Food Research 2 (6) : 564 - 571 (December 2018)
Journal homepage: http://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Assessment of variability pattern of flesh color in 'Harumanis' mango (*Mangifera indica* L.) from diverse Perlis geographical origin

[1,*] Yusuf, A., [1]Rahman, A.M.A., [1]Zakaria, Z., [2]Wahab, Z. and [3]Kumar, S.V.

[1]*Department of Chemical Engineering Technology, Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Sungai Chuchuh, 02100 Padang Besar, Perlis.*
[2]*Department of Mechanical Engineering Technology, Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Sungai Chuchuh, 02100 Padang Besar, Perlis.*
[3]*Biotechnology Research Institute, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia.*

Article history:
Received: 28 May 2018
Received in revised form: 12 September 2018
Accepted: 17 September 2018
Available Online: 6 November 2018

Keywords:
Harumanis,
Flesh color,
Geographical region,
Variability

DOI:
https://doi.org/10.26656/fr.2017.2(6).108

Abstract

'Harumanis' (*Mangifera indica* L) is one of the mango cultivars which has high market value because of the excellent quality of the fruit which has attractive color, good aroma, delicious taste and high nutritive values. In this study, fifty accessions from five different collection sites which belonging to North (Paya Kelubi and Chelong Balik Bukit, Padang Besar), West (Santan, Kangar), East (Alor Ara Timur, Arau) and South (Simpang Empat, Kangar) region of Perlis were analyzed according to flesh color traits based on their region of origin. The analysis of variance using Kruskal-Wallis test resulted in significant differences among the geographical region for traits of fruit flesh color such as L*, a*, chroma and hue at ($P<0.05$). The correlation result shows that the intensity pattern of the orange color of the fruit samples mesocarp was associated by an increase in the values of a*, b* and C*, and a decrease in the values of L* and *h*. By performing Cluster analysis using Ward's method and Euclidian distance, five distinct clusters were successfully identified. The finding shows a high distribution of 'Harumanis' accessions from different locations in each distinct group. This study also reveals the relationship of variability in fruit traits with their places of origin. However, these differences cannot be explained in firm via morphological characterization only. Other methods such as molecular characterization are strongly recommended.

1. Introduction

Color is a vital parameter for food quality indicator since it is able to influence the consumer perception in term of flavor, sweetness and also elicit human emotional feelings. In the case of mango, epidermis color plays an important role in the perception of overall quality and is associated with the determination of appropriate maturity for harvest. One of the main factors which contribute towards the yellow-orange color of mango epidermis and mesocarp is carotenoids. Previously, the color measurement has been used for carotenoid estimation of 'Manila' and 'Ataulfo' mangoes (Ornelas-Paz *et al*., 2008). *β*-carotene has been emphasized as the main component that is interrelated with flesh color and resulting vitamin A values (Golob *et al*., 2012).

The climatic condition has been stated as one of the major factors in the determination of accumulation of carotenoid. Since mango is a climatic fruit, this factor is postulated to play an important role in its carotenoid accumulation. For example, ripe 'Keitt' mango from Bahia, Brazil (hot climate) possesses more than twice the *β*-carotene content than those from São Paulo (moderate climate) (Mercadante and Rodriguez-Amaya, 1998). Thus, it can be postulated that the hot climatic condition is favourable for *β*-carotene accumulation and can further result in fruit color variation which basically varies based on the origin of the mangoes.

In Malaysia, the Department of Agriculture has registered 209 clones of mango grown in this country which originated from India, Indonesia and other. From these registered clones, some of them are possessing high enough qualities to be recommended for general plantings such as Malgoa and Apple Mango (for home planting), MA 128, MA 162, Bahagia, MA 165, Bombay Green, MA 204 and MA 205 (Ynus, 1984). Among these mango cultivars, 'Harumanis' or also known as MA 128

*Corresponding author.
Email: *mukhlis@unimap.edu.my*

eISSN: 2550-2166

is one the most favourable and is grown widely in Perlis. Therefore, the present work will focus on the evaluation of 'Harumanis' flesh color trait variation in correlation with different locations by application of morphological characterization method.

2. Materials and methods

2.1 Description of study area

Samplings were conducted for over four months (March, April, May and June 2017). Prior to sampling, ecogeographical survey and plant tagging were performed. From the survey, five locations were selected which covered all three main regions of Perlis as indicated in Table 1.

