Variability in fruit characteristics of Chokanan mango (Mangifera indica L.)

Abstract
This study was conducted with the aim to evaluate the characteristics of Chokanan mango at harvest. The Chokanan fruits were harvested from selected trees in commercial mango plot at Sintok MARDI Research Station, Kedah, Malaysia. Data on the fruit characteristics such as weight, length (L), width (W), thickness (T) and total soluble solid (TSS, °Brix) were measured and recorded for 13 weeks. The results revealed high significant differences (p <0.001) in terms of recorded weight, W, L, T, size (W x L x T) and TSS of the Chokanan fruits among the selected trees. The mean value of the fruits weight at harvest ranged from 120 to 380 g and TSS ranged from 14.5 ºBrix to 22.8 ºBrix. In the present study, the distribution of fruits weight was skewed to the left indicating larger percentage of smaller fruits, but normal distribution was recorded for the TSS. Apart from that, high significant correlation (R² >0.80) was found in the weight and size, L, W and T of the fruits. However, the weight and size of Chokanan were inversely correlated with TSS. The coefficient of variation (cv) differed among the harvested trees with the highest were recorded on weight and size of fruits (cv = 9.5 and 11.4, respectively). Finally, the possible causes of variability of Chokanan fruits were reported and discussed.

Keywords: fruit weight, size, total soluble solid, fruit distribution

Introduction
Mango (Mangifera indica L.) is one of the popular tropical fruits in the Northern Region of Malaysia, especially in Perak, Kedah and Perlis. In the year of 2014, an estimated of 5,283 ha area has been planted with mango trees in Malaysia (Anon. 2016). The highest mango planting area is in Perak with 1,274.8 ha. In Malaysia, most mango trees are widely grown as commercial mixed home gardens (Tengku Ab. Malik 2000c). Besides consumed fresh, local mangoes are also used for food processing, such as juice, fresh salad and dry snack. Chokanan is one of the mango cultivars that have been commercially planted in Malaysia. Originated from Thailand (Chintanawong et al. 2001), this type of mango cultivar has good external appearance with golden yellow skin when ripe and sweet taste with high TSS content (Zainal Abidin and Tengku Ab. Malik 1996b). Even though Chokanan mango is well accepted by the consumers in Malaysia, fruits produced at harvest were highly variable and it is believed that it may directly or indirectly
affect consumer preferences. Also, the characteristics of Chokanan fruits such as weight, size and sweetness at harvest were highly variable between trees and season. To the researchers’ knowledge, no study has looked into the variation on fruit characteristics or morphological traits of this type of mango. Only a few publications on the effect of preharvest and postharvest factors on local mango cultivars have been reported (e.g. Mohd Azhar et al. 2013; Pauziah Muda et al. 2014). It is noteworthy that the knowledge of correlations within the fruit traits is beneficial in order to improve breeding selection, which focuses on special traits such as the size and colour of the fruit. Apart from that, the assessment of variability that present in this fruit crop may be useful to improve the breeding programme, especially in developing suitable variety for better yield and quality. Also, this information is of utmost importance for the enhancement of cultural management of mango (Tengku Ab. Malik et al. 2000c; Léchaudel and Joas 2007). Given such a backdrop, the present study was undertaken to evaluate the variability of Chokanan mango fruit at harvest. Hence, the possible reason for the variability of Chokanan fruit characteristics were reported and discussed.

**Materials and methods**

**Study site and growing condition**

This study was carried out during fruiting season at Sintok MARDI Research Station, Bukit Kayu Hitam, Kedah, Malaysia. The five-year-old Chokanan trees were planted at 12 m x 12 m distance and managed under standard normal horticultural practices for mango in the Northern Region of Malaysia (Tengku Ab. Malik et al. 1996). Based on the standard nursery propagation method in Malaysia, the trees were cleft grafted onto seedling rootstock cv. Telur. As regards the present study, twenty fruits per tree were randomly harvested on the selected trees (eleven trees) at 13 weeks after fruit setting. The fruits were ripened by means of using standard practice, i.e. using calcium carbide induction method (Tengku Ab. Malik et al. 1996).

**Measurement of fruit characteristics**

Digital balancing was used to measure the fruit weight (g) at harvest (Satorius, ELT6000). The characteristics of fruits such as length-L (mm), width-W (mm) and thickness-T (mm) were measured using digital calliper (Mitutoyo, Digimatic Calliper Series 500). The size of fruits expressed by L x W x T was also calculated and total soluble solid (TSS) was measured by using handheld Refractometer (Atago Model DBX -55, Japan). A few drops of solid liquid from the sampled fruits were applied to the measuring surface of the prism and the results displayed on the screen panel were recorded in °Brix.

