ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Short Communication

On-Tree Harumanis Mango Fruit Sizing through Digital Image Analysis

Nur Adilah Zulkifli[1], Muhammad Firdaus Abdul Muttalib[1*], Muhammad Nur Aiman Uda[1,2], Zainal Abidin Arsat[1], Fadhilnor Abdullah[1,3], Mohd Khairul Rabani Hashim[1], Fathin Ayuni Azizan[1], Mohd Fauzie Jusoh[1,4], Syarifah Rokiah Syd Kamaruzaman[3], Ahmad Azudin Nordin[3]

[1]Faculty of Mechanical Engineering & Technology, Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, Malaysia.

[2]Institute of Nano Electronic Engineering, Universiti Malaysia Perlis, 01000 Kangar, Perlis, Malaysia.

[3]Institute of Sustainable Agrotechnology (INSAT), Universiti Malaysia Perlis,02100 Padang Besar, Perlis, Malaysia.

[4]Faculty of Agro Based Industry, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia.

*Corresponding author: Muhammad Firdaus Abdul Muttalib, Address; firdausmuttalib@unimap.edu.my

Abstract: The study sought to precisely determine the dimensions of Harumanis mango fruit while they are still attached to the tree, using digital image processing methods. Harumanis mangoes images were photographed at varying distances (1, 2, and 3 meters) and heights (0.5, 1, and 1.5 meters) using a camera and then analysed with MATLAB software. The study showed that the lowest percentage errors for fruit length and width were 1.16% and 0.22%, respectively, when the camera was placed 2 meters away and 1 meter above the fruits. The average growth rate of fruit width and length was found to be around 1 cm/week and 0.44 cm/week, respectively, using digital image analysis. The coefficient of determination (R^2) values for fruit length and width was 0.79 and 0.88, respectively, indicating the dependability of the estimated results. This method can be utilized to monitor the fruit's sizes, effectively replacing the tedious manual measuring procedure.

Keywords: on-tree harumanis mango; fruit size; digital image analysis

Received: 23rd July 2024

Accepted: 13th November 2025

Available Online: 21st November 2025

Published: 2nd December 2025

Citation: Zulkifli, N. A., Muttalib, M. F. A., Uda, M. N. A., *et al*. On-tree Harumanis mango fruit sizing through digital image analysis. *Adv Agri Food Res J* 2025; *6*(2): a0000614. https://doi.org/10.36877/aafrj.a0000614.

1. Introduction

Harumanis mango (MA 128) is one of the popular mango cultivars in the Malaysia due to its delightful aroma, sweetness, flavour and fine texture (Ahmad *et al.*, 2023; Uda *et al.*, 2020). The Harumanis mango shape is elongated with a curved distal end, while the skin is green in colour and typically turns yellowish green when ripe. The fruit weighs between 0.3 to 1.0 kg, has a 14° to 17° Brix value (Sani *et al.*, 2018; Yusuf *et al.*, 2020). In Malaysia, the Harumanis mango is commercially produced in Perlis with high yield due to its hot and dry weather with low precipitation climatic condition (Mohd Aziz *et al.*, 2019; Nasron *et al.*, 2021; Yusuf *et al.*, 2020). These climatic conditions are required continuously for a two-month period, usually from January to February to ensure the tree can produce healthy flowers. High precipitation during flowering stage may cause Harumanis flowers to fall and increases post-harvest diseases thus potentially disrupting fruit production (Mohd Aziz *et al.*, 2019; Nasron *et al.*, 2021). The Harumanis mango is harvested around April to June. The price of Harumanis mango can range up to USD 10/kg (Uda *et al.*, 2020), depending on supplies and demands. Recently, the production of Harumanis mango in Perlis has been reduced due to unpredictable dramatic climate changes (Talib *et al.*, 2020). Long heavy rainfall season causes Harumanis flowers to fall and increases post-harvest diseases. Unusually hot and dry temperature caused by the El Nino makes the flowers wilt before they can be pollinated thus delaying the flowering process. This phenomenon makes the Harumanis mango's size and maturity vary widely, which impacts the timing of harvest and farm management (Farook *et al.*, 2012). Therefore, plant growth monitoring such as fruit size is essential to describe the physiological responses of crop plants to environmental variables such as temperature, humidity, light intensity and atmospheric carbon dioxide concentration (Wang *et al.*, 2017).

An established method involves checking fruit size manually using a vernier scale (Durán Zuazo *et al.*, 2021). This practice involves highly subjective assessments, leading to variability, labor intensive, unpleasant and expensive. Repeated measurement using the vernier scale may cause bruising on the fruit due to frequent direct contact. Hence, linear variable differential transducers (LVDTs) technique has been used to automatically measure the fruit size, eliminating the requirement for manual labour (Cohen *et al.*, 1998; Link *et al.*, 1998; Morandi *et al.*, 2007). However, the system requires a highly sturdy support structure and precise calibration due to its high sensitivity. Alternatively, fruit size monitoring methods using machine vision and digital image analysis have been explored (Ganiron, 2014; Momin *et al.*, 2017; Spreer & Müller, 2011). This technique allows rapid and non-contact measurement of fruit size but only works on fruits that have been harvested. Researchers have developed a digital image analysis technique to evaluate fruit size in the field using a phone camera (Wang *et al.*, 2018). Nevertheless, this technique is not completely automated because an operator is required to capture the fruit image in field using an Android application. Machine vision is increasingly being used to detect fruits and count the count the quantity on tree as demonstrated by Sa *et al.* (2016), Stein *et al.* (2016) and Wang *et al.*

(2017). However, the application of machine vision and image analysis to measure the Harumanis mango size directly on a tree cultivated inside a greenhouse has rarely been explored. Thus, the aim of this work is to quantify the size (length and width) of on-tree Harumanis fruit grown in a greenhouse by digital image analysis.