2.2 Fruit sampling strategy

About fifty accessions were considered for harvesting purpose. Five dates have been chosen for collection based on the usual commercial harvest time of this variety (April till June 2017). The recommendation period of 'Harumanis fruit collection is ninety to hundred days after full bloom (Muhammad and Ding, 2006) and followed by a post-harvest treatment as indicated in Table 2. Selected 'Harumanis' fruits need to fulfill several criteria for full maturity confirmation such as has outgrown shoulders, formation of a depression with ridges at the stem end and already full round grow (Shahir and Visvanathan, 2014).

Table 2. Harvest and Post-harvest process of 'Harumanis'

Stage	Week	Orchard (small scale production)
1	0-7	Pre-mature: Not yet harvested Mature: Fruit harvesting
2	8 (Day 1)	Mature: Right after being harvested, remove the fruit wrapper, cleaned, dried and conducted artificial ripening with calcium carbide.
3	8 (Day 3)	Fruit exposure to open air to release ethylene gas.
4	8 (Day 6)	Fruit traits analyses

2.3 Pulp color measurement

Color measurement of mangoes was assessed by application of a portable colorimeter (CR-400 Minolta) set to L*, a*, b* mode. In standard Commission Internationale de l'Eclairage (CIE), the L*a*b* color space indicates different degree of color measurement, in which L* value indicates the lightness [black [L*=0] and [L* = 100]], a* value indicates redness-greenness (red [a* = 100] and green [a* = (-100)]) and b* indicates yellowness-blueness (yellow [b* = 100] and blue [b* = (-100)]). Both chroma and hue are derived from a*and b* using the following equations: chroma measures intensity coloration [C = (a*) 2 + (b*) 2]1/2] and hue angle [h = arc tan (b*/a*)] (Varakumar *et al*., 2011). The color coordinate is able to show the variation between

Table 1. List of 'Harumanis' mango accessions (collections) and their collection sites.

No	Accession Name	Location	No	Accession Name	Location
S1	HM-Acc-1	1	S26	HM-Acc 26	3
S2	HM-Acc-2	1	S27	HM-Acc 27	3
S3	HM-Acc-3	1	S28	HM-Acc-28	3
S4	HM-Acc-4	1	S29	HM-Acc-29	3
S5	HM-Acc-5	1	S30	HM-Acc 30	3
S6	HM-Acc-6	1	S31	HM-Acc-31	4
S7	HM-Acc-7	1	S32	HM-Acc-32	4
S8	HM-Acc-8	1	S33	HM-Acc-33	4
S9	HM-Acc-9	1	S34	HM-Acc-34	4
S10	HM-Acc-10	1	S35	HM-Acc-35	4
S11	HM-Acc-11	2	S36	HM-Acc-36	4
S12	HM-Acc-12	2	S37	HM-Acc-37	4
S13	HM-Acc-13	2	S38	HM-Acc-38	4
S14	HM-Acc-14	2	S39	HM-Acc-39	4
S15	HM-Acc-15	2	S40	HM-Acc-40	4
S16	HM-Acc-16	2	S41	HM-Acc-41	5
S17	HM-Acc-17	2	S42	HM-Acc-42	5
S18	HM-Acc-18	2	S43	HM-Acc-43	5
S19	HM-Acc-19	2	S44	HM-Acc-44	5
S20	HM-Acc-20	2	S45	HM-Acc-45	5
S21	HM-Acc-21	3	S46	HM-Acc-46	5
S22	HM-Acc-22	3	S47	HM-Acc-47	5
S23	HM-Acc-23	3	S48	HM-Acc-48	5
S24	HM-Acc-24	3	S49	HM-Acc-49	5
S25	HM-Acc-25	3	S50	HM-Acc-50	5

Location 1: Chelong Balik Bukit, Padang Besar, Location (6.535464◦ [N],100.288332◦ [E]), Location 2: Paya Kelubi, Padang Besar (6.535175◦ [N], 100.253759◦ [E]), Location 3: Alor Ara Timur, Arau (6.456431◦ [N], 100.263158◦ [E]), Location 4: Santan, Kangar(6.482817◦ [N], 100.230928◦ [E]) and Location 5: Simpang Empat, Kangar (6.322332◦ [N], 100.206032◦ [E]).

eISSN: 2550-2166

the basic colors. The hue angle also able to determine the intermediate colors between adjacent pairs of these basic colors. Chroma is the saturation or vividness of color. As chromaticity increases, a color becomes more intense; as it decreases, a color becomes duller. Hue angle is the basic unit of color and can be interpreted, for example, as (0 = red and 90 = yellow). Prior to use, the calorimeter was calibrated by using calibration with white plate (L* = 98.15, C* = 1.92, *h* = 93.8, a* = 0.13 and b* = 1.92). Each accession was measured as triplicates at least by measuring both the equatorial regions of each fruit. The pulp color was measured by an internal reading at the central region equidistantly. The colorimeter was set to enable the light pulse to move to 3 locations of each mango surface for every measurement. Thus, this will allow the assessment of mango pulp 'true' color since each measurement will represent average reading (Ayala -Silva *et al*., 2005).