**Statistical analysis**

All the data were manually recorded in an Excel spreadsheet and summarised using Pivot Table Microsoft Excel. The ANOVA procedure of SAS (version 9.0, SAS Institute Inc., NC USA) was used to carry out the analysis and the mean separation were compared by using Duncan Multiple Range Test (DMRT) at p = 0.05. The correlation matrix between variables in this study was analysed using Pearson Correlation Coefficients in SAS to identify the interaction among the characteristics. The distributions of selected variables were analysed using Kolmogorov-Smirnov at the 95% significance level (9.0, SAS Institute Inc., NC USA). Data for the general characteristics, correlation and distribution analyses were conducted on pooled data from all trees.

**Results and discussion**

**The general characteristics of fruits**

The weight of fruits ranged from 120 – 380 g with an average fruit weight of 200.9 g. The length (L), width (W) and
thickness (T) of Chokanan fruits varied from 7.8 mm to 13.4 mm, 5.3 mm to 8.3 mm, and 4.4 mm to 6.6 mm, respectively. In addition, the size of Chokanan fruit expressed by L x W x T ranged from 215 mm$^3$ to 723 mm$^3$ (Table 1). The average of TSS was 18.8 °Brix and ranged from 14.5 °Brix to 22.8 °Brix. Figure 1 presents the distribution and descriptive statistics of fruit weight and TSS. The fruit size distributions (Figure 1a) of Chokanan cultivars (n = 220) into six different classes showed a skewed distribution curve to the left indicating larger percentage of smaller fruit (i.e. more than 30% is smaller than 250 g).

As demonstrated in Figure 1a, this result was confirmed by the statistical significance ($p < 0.01$) on the distribution analysis. In contrast, the distribution of TSS into nine different classes (Figure 1b) is closely approximated to the normal distribution ($p > 0.15$) with more than 50% TSS higher than 18% °Brix.

The researchers deemed that the correlation studies between the selected traits of the crop will be of the breeders’ interest in planning the hybridization programme and evaluating the individual plants in segregating populations. Based on the correlation matrix analysis (Table 2), high significant correlation ($p < 0.0001$) was discovered among the fruits characteristics of Chokanan mango. With regards to the present study, the size of Chokanan fruits was correlated well with fruit weight (Table 2). The highest correlation coefficient was recorded between fruit weight and size ($R^2 = 0.96$, Table 2), suggesting that the yield per tree of Chokanan mango can be predicted by simple measurement of L.

Table 1. The general characteristics of Chokanan mango fruits at harvest (n = 220)

<table>
<thead>
<tr>
<th>Fruit characteristics</th>
<th>Means</th>
<th>Ranged (min – max)</th>
<th>Standard deviation</th>
<th>Standard error (±)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit weight (g)</td>
<td>200.9</td>
<td>120 – 380</td>
<td>51.2</td>
<td>± 4.9</td>
</tr>
<tr>
<td>Fruit length - L (mm)</td>
<td>10.6</td>
<td>7.8 – 13.4</td>
<td>1.1</td>
<td>± 0.1</td>
</tr>
<tr>
<td>Fruit width - W (mm)</td>
<td>6.2</td>
<td>5.3 – 8.3</td>
<td>0.6</td>
<td>± 0.1</td>
</tr>
<tr>
<td>Fruit thickness - T (mm)</td>
<td>5.2</td>
<td>4.4 – 6.6</td>
<td>0.5</td>
<td>± 0.0</td>
</tr>
<tr>
<td>Fruit size (L x W x T) (mm$^3$)</td>
<td>349.0</td>
<td>215.0 – 722.7</td>
<td>100.1</td>
<td>± 9.5</td>
</tr>
<tr>
<td>TSS (°Brix)</td>
<td>18.8</td>
<td>14.5 – 22.8</td>
<td>1.9</td>
<td>± 0.2</td>
</tr>
</tbody>
</table>

Table 2. Correlation coefficients among different fruit characteristics in Chokanan mango

