruit number and total weight of fruits harvested, while fruit quality was assessed based on fruit weight, fruit length, fruit width, total soluble solid (TSS) content and seed number per fruit.

Analysis of variance showed that the clones were highly significant for all the parameters evaluated. B10 produced the highest yield (36.14 t/ha) while B17 produced the highest TSS (12.9 °Brix). The results further showed that B6 had the same mean fruit weight but less sweet than B17, but smaller in fruit weight with the same TSS as compared to B10. Among the eight clones evaluated, B6 emerged as another additional choice for grower in terms of yield and fruit quality.

Introduction

Starfruit (*Averrhoa carambola* L.), an evergreen tropical fruit tree, has attained a commercial status in Malaysia. The crop has been cultivated since 1937 (Anon. 1995) and planting of commercial orchards began in 1983 (Anon. 2002). Since then, many superior clones have been registered and propagated. The planted hectarage in orchards increased sharply from 80 ha in 1980 to 1,934 ha in 1993. Although demand for export is good, the high labour requirement has forced many growers to abandon the farm. The cultivated area has decreased to approximately 600 ha in 2002 (Anon. 2002).

However, due to good demand of starfruit for export to European and Middle East markets lately, there has been positive response by growers to increase the production areas and further improve the productivity of existing clones, thus increasing plantings throughout Malaysia. For example, starfruit planting has extended to Johor under the opening of new area for food production scheme (Anon. 2002).

To date, the Department of Agriculture (DOA) has registered 19 starfruit clones (Anon. 1995). In addition, MARDI has characterised and evaluated 90 accessions in its starfruit improvement programme. Two clones, namely B10 and B17, were selected

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by growers because of their performance, and since then became the recommended clones for cultivation. Grower's choice of clones had largely been based on high yields, and also on superior performance in specific growing areas in many states such as Selangor, Negeri Sembilan and Pahang.

Starfruit productivity is determined by many factors, including physical and physiological factors such as the age of the planting, and the development stages in the economic crop life of 25 years (Galan Sauco 1993). It has been reported that the maximum total number of fruits harvested may occur in the 10–15 years of its crop life (Galan Sauco 1993). These factors are important in determining the yield, as well as the fruit quality (Clipson 1994). The yield performance of the present starfruit clones is largely dependent on fruit number and weight.

The characteristics that affect the fruit quality are primarily size and colour (Parker et al. 1991; Bruhn 1995; Kupferman 2002). Bright and clear fruit colours are also preferred (Francis 1995). Since starfruit is climacteric in nature, the fruit colour will not change significantly but fruit at stage 3 will turn yellow upon storage. Therefore, it can be harvested at various harvest indices to cater for different export purposes.

Starfruit selection in early days (before 1980s) was based on fruit size, whereby consumer preferred bigger fruits. B10 and B17 clones have big fruit (more than 200 g) and this characteristic contributes to the higher yield. Fruit size has a large genetic component, thus selecting for larger fruits in any crop improvement programme is relatively straight-forward (Janick and Moore 1996). Fruit size is a function of cell number, cell volume, and cell density (Coombe 1976; Scorza et al. 1991).

The most important aspect of fruit quality is the taste. Consumer preference is for sweeter fruit, more intense flavour, and firmer fruit before consumption (Bruhn 1995; Stockwin 1996; Baldwin 2002; Kader 2002). However, this characteristic is very subjective and it depends a lot on the consumer's preferences. Locally, starfruit is mainly consumed fresh and little is processed into products, therefore, fruit sweetness and flavour play a major part in determining consumer's choice such as in B17. However, in Europe, consumer prefers fruit which are less sweet such as in B10.

Majority of temperate and tropical fruit have total soluble solid (TSS) content of 9– 20 °Brix (refractometry measure of soluble solids) when ripe (Callahan 2003). Brix is highly correlated with the amount of sugars in the fruit juice. The levels of sucrose, fructose, and glucose determine the fruit sweetness. However, the level of acidity also affects the perception of sweetness, for example, fruits with high sugar and moderate levels of acid will be perceived to be as sweet as fruit with moderate levels of sugar and low acid. The acid levels are primarily based on the concentration of malic or citric acids (Coombe 1976; Byrne et al. 1991; Parker 1993; Janick and Moore 1996; Baldwin 2002).