2.4 Statistical analyses

All the measurements were performed in triplicate. The values were then tabulated into a Microsoft Excel file and SPSS IBM ver 19.0 software. Descriptive analysis and test of normality were performed for diversity within the variety evaluation. For descriptive analysis, the values of minimum, maximum, mean and coefficient of variation (CV) were computed for each fruit traits. These descriptive statistics were important to assess the variation among the samples and the CV was vital for variability index. Due to violation towards the normality distribution assumption, non parametric Kruskal-Wallis with the multiple Dunn test was applied. Non parametric Kruskal Wallis with the multiple Dunn test was purposely performed to test the significant difference of phenotype distribution in correlation with the locations and also to test the heterogeneity effect between the traits. Bivariate Spearman's correlation was performed for evaluation of the correlation between the phenotype and geographical region and also the correlation between the traits. P-value correlation matrix was assessed for level of correlation indicator.

3. Results and discussion

3.1 Descriptive statistics

The data collected from the study were subjected to descriptive statistical analysis as indicated in Table 3. Overall, the +a* mean values range from 13.97 to 20.45 indicated the red color direction, while +b* from 63.42 to 67.66 mean values range indicated the yellow color direction (Itle and Kabelka, 2009). A range of L*, lightness (72.25) to darkness (66.80) of color, and chroma mean range values indicated vividness of color as the mean range within 63.42 to 67.66. The L* and chroma values may reflect different concentrations of pigments as both parameters could be correlated with the total pigment of fruit mesocarp (Itle and Kabelka, 2009). Among the five color space values, a* presents the highest CVs especially for accessions from Simpang Empat (30.27%) which is greater than 20.00%, indicated a high variability (Norouzi *et al*., 2017).

3.2 Analysis of variance and Bivariate Spearman correlation.

A significant ($P<0.05$) differences were observed among locations for the flesh color represented by the four color space value: L*, a*, chroma and hue. This demonstrates that the flesh color space of 'Harumanis' accessions was varied for different locations. This relationship is revealed by Dunn pairwise by comparing the mean values as indicated by color space values of 'Harumanis Paya Kelubi' with other location (Alor Ara Timur, Santan, and Simpang Empat. A significant difference of p-value less than 0.05 specifically for L* and *h* was recorded between 'Harumanis Paya Kelubi' with other locations (Alor Ara Timur, Santan, and Simpang Empat) samples. This finding shows that there is a presence of phenotypic variation in flesh color of 'Harumanis' fruits from different locations. The colors of the mango flesh in this study varies from orange, orange-yellow, yellow-orange to yellow. This could be related to the facts that any continuous inbreeding of the clones may produce heterozygous with severe loss. One of the major mechanism which contributes towards this phenomenon is the interaction of gene (G), environment (E) and G x E interaction over the population mean (h). It is also mentioned that carotenoid metabolism is a complicated process, which is regulated by developmental stages and environmental conditions (Zhang *et al*., 2015). The findings of this study are in agreement with this as the values demonstrate that the 'Harumanis' accessions flesh colors were varied for different locations since different locations may possess different environmental condition (Itle and Kabelka, 2009).

Based on Spearman's rank correlation tests in Table 4, the correlation showed fair and intermediate significant correlation between a* (r_s = 0.355) and b* (r_s = 0.789) with chroma. The chroma values could be correlated with the total pigment of fruit mesocarp (Itle and Kabelka, 2009) since it measures the intensity of coloration as present by previous. These findings able to meet the previous which states that a positive correlation between chroma with parameter a* and b* could be predicted as any increase in pigment would increase the darkness and thereby increase the saturation. L* and *h* gave negative correlation with C* with (r_s = -0.397) and (r_s = -0.051) (Ornelas-Paz *et al*., 2008). These both

Table 3. Descriptive statistics of hunter colour of selected 'Harumanis' mangoes.