<table>
<thead>
<tr>
<th>Fruit characteristics</th>
<th>Fresh weight (g)</th>
<th>Fruit-L (mm)</th>
<th>Fruit-W (mm)</th>
<th>Fruit-T (mm)</th>
<th>TSS (°Brix)</th>
<th>Fruit size (L x W x T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit weight (g)</td>
<td>-</td>
<td>0.85***</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fruit-L (mm)</td>
<td>0.80***</td>
<td>0.63***</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fruit-W (mm)</td>
<td>0.91***</td>
<td>0.65***</td>
<td>0.75***</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fruit-T (mm)</td>
<td>-0.37***</td>
<td>-0.45***</td>
<td>-0.30**</td>
<td>-0.24*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TSS (°Brix)</td>
<td>0.96***</td>
<td>0.86***</td>
<td>0.89***</td>
<td>0.90***</td>
<td>-0.39***</td>
<td>-</td>
</tr>
</tbody>
</table>

*significant at $p = 0.05$, **significant at $p = 0.01$ and ***significant at $p = 0.0001$ according to Pearson Correlation Coefficients Analysis (9.0, SAS Institute Inc., NC USA)
Variability in fruit characteristics of Chokanan mango

It is worthy of note that fruit size is an important factor influencing mango orchard profitability due to the fact that mango fruit in Malaysia is normally graded by the size (the economic value of a fruit). For future study, estimating yield from equations using simple measurements of L, W and T of fruits could be employed as a non-destructive alternative method for assessing mango yield at the orchard level.

Additionally, weight and size of Chokanan fruit were positively correlated with L, W and T of fruits ($R^2 > 0.80$, $p < 0.0001$). However, they were inversely correlated with TSS (Table 2). A general trend indicating that higher fruit weight and size may contain lower TSS (Figure 2a and b) was also observed. Although the correlations are weaker ($R^2 = 0.14$ and 0.16), these trends suggest that Chokanan fruits with smaller size and less weight tended to have higher soluble solid and sugar content compared to bigger fruits size. As soluble solid and sugar content are related to dry matter content (Saranwong et al. 2004; Léchaudel and Joas 2007), it would also be reasonable to suggest that smaller fruit size of Chokanan mango may have higher dry matter content compared to bigger fruit size. Thus, it would be interesting for future study to evaluate the dry matter content of Chokanan fruits by specifically looking into whether there is a relationship with the different individual size. Since dry matter content is also related to the fruit quality attribute (Saranwong et al. 2004; Léchaudel and Joas 2007), smaller size Chokanan fruits is deemed to be graded as unmarketable fruit and discarded for marketing. Nevertheless, further study is still needed to evaluate this aspect of Chokanan and other tropical mango cultivars.

Figure 1. Percentages of fruit distributed into (a) different range of fruit weight (g) and (b) different range of total soluble solid (°Brix)
Various sizes and shapes of Chokanan mango fruits were found during harvest (Figure 3). The coefficient of variation (cv) also differed among the harvested trees (Table 3) with the highest were recorded on weight and size of fruits (cv = 9.5 and 11.4, respectively). These results imply that the fruit weight and size had higher amounts of genetic variability compared to other characteristics (Table 3). Notably, the weight, L, W, T and TSS of fruits among the trees were significantly different ($p < 0.0001$) (Table 3). The highest mean fruit weight was recorded in trees R24T21, followed by R1T17 and R7T15 with more than 200 g. According to Tengku Ab. Malik (1996), the standard fruit weight of Chokanan mango in Malaysia ranged from 250 g to 350 g. In the present study, 82% of the observed trees produced fruits that are weight less than 250 g. In Thailand, the fruit weight of more than 300 g is considered as the highest weight class and the weight below 200 g is classified as not marketable (Speer et al. 2007). In addition to this result, the size (L x W x T) of Chokanan fruits was also significantly different ($p < 0.0001$) among the trees (Table 3). It is evidenced in the present study that the mean value for L, W and T of Chokanan mango are slightly lower than the observation made by Speer and Müller (2011). They found that the mean value of L, W and T of Chokanan mango in Thailand were around 115.8 mm, 74.0 mm and 64.3 mm, respectively (Speer and Müller 2011). The differences in results were due to the differences in the number of samples collected, cultural management and environmental condition.