Abd Rahman and Mohamad (2003a, b) reported the trend of yield and fruit quality of these eight clones throughout five years after crop establishment. These clones were found to have achieved stability in terms of yield and fruit quality after five years. The objective of the study was to evaluate the yield and fruit quality of eight selected clones on the fifth year of field production. For comparison, these eight clones were evaluated against two commercial clones as control namely B10 and B17 grown for export and local market respectively.

Materials and methods

Eight selected DOA-registered clones of starfruit namely B1, B2, B4, B6, B9, B11, B13, B16 and two commercial clones namely B10 and B17 as check clones were established in a field trial at MARDI Station, Kluang, Johor in 1989. The trial was established as single tree plot using Randomised Complete Block Design

(RCBD) with six replicates. Planting of individual trees was done at 6 m x 6 m spacing. The standard agronomic practices as recommended by MARDI (Abd Rahman et al. 1992) were followed.

Yield assessment was based on number of fruits harvested and fruit weight from individual trees which were harvested in the fifth year involving 12 monthly harvests. Fruit samples from every harvest were taken for the analysis on fruit quality. From each harvest, ten fruits were randomly sampled, and their fruit quality traits namely fruit weight (g), fruit width (cm), fruit length (cm), total soluble solids content (°Brix) and number of seeds per fruit were measured and recorded. Analysis of variance and Duncan Multiple Range Test was used to distinguish the plant means (SAS Inst.1990).

Results and discussion

Analysis of variance showed that the eight clones were significantly different (p <0.01) for both yield and fruit quality traits *(Table 1)*. This indicates that the clones were significantly different from each other in terms of total fruit weight harvested per tree, total number of fruits harvested per tree, fruit weight, fruit width, fruit length, total soluble solids content and number of seeds.

Means of yield and quality traits of the clones are shown in *Table 2*. Coefficient of variation (CV) analysis showed that yield and many fruit quality traits had high variability, with CV values ranging from 9.7 for fruit width to 71.8% for total fruit weight harvested per tree. The CV value for yield ranged from 61.7% to 71.8% while the quality traits ranged from 9.7% to 44.9%. Thus, these statistics indicated that yield trait was highly variable as compared to other fruit quality traits.

Yield traits

Total fruit weight harvested per tree The mean of total fruit harvested was 57.3 and the range of harvested yield for individual trees was 3.5–154.3 *(Table 2)*. All eight clones except for B6 were significantly different (p <0.05) from the two commercial clones and their total fruit weight harvested were lower *(Table 3)*. The lowest total harvested yield was recorded for B1 (10.2 kg/tree/year) while the highest was achieved by B10 (130.0 kg/tree/year). The highest total fruit weight harvested among the eight clones was achieved by B6 (87.9 kg/tree/year); however, this was not significantly different from that of B17 (100.4 kg/tree/year), but was significantly lower than B10 (130.0 kg/tree/year).

These data from this study appear to be less than the average estimated total fruit weight harvested for the fifth year, which was estimated at 178.1 kg/tree/year for B10 (Raziah 1992). It was also estimated by Abd Rahman and Mohamad (2003b) that the average total fruit weight increased from 59.7 in the second year to 238.8 kg/tree/year in the ninth year and onwards. Thus, B6 achieved comparably lower yields, estimated

Table 1. Mean squares from ANOVA for yield and quality traits of 10 clones comprising 8 selected clones and 2 commercial clones

Source	Df	Yield traits		Quality traits				
		Total fruit weight harvested per tree	Number of fruits per tree	Fruit weight	Fruit length	Fruit width	TSS	Number of seeds per fruit
Clone	9	9691**	135064**	26077**	14.73**	3.04**	11.73**	176.92**
Error	90	251	4298	689	0.42	0.27	0.39	10.11
Total	99							

**Significantly different at p <0.01

Table 2. Mean, standard deviation, coefficient of variation (CV) and range of yield and fruit quality traits of 10 clones comprising 8 selected clones and 2 commercial clones