Location	Descriptive statistics	L*	a*	b*	Chroma (C)	Hue angle (h°)
1	Average	70.03	16.52	65.78	67.85	75.89
	Min value	65.58	13.58	61.60	64.26	73.45
	Max value	73.17	19.62	68.25	70.08	78.35
	Standard deviation	2.08	1.84	1.77	1.66	1.64
	Coefficient variation (%)	2.98	11.12	2.69	2.44	2.16
2	Average	66.80	20.45	66.38	69.51	72.71
	Min value	60.57	17.11	60.85	65.59	68.09
	Max value	70.01	24.48	69.98	72.04	76.01
	Standard deviation	2.81	2.23	2.32	1.60	2.23
	Coefficient variation (%)	4.21	10.93	3.50	2.30	3.07
3	Average	72.75	14.10	64.15	65.73	76.06
	Min value	68.37	11.73	52.22	54.08	68.37
	Max value	75.11	19.83	70.27	71.52	79.32
	Standard deviation	2.05	2.37	6.31	6.28	4.26
	Coefficient variation (%)	2.82	16.83	9.83	9.56	5.60
4	Average	71.98	13.97	67.66	69.13	78.35
	Min value	69.44	10.53	66.5	67.5	74.1
	Max value	74.47	19.34	68.85	70.82	81.09
	Standard deviation	1.77	2.66	0.66	1.02	2.10
	Coefficient variation (%)	2.46	19.02	0.96	4.57	2.67
5	Average	72.62	14.30	63.42	64.99	77.544
	Min value	60.22	2.96	52.52	54.66	73.44
	Max value	81.44	17.84	69.26	70.64	87.13
	Standard deviation	5.24	4.33	6.01	5.95	3.83
	Coefficient variation (%)	7.22	30.27	9.48	9.16	4.95

Values presented are mean of triplicate analysis. Chroma(C) = [(a*) 2 + (b*) 2]1/2 and hue angle (h°) = arc tan (b*/a*)

Table 4. Hunter colour and Location Correlation Coefficient of selected 'Harumanis' mangoes.

Rho Spearman		Fruit Trait				
		L*	a*	b*	Chroma (C)	Hue angle (h°)
L*	r_s	1.000				
a*	r_s	-.878**	1.000			
b*	r_s	.000	.041	1.000		
Chroma (C)	r_s	-.397**	.355*	.789**	1.000	
Hue angle (h°)	r_s	.690**	-.837**	.344*	-.051	1.000

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Table 5. Minimum and maximum value of five quantitative and one qualitative key descriptors used for morphological classification of 50 Harumanis mango samples separately for the five identified clusters based on z score standardization.

Morphological characteristics	Cluster 1 (n = 5)	Cluster 2 (n = 11)	Cluster 3 (n = 13)	Cluster 4 (n = 9)	Cluster 5 (n = 11)	Cluster 6 (n = 1)
Accesion (HM-Acc-)	11, 12, 16, 24 and 30	2, 6, 13, 14, 17, 18, 19, 20, 42, 44 and 37	3, 4, 5, 8, 9, 10, 15, 21, 27, 32, 35, 45 and 46	1, 7, 26, 29, 38, 41, 43, 47 and 48	25, 28, 31, 33, 34, 36, 39, 40, 49, 49, 22 and 23	50
Location	2 and 3	1, 2, 4 and 5	1, 2, 3, 4 and 5	1, 3, 4 and 5	3, 4 and 5	5
Hue angle, *h* (◦)	68.09-71.65	73.03-74.1	74.59-76.83	77.17-78.35	78.75-81.09	87.13
Flesh color	Orange and orange yellow	Orange yellow	Orange yellow and yellow orange	Yellow orange	Yellow orange and yellow	Yellow

correlation values indicates that the intensity of the orange color of the mesocarp was associated with an increase in the values of a*, b* and C*, and a reduction in the values of L* and *h*. An identical performance was reported by several mango cultivars such as 'Dashehari', Nam Dok Mai', Kaew', Mahahanaka', 'Manila' and 'Ataulfo (Ornelas-Paz *et al*., 2008). The correlation value between *h which* and a* presents a high negative correlation (r_s= -0.837) with a significant level of p-value less than 0.05. The negative correlation observed between *h* and the a* estimated in this investigation proposes that as hue angles decrease and a* increase, carotenoid concentrations would increase. These inverse correlation between *h* and a* indicates the expression of a deep orange-yellow color and related to high *β*-carotene content (V´azquez-Caicedo *et al*., 2004). This result is strongly in agreement with the previous correlation result of 'Langra' mango (Gill, 2017), since it also shows a high negative correlation (r =-0.955) between *h* and a*. Each of the four reports viewed colorimetric investigation as a fitting estimator of carotenoid concentration (Itle and Kabelka, 2009). These discoveries are as per those of Godoy and Rodriguez-Amaya (1989), who showed that the most vital carotenoid of mango is all-trans-β-carotene, with 48 to 84% of aggregate carotenoid content, depending on cultivar and fruit maturity stage (Mercadante and Rodriguez-Amaya, 1998).