The largest fruit size was obtained from the trees with code number R24T21, followed by R1T17 and R7T15 with the size value of 58,303.2 mm$^3$, 45,452.8 mm$^3$ and 40,769.3 mm$^3$, respectively (Table 3 and Figure 3). Depending on the environmental condition, the accumulation of water and dry matter in mango is in the various parts of fruits, for example the skin, stone and flesh during fruit growing stage that may influence the final size (Léchaudel et al. 2002). It has been reported that the crop load may affect the final fruit size of mango (Bally 2007). Therefore, it is suggested that
Variability in fruit characteristics of Chokanan mango

Table 3. Comparison of the characteristics of Chokanan mango fruits at ripening stage from different individual trees

<table>
<thead>
<tr>
<th>Tree code</th>
<th>Fruit weight (g)</th>
<th>Fruit length-L (mm)</th>
<th>Fruit width-W (mm)</th>
<th>Fruit thickness-T (mm)</th>
<th>Total soluble solid (°Brix)</th>
<th>Fruit size (L x W x T) (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1T17</td>
<td>256.0 b</td>
<td>111.3 c</td>
<td>69.1 b</td>
<td>59.1 b</td>
<td>18.2 bc</td>
<td>45452.8 b</td>
</tr>
<tr>
<td>R6T27</td>
<td>196.0 d</td>
<td>102.1 d</td>
<td>59.8 cdef</td>
<td>51.8 de</td>
<td>20.9 a</td>
<td>31626.9 d</td>
</tr>
<tr>
<td>R6T28</td>
<td>144.0 f</td>
<td>88.3 e</td>
<td>55.9 f</td>
<td>50.5 def</td>
<td>20.8 a</td>
<td>24926.6 f</td>
</tr>
<tr>
<td>R7T15</td>
<td>237.0 c</td>
<td>117.9 b</td>
<td>63.8 c</td>
<td>54.2 c</td>
<td>18.6 bc</td>
<td>40769.3 c</td>
</tr>
<tr>
<td>R13T11</td>
<td>162.0 f</td>
<td>103.3 d</td>
<td>56.8 f</td>
<td>47.1 g</td>
<td>17.7 c</td>
<td>27635.6 ef</td>
</tr>
<tr>
<td>R19T15</td>
<td>180.0 def</td>
<td>101.7 d</td>
<td>59.8 cdef</td>
<td>50.1 ef</td>
<td>19.4 b</td>
<td>30469.1 de</td>
</tr>
<tr>
<td>R21T10</td>
<td>163.0 f</td>
<td>92.1 e</td>
<td>57.8 ef</td>
<td>49.5 f</td>
<td>18.6 bc</td>
<td>26137.8 f</td>
</tr>
<tr>
<td>R23T10</td>
<td>176.0 ef</td>
<td>105.4 d</td>
<td>59.2 def</td>
<td>48.9 f</td>
<td>16.6 d</td>
<td>30512.0 de</td>
</tr>
<tr>
<td>R24T21</td>
<td>315.0 a</td>
<td>127.4 a</td>
<td>74.9 a</td>
<td>61.1 a</td>
<td>16.3 d</td>
<td>58303.2 a</td>
</tr>
<tr>
<td>R25T16</td>
<td>183.0 de</td>
<td>103.1 d</td>
<td>63.3 c</td>
<td>51.8 de</td>
<td>18.5 bc</td>
<td>33805.9 d</td>
</tr>
<tr>
<td>R27T11</td>
<td>197.0 d</td>
<td>105.1 d</td>
<td>61.6 cde</td>
<td>52.5 dc</td>
<td>21.1 a</td>
<td>33989.3 d</td>
</tr>
</tbody>
</table>

CV 9.51 5.18 7.05 3.84 6.32 11.41

Significance p <0.0001 p <0.0001 p <0.0001 p <0.0001 p <0.0001

*Means followed by similar letter within columns are not significantly different according to Duncan Multiple range Test (DMRT) at p = 0.05
CV – Coefficient of variation

Figure 3. Variability of fruit size and shape of Chokanan mango at harvest (Scale: 1 section black or white equal to 3 cm)
future studies should focus on evaluating the relationship between fruit size and crop load in tropical mango. In addition, as, manipulation on the fruit growth is also required in order to increase the percentage of bigger fruit since tropical mango such as Chokanan is graded by size. Hence, this will help the growers to get higher income.

From the breeding perspective, one possibility is to grow a selected Chokanan accession with an inherent ability to produce big fruit. Even though an attempt has been made to breed and select a potential Chokanan accession (e.g. Mohd Azhar et al. 2013), conventional breeding of mango fruit trees is still constrained to certain inherent characteristics, such as long juvenile period and complex reproductive biology (Iyer and Degani 1997).