In this study, a reference object of known size was included in the captured image to estimate the size of target objects by referring them to the reference scale. The impact of camera heights and distances on the accuracy of fruit size detection was evaluated. The growth rate of the on-tree Harumanis mango will be analysed. Finally, the percentage error between the actual and detected fruit dimensions was calculated for each configuration.

2. Materials and Methods

2.1 Study Location

The study was conducted at a greenhouse (GH1) located at the Institute of Sustainable Agrotechnology (INSAT), Universiti Malaysia Perlis (UniMAP), Padang Besar, Perlis, Malaysia from January to May 2019. The greenhouse is situated at coordinates N6.652826, E100.261513 and 53 meters above sea level, as depicted in Figure 1. The average plant trunk diameter was 20 ± 2 cm, and the average height was 2.4 ± 1 m. The average leaf area, length and width were 76.23 ± 4.34 cm^2, 18.5 ± 0.54 cm and 5.38 ± 0.17 cm respectively. The average plant age was 9 years.

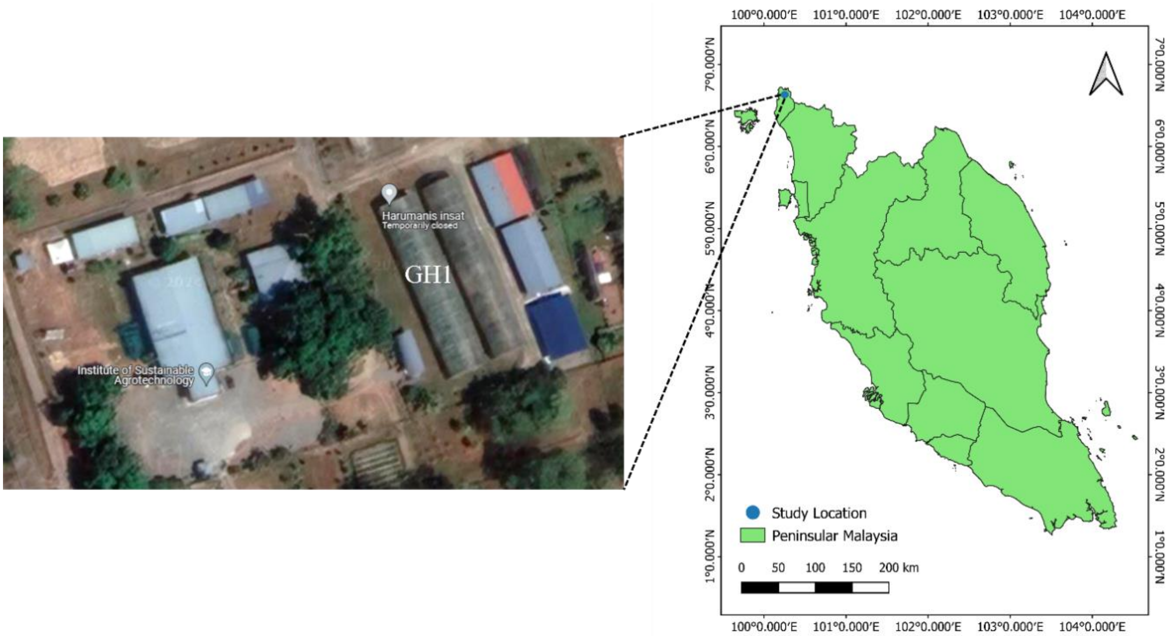

Figure 1. Location of the experimental site greenhouse GH1 located at Institute of Sustainable Agrotechnology (INSAT), Universiti Malaysia Perlis (UniMAP), Padang Besar, Perlis, Malaysia.

2.2 Digital Image Analysis

Figure 2 illustrates the image analysis processes used to determine the fruit size in this study. The process consists of five steps: image acquisition, image pre-processing, image segmentation, feature extraction, and fruit size measurement.

Figure 2. The flowchart of image analysis performed in this work.

Pre-processing can optimize image quality and enhance computational efficiency. Pre-processing aims to minimize image variance while retaining essential information. Multiple sources of variation occur during image acquisition (Hsu & Wang, 2015). Segmentation involves dividing an image into its individual parts or objects (H. D. Cheng *et al.*, 2001; Pal & Pal, 1993). It differentiated items of interest from those related to the context, like optical character recognition (OCR) systems. Feature extraction technique is utilized to differentiate between several photos. These features could be used for images matching, information processing and detection. Feature selection and extraction efficiency