3.3 Clustering analysis

By performing hierarchical clustering and overall profile analyses, two distinct groups were identified. The clustering analysis was constructed by utilizing the color space value of *h* as shown in Figure 1 and Table 5. Hue angle was selected as a key descriptor in this analysis since it is identified as one of the methods of reporting color which able to exhibit the estimation of visual attributes (Mclellan *et al*., 1994). The first main cluster included 29 accessions and was divided into three sub-clusters. The first sub-cluster contained five accessions while 11 accessions included in the second sub-cluster. Third sub-cluster contained most of the population study with 13 accessions. Meanwhile, about 21 accessions were subjected into second main clusters by dividing into other three sub-clusters. The fourth sub-cluster consist of nine accessions, whilst cluster 5 included about eleven accessions. The 'Accession 50' which subjected into cluster 6 was excluded from this study since it was identified as an extreme outlier. This clustering analysis able to visualize the high distributional behavior which indicated by the five populations of 'Harumanis' in Perlis.

By referring to the standard of mango flesh color classification provided by Royal Horticultural Society's Colour Chart score in combination with previous mango flesh color classification as attained by African bush mango trees (*Irvingia* species) in West Africa (Romaric *et al*., 2013), these sub-clusters were classified into several color groups as shown in Table 5. This color analysis is conducted to examine any presence of phenotypic variation of flesh color among the 'Harumanis' accessions from different locations. The color analysis is determined by comparing the value of hue angle with the color wheel which able to show an abstract illustrative organization of color hues around a circle (Stancil and Jordan, 1985).

Cluster 1 grouped 'Harumanis' five mango samples from the East (Alor Ara Timur, Arau) and North (Paya Kelubi, Padang Besar) region of Perlis which have the densest flesh color (orange and orange-yellow) as the mangoes scored lowest *h* range values from 68.09° to 71.65°. The greatest mean of *h* value was presented by cluster 5 which consists of populations from three locations (3, 4 and 5) and showing yellow-orange and yellow fruit flesh according to the color wheel. This is in agreement with previous findings which indicated that low values of *h* in peel or pulp indicates a deep orange-yellow color (V´azquez-Caicedo *et al*., 2004).

Color analyses of 'Harumanis' were performed on the fruit flesh as this cultivar usually retains its green color even if it is physiologically mature and ripe. Mango has a high content of carotenoids in mesocarp tissues which responsible for the intense yellow color and this attribute is an important role in determining the fruit quality (Muhammad and Ding, 2006). In mango, as ripening progressed, the color of pulp turned orange, which is attractive and engaging for consumption. Beforehand, for commercialization purpose, a high bright red shading of fruit like tomato cultivars have been associated with a strong positive impact among the buyers, whereas a light (low red shading have been related with a negative reaction by the shopper (Ayala-Silva *et al*., 2005).

Content and compositions of carotenoid play a critical part in the formation of fruit color. Color changes during fruit ripening include the conversion of chloroplast to chromoplast. As a result of the loss of photosynthetic capacity of the chloroplast, thylakoid structures become sites for the accumulation of carotenoids in the fruit cells. For instance, the chlorophyll content is moderately high in the green natural products, while the red and orange organic products are portrayed by high lycopene and carotene substance, separately (Li *et al*., 2018). As mentioned before, the most important carotenoid in mango is all-