Also, it was reported that the choice of rootstocks and interstock may affect the fruit quality and yield of mango, as discovered on tropical cultivars such as Masmuda and Harumanis (Ahmad Tarmizi et al. 2005; Tengku Ab. Malik 2000a; b) and other mango cultivars (Avilán et al. 1996; Smith et al. 1996; 2003). To date, the effect of rootstock on fruit quality of Chokanan and other tropical mangoes is still unknown. Nonetheless, considerable effort has been made to study this matter in recent years (e.g. Fadhilnor 2016). Other important characteristics in mango are TSS and sugar contents, which are related to dry matter content (Léchaudel and Joas 2007). In the present study, it was found that TSS (°Brix) of Chokanan mango varied significantly ($p < 0.0001$) among trees (Table 3).

Generally, the TSS of Chokanan mango is between 16 and 17 °Brix (Zainal Abidin and Tengku Ab. Malik 1996b). The result from the present study indicated that fruits from some trees tended to produce higher TSS up to 21 °Brix (Table 3). Similarly, Mohd Azhar et al. (2013) also found that a few selected Chokanan accessions produced higher TSS. Dry matter content in mango mainly consists of carbohydrates and almost 60% compounds are sugar and acids (Ueda et al. 2000). Both compounds contributed to the sweetness and acidity of the mango fruits (Malundo et al. 2001). It is noteworthy that the carbohydrate level in mango fruit is dependent on the amount produced by leaf photosynthesis and the availability of the reserve pool, and also sink demand (Léchaudel and Joas 2007). However, in most tropical mango cultivars, the knowledge of these aspects is still wanting.

As regards tropical mango, it is worth highlighting that the source of variation for fruit characteristics within a tree, such as limb position, canopy position and fruit position within a cluster have not been characterised. The researchers strongly believe that various factors such as environmental condition (i.e. light, canopy management and crop load) and pre-harvest cultural practices may influence the final quality of tropical mango (Léchaudel and Joas 2007). Moreover, phenotypic variation of Chokanan mango fruits could also be affected by genetic effect of maternal plants as found in the present study. Therefore, to improve the manipulation of quantitative and qualitative traits of tropical mango trees, these aspects warrant further study in the future.

Furthermore, information with regards to fruit and tree variability is a prerequisite for the cultivar improvement or breeding purposes. The phenotypic variability among fruit characteristics provides an indication of potential genotypic variability. Further research to explore more on phenotypic and genotypic characteristics in tropical mango trees is of utmost importance.

Conclusion
It is of advantageous to breeders to know the information of variability that is available in some important economic traits and their heritability in order to improve breeding programmes for tropical mango. Overall, it was found that the characteristics of Chokanan mango at harvest were highly variable and this supported the review by the Léchaudel and Joas (2007).
As highlighted in the literature, variation in fruit characteristics of mango at harvest is believed to affect the final quality and consumer preferences. The results of the present study can be employed for further evaluation on breeding program of Chokanan cultivar. Furthermore, similar studies on other local mango cultivars such as Harumanis and Sala are needed in order to gain information on preharvest and postharvest factors that may affect the quality of local mango cultivars in Malaysia.

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References


**Abstrak**

Kajian ini dijalankan bertujuan untuk menilai ciri-ciri buah mangga Chokanan semasa tuaian. Buah Chokanan tersebut dituai daripada pokok yang terpilih di plot mangga komersial di Stesen Penyelidikan MARDI Sintok, Kedah, Malaysia. Data ciri-ciri buah seperti berat, panjang (L), lebar (W), ketebalan (T) buah-buahan dan jumlah larut pepejal TSS (°Brix) telah diukur dan direkodkan pada minggu ke-13. Keputusan kajian menunjukkan perbezaan yang bererti (*p* <0.001) telah direkodkan pada berat buah, W, L, T, saiz (W x L x T) dan TSS daripada buah Chokanan di antara pokok. Berat minimum buah yang dituai adalah di antara 120 – 380 g dan TSS adalah di antara 14.5 °Brix dan 22.8 °Brix. Kajian ini mendapati bahawa taburan berat buah telah condong ke kiri dan menunjukkan bahawa peratusan yang lebih besar untuk buah yang kecil, tetapi taburan normal dicatatkan bagi TSS. Selain itu, hubungan yang amat bererti (*R*² >0.80) telah diperoleh antara berat dan saiz, L, W dan T buah. Walau bagaimanapun, perhubungan yang songsang telah dikaikan antara berat buah dan saiz Chokanan dengan TSS. Di samping itu, pekali variasi (cv) juga berbeza antara pokok-pokok dengan berat dan saiz buah menunjukkan catatan yang tertinggi (cv = 9.5 dan 11.4, masing-masing). Akhir sekali, kemungkinan dan punca kepelbagaian ciri-ciri buah Chokanan turut dilaporkan dan dibincangkan.

F. Abdullah