	Mean	Standard deviation	Coefficient of variation	Range
Yield traits				
Total fruit weight harvested per tree (kg)	57.3	41.1	71.8	3.5–154.3
Number of fruits per tree	252	156	61.7	14–617
Fruit quality traits				
Fruit weight (g)	221.5	54.7	24.7	90.0–310.0
Fruit length (cm)	13.3	1.3	9.9	9.7–15.2
Fruit width (cm)	7.4	0.7	9.7	6.2–9.2
TSS (°Brix)	10.1	1.2	11.8	8.0–13.8
Number of seeds per fruit	11	5	44.9	3–23

Table 3. Mean of yield and quality traits of 10 clones comprising 8 selected clones and 2 commercial clones

	Yield traits		Fruit quality traits				
	Total fruit weight harvested (kg/tree/year)	Number of fruits per tree	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	TSS (° Brix)	Number of seeds per fruit
B1	10.2e	36.7e	276.0a	14.0ab	7.6bcd	10.4b	10.1cde
B2	21.7e	109.0e	199.0e	13.1c	7.2de	10.2bc	11.5cd
B4	57.1d	260.7cd	218.5de	13.0c	7.2de	10.3b	7.7ef
B6	87.9bc	401.5b	219.0de	14.4a	7.1de	10.0bc	19.1a
B9	71.6cd	285.2c	251.0bc	14.0ab	8.1ab	9.3d	7.5ef
B11	53.6d	255.2cd	210.0de	13.5bc	6.9ef	9.9bcd	15.2b
B13	18.5e	193.2d	95.5f	10.1d	6.5f	9.7cd	5.4f
B16	21.9e	96.7e	227.0cd	13.2c	7.8abc	8.8e	8.8de
B10 (check)	130.0a	519.8a	250.0bc	13.3c	8.3a	9.7cd	15.0b
B17 (check)	100.4b	365.7b	269.0ab	14.0ab	7.5cd	12.9a	11.9c

Mean values with the same letter are not significantly different at $p < 0.05$

about 67.6% of that of B10, and about 87.5% of that of B17. However, in more recent estimates by MARDI (2005) indicated that the average total fruit weight for B10 increased from 46.8 kg in the third year to 143.9 kg/tree/year in the seventh year and onwards. Comparing the average total fruit weight of 107.9 kg/tree/year in the fifth year, B6 achieved 81.5% yield performance.

Number of fruits per tree The mean number of fruits per tree was 252, and the range was from 14–617 *(Table 2)*. All eight clones except for B6 were significantly different ($p < 0.05$) from the two commercial clones and their numbers of fruits per tree were lower *(Table 3)*. The lowest number of fruits per tree was recorded for B1 (36.7) while the highest was achieved by B10 (519.8). The highest number of fruits per tree among the eight clones was achieved by B6 (401.5); however, this was not significantly different from that of B17 (365.7), but was significantly lower than B10 (519.8).

These data appear to be less that the average number of fruits per tree for the fifth year, which was estimated at 593.5

fruits/tree/year for B10 (Raziah 1992). It was also estimated that number of fruits per tree increased from 199.1 in the second year to 796.2 in the ninth year and onwards. Thus, B6 produced quite comparable number of fruits per tree, about 77.2% of that of B10, and about 109.8% of that of B17 (but not significantly different). However, more recent estimates by MARDI (2005) indicated that the number of fruits per tree for B10 increased from 347.1 in the third year to 696.3 in the seventh year.

Fruit quality traits

Abd Rahman and Mohamad (2003a) reported that the fruit quality traits such as fruit size, fruit length, fruit width and TSS content are generally improved over years of planting except for the number of seeds per fruit. Fruit size increased by approximately 40% from 157.6 to 221.6 g/fruit; fruit length increased by 14% from 11.5 to 13.1 cm; fruit width increased by 15.6% from 6.42 to 7.42 cm; and total soluble solids content increased by 20.5% from 8.4 to 10.1°Brix. The number of seeds per fruit initially decreased until the third year, but increased afterwards until the fifth year. However, the number of seeds per fruit decreased by approximately 15% from 13.3 to 11.3.