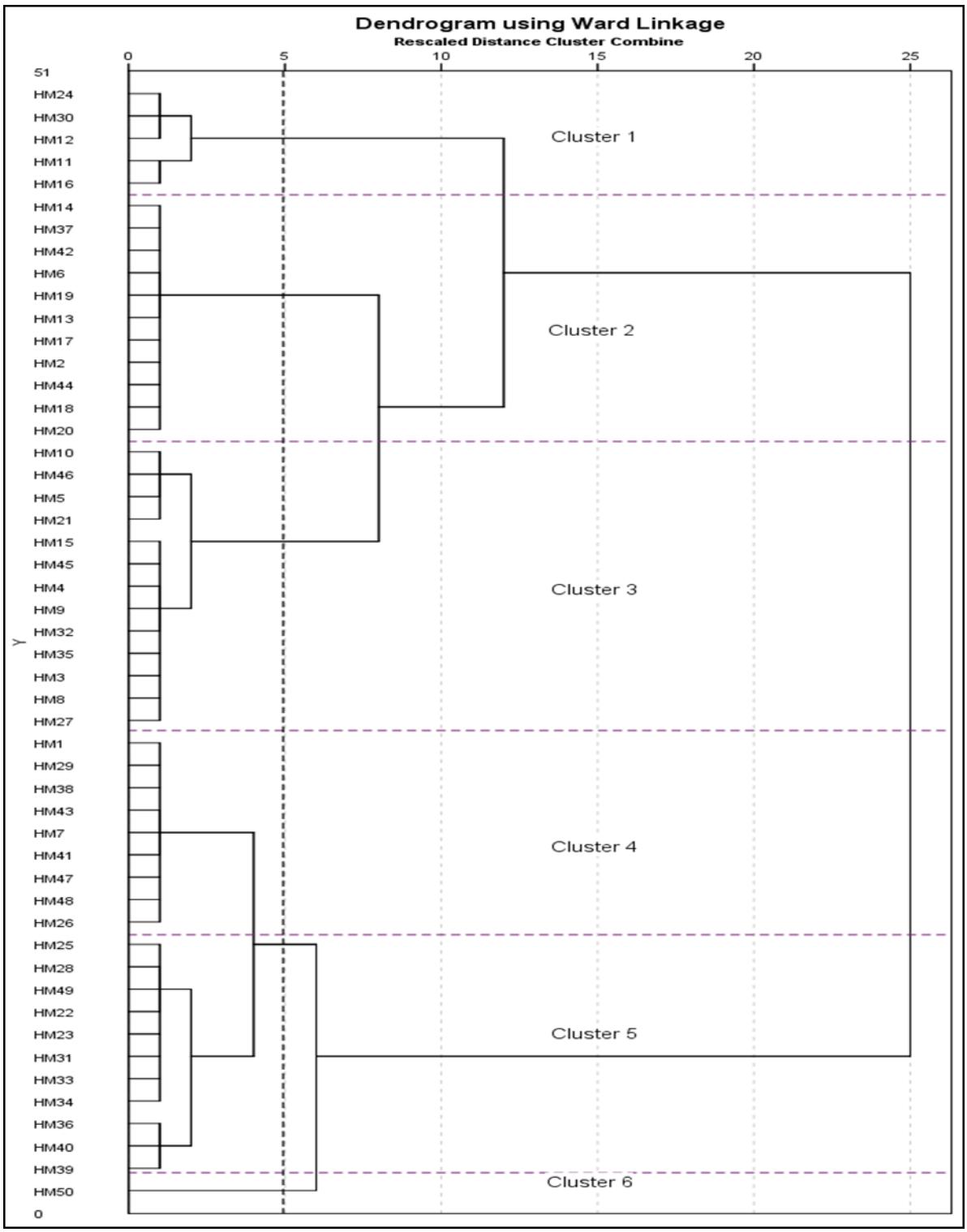

Figure 1. Final dendogram showing five clusters as a result of cluster analysis (Ward method, Euclidian distance, z-score standardization of variables using two color space value key descriptor (*h*) on 50 'Harumanis' mangoes samples collected from North (Paya Kelubi and Chelong Balik Bukit, Padang Besar), West (Santan, Kangar), East (Alor Ara Timur, Arau) and South (Simpang Empat, Kangar) region of Perlis. The cutting line for the cluster formation is marked as a dotted line. Cluster six was excluded as it identified as extreme outlier.

trans- β-carotene representing 48 to 84% of total carotenoid content, depending on the cultivar and fruit maturity stage (Mercadante and Rodriguez-Amaya, 1998).

Among the color space parameters, a high a* values reflect a high β-carotene content (V´azquez-Caicedo *et al*., 2004.). This study found that the a* values are inversely correlated with the value of *h.* This result was strongly in agreement with a previous report on 'Langra' mango (Gill, 2017) which showed a high negative correlation result between a* and *h*. The inverse correlation between *h* and a* expresses the deep orange-yellow color and a high β-carotene content (V´azquez-Caicedo *et al*., 2004). This relationship well explained the color pattern attained by the flesh of 'Harumanis' samples in Cluster 1 which has the lowest *h* range among the sample clusters and the densest orange color. This

result is consistent with previous studies which exposed that any increase in the intensity of yellowness of the mesocarp was accompanied by an increase in a*, b* and C* values and a subsequent decrease in L* and *h* values (Ornelas-Paz *et al*., 2008).

From the analyses of variance, it is concluded that there is a presence of environmental influences towards the flesh color space values with significant ($P<0.05$) differences among locations. This finding is reciprocal with the cluster analysis results as there is a high distribution of 'Harumanis' accessions from different locations in each distinct group. In an earlier report, carotenoid content in flesh are varied among cultivars, while carotenoids compositions were generally stable (Ornelas-Paz *et al*., 2008). It is well archived that the content and composition of carotenoid development regulation is influenced by environmental stimuli (Cazzonelli and Pogson, 2010). Among the environmental factor, light has been identified as one of the important elements which able to regulate carotenoid metabolism in plants (Zhang *et al*., 2015). Meanwhile, a former study revealed that hot climatic condition plays an imperative part in the accumulation of carotenoids such as 'Keitt' mango from Bahia (hot climate) (Mercadante and Rodriguez-Amaya, 1998). This is complemented with the earlier discoveries which mention that practically, light intensity was correlated with temperature, particularly in the open air (He *et al*., 2018) and it was also demonstrated that the temperature was at significant linear to the light intensity (Gou *et al*., 2015).

For this analysis, the surface meteorological temperature observation data (January till June 2017) obtained from the Malaysian Meteorological Department was used involving two regions which are Chuping representing orchards in Chelong Balik Bukit, Paya Kelubi, Santan and Alor Ara Timur and Kangar representing orchards in Simpang Empat. The trend shows a consistent and not much difference in the temperature between the two regions with a average temperature of (28.4°C) for Kangar and (27.7°C) for Chuping. Meanwhile, the high distribution of the 'Harumanis' accessions from different locations expresses the presence of phenotype variation for the fruit flesh color trait and thus indicated high variability between the individuals. This can be clearly seen in Table 5, 'Harumanis Simpang Empat' samples (HM41, HM42, HM43, HM44, HM45, HM46, HM47, HM48, HM49, and HM50) were highly distributed into distinct groups which further do not represent a significant relationship of differences in fruit flesh color with the environmental condition. Thus, it can be postulated that the temperature of Perlis regions is not a crucial environmental factor in the 'Harumanis' cultivar flesh color trait variation which usually associated with the carotenoid accumulation. Earlier, it is also reported that, other than environmental conditions, transcriptional regulation of the structural carotenoid pathway gene during developmental stages, specifically ripening part, could also influence the carotenoid metabolism. (Ma *et al*., 2018). This is in accordance with past research which reported that carotenoid metabolism is a complicated process which is regulated by both the developmental stages and environmental conditions (Zhang *et al*., 2015). Evidence in support of this explanation is carotenoid accumulation patterns in different cultivars and during fruit development and ripening is correlated with the expression of key biosynthetic genes such as LCYB, LCYE, PSY, PDS, ZDS, BCH and ZEP (Ma *et al*., 2018).

4. Conclusion

In summary, there are significant differences in 'Harumanis' accessions flesh color different locations. In addition, 'Harumanis' accessions which belong to different color groups were successfully identified. This identification may be useful for selection of 'Harumanis' individuals with desirable characteristics as valuable genetic resources specifically for the breeding program. Consequently, this evaluation and assessment can be a good basis for the establishment of 'Harumanis' seed program since the selection of good offspring is important as trait like the color is able to influence the fruit markets.

Acknowledgement

The authors would like to acknowledge the financial support provided by the Ministry of Education Malaysia under the Fundamental Research Grant Scheme (FRGS) (FRGS/1/2016/WAB01/UNIMAP/03/2).

References

Ayala-Silva, T., Schnell, R.J., Meerow, A.W., Winterstein, M., Cervantes, C. and Brown, J.S. (2005). Determination of Color and Fruit Traits of Halfsib Families of Mango (*Mangifera Indica* L.). *Proceedings of the Florida State Horticultural Society*, 118, 253-257.

Cazzonelli, C.I. and Pogson, B.J. (2010). Source to sink: regulation of carotenoid biosynthesis in plants. *Trends in Plant Science*, 15(5), 266-274. https://doi.org/10.1016/j.tplants.2010.02.003

Gill, P.P.S. (2017). Transitions in mesocarp colour of mango fruits kept under variable temperatures. *Journal of Food Science and Technology,* 54(13),

4251–4256. https://doi.org/10.1007/s13197-017-2894-z

Golob, P., Farrell, G. and Orchard, J.E. (2012). Crop Post-Harvest : Science and Technology, Vol. 1: Principles and Practice. USA: Wiley-Blackwell.