Fruit weight The mean fruit weight was 221.5 g with the range of 90–310 g *(Table 2)*. The eight clones were significantly different from the two commercial clones *(Table 3)*. The lowest fruit weight was recorded for B13 (95.5 g) while the highest was produced by B1 (276 g). The highest fruit weight among the eight selected clones was achieved by B1 (276 g); however this was not significantly different from that of B17 (269 g) but significantly higher than B10 (250 g). Market standards for fruit weight or grade are available for B10 for local and export markets and for B17 for local market only (Abd Rahman and Mohamad 2003b). By approximation, when compared to both B10 and B17, among all the eight clones selected, one clone was observed to be similar to B10 (B9) and one clone was similar to B17 (B1) in terms of fruit weight.

Fruit length The mean fruit length was 13.3 cm with the range of 9.7–15.2 cm. Some of the eight clones were significantly different from the two commercial clones. The minimum fruit length was recorded for clone B13 (10.1 cm) while the maximum fruit length was achieved by B6 (14.4 cm). However this was not significantly different from that of B17 (14.0 cm), but significantly longer than B10 (13.3 cm).

Fruit width The mean fruit width was 7.4 cm with the range of 6.2–9.2 cm. Some of the eight clones were significantly different from the two commercial B10 and B17. The minimum fruit width was recorded for clone B13 (6.5 cm) while the maximum fruit width was achieved by B10 (8.3 cm). The maximum fruit width among the eight selected clones was achieved by B9 (8.1 cm); however this was not significantly different from that of B10 (8.3 cm) and significantly higher than that of B17 (7.5 cm).

Total soluble solid content The total soluble solid data was measured at the stage 4 of harvest indices. The mean of TSS was 10.1 °Brix and the range of TSS for individual trees was 8.0–13.8 °Brix. The eight clones were significantly different from B17 and some not significantly different from B10. The lowest TSS was recorded for B16 (8.8 °Brix) while the highest was achieved by B17 (12.9 °Brix). The highest TSS among the eight selected clones was achieved by B1 (10.4 °Brix) and this was significantly different from that of B17 (12.9 °Brix) and B10 (9.7 °Brix). Starfruit is considered as fruit with low sweetness. Result showed that B17 produced highest TSS (12.9 °Brix) but has astringent taste. This clone is highly demanded in Malaysia and Middle East countries due to its sweetness.

Number of seeds per fruit The mean number of seeds was 11 and the range was 3–23. The eight clones were not significantly different from the two commercial clones. The lowest number of seeds was recorded for B13 (5.4) while the highest was from B6 (19.1). The highest number of seeds among the eight selected clones was from B6 (19.1) and this was significantly different from that of B17 (11.9) and B10 (15.0).

Conclusion

This trial showed that B6 can be considered as another additional clone besides B10 and B17 for growers to consider for planting starfruit. Its fruit quality traits generally improved with age except for the number of seeds per fruit which showed more stable character and not affected by environmental factors. This study also showed that B6 had the same yield and fruit weight, but less sweet as compared to B17, and smaller in size with similar degree of sweetness as compared to B10.

However since this assessment was carried out at the fifth year, the full potential of this eight clones may not be evidenced and may change over the economic crop life. The trial also indicated that most clones began to achieve stability in yield traits beginning in the fifth year.

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Abstrak

Lapan klon yang telah didaftarkan oleh Jabatan Pertanian iaitu, B1, B2, B4, B6, B9, B11, B13 dan B16 telah dinilai bersama klon komersial B10 dan B17. Sebanyak enam pokok ditanam dalam plot reka bentuk blok lengkap terawak. Penilaian telah dibuat pada pokok selepas lima tahun ditanam di Kluang, Johor. Ciri hasil dinilai berdasarkan bilangan dan berat buah yang dituai manakala kualiti buah dinilai berdasarkan berat buah, panjang buah, lebar buah, kandungan jumlah pepejal terlarut (TSS) dan bilangan biji.

Analisis varian menunjukkan bahawa klon-klon tersebut mempunyai perbezaan yang sangat bermakna untuk semua ciri yang dinilai. Klon B10 memberikan hasil yang tinggi (36.14 t/ha) dan B17 mempunyai TSS yang tertinggi (12.9 °Brix). Keputusan menunjukkan bahawa klon B6 mempunyai berat yang sama tetapi kurang manis berbanding dengan klon B17, dan B6 juga kurang berat serta mempunyai TSS yang sama berbanding dengan B10. Antara lapan klon yang dinilai, klon B6 berpotensi sebagai klon pilihan tambahan kepada penanam dari segi hasil dan kualiti buah.

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