Gou, Z., Lau, S.S.-Y. and Qian, F. (2015). Comparison of mood and task performance in naturally-lit and artificially-lit environments. *Indoor and Built Environment*, 24(1), 27–36. https://doi.org/10.1177/1420326X13507792

He, Q., Yang, H. and Hu, C. (2018). Effects of temperature and its combination with high light intensity on lipid production of Monoraphidium dybowskii Y2 from semi-arid desert areas. *Bioresource Technology*, 265, 407–414. https://doi.org/10.1016/j.biortech.2018.06.044

Itle, R.A. and Kabelka, E.A. (2009). Correlation Between Lab Color Space Values and Carotenoid Content in Pumpkins and Squash (*Cucurbita* spp.). *HortScience*, 44(3), 633–637.

Li, F., Song, X., Wu, L., Chen, H., Liang, Y. and Zhang, Y. (2018). Scientia Horticulturae Heredities on fruit color and pigment content between green and purple fruits in tomato. *Scientia Horticulturae*, 235, 391–396. https://doi.org/10.1016/j.scienta.2018.03.030

Ma, X., Zheng, B., Ma, Y., Xu, W., Wu, H. and Wang, S. (2018). Carotenoid accumulation and expression of carotenoid biosynthesis genes in mango flesh during fruit development and ripening. *Scientia Horticulturae*, 237, 201–206. https://doi.org/10.1016/j.scienta.2018.04.009

Mclellan, M.R., Lind, L.R. and Kime, R.W. (1994). Hue Angle Determination and Statistical for Multiquadrant Hunter L, a, b Data. *Journal of Food Quality*, 18(3), 235–240. https://doi.org/10.1111/j.1745-4557.1995.tb00377.x

Mercadante, A.Z. and Rodriguez-Amaya, D.B. (1998). Effects of ripening, cultivar differences, and processing on the carotenoid composition of mango. *Journal of Agricultural and Food Chemistry*, 46(1), 128-130. https://doi.org/10.1021/jf9702860

Muhammad, H. and Ding, P. (2006). Cellular Changes During Ripening Mango of Harumanis. *Malaysian Journal of Microscopy*, 3, 19-24.

Norouzi, E., Erfani-Moghadam, J., Fazeli, A. and Khadivi, A. (2017). Morphological variability within and among three species of *Ziziphus* genus using multivariate analysis. *Scientia Horticulturae*, 222, 180–186. https://doi.org/10.1016/j.scienta.2017.05.016

Ornelas-Paz, J.D.J., Yahia, E.M. and Gardea, A.A. (2008). Changes in external and internal color during postharvest ripening of "Manila" and "Ataulfo" mango fruit and relationship with carotenoid content determined by liquid chromatography-APcI+-time-of-flight mass spectrometry. *Postharvest Biology and Technology*, 50(2–3), 145–152. https://doi.org/10.1016/j.postharvbio.2008.05.001

Romaric, V., Ronald, G.V.D. and Marc, S.M.S. (2013). Morphological characterization of African bush mango trees (*Irvingia* species) in West Africa. *Genetic Resources and Crop Evaluation*, 60(4), 1597-1614. https://doi.org/10.1007/s10722-013-9969-0

Shahir, S. and Visvanathan, A.R. (2014). Maturity measurement of mango and banana as related to ripening. *Journal of Trends in Bioscience*, 7(9), 741–744.

Stancil, W.C. and Jordan, D. (1985). Precise color communication. Book of papers. National Technical Conference, p. 33-35. USA: AATCC

V´azquez-Caicedo, A.L., Neidhart, S. and Carle, R. (2004). Postharvest ripening behavior of nine Thai mango cultivars and their suitability for industrial applications. *ISHS Acta Horticulturae*, (645), 617–625. https://doi.org/10.17660/ActaHortic.2004.645.81

Varakumar, S., Kumar, Y.S. and Reddy, O.V.S. (2011). Carotenoid composition of mango (mangifera indica l.) wine and its antioxidant activity. *Journal of Food Biochemistry*, 35(5), 1538–1547. https://doi.org/10.1111/j.1745-4514.2010.00476.x

Ynus, N. (1984). Mango Cultivation in Malaysia. The Archives of The Rare Fruit Council of Australia. Retrieved from website: http://rfcarchives.org.au/Next/Fruits/Mango/MangoCultivation9-84.htm

Zhang, L., Ma, G., Yamawaki, K., Ikoma, Y., Matsumoto, H., Yoshioka, T. and Kato, M. (2015). Effect of blue LED light intensity on carotenoid accumulation in citrus juice sacs. *Journal of Plant Physiology*, 188, 58–63. https://doi.org/10.1016/j.jplph.2015.09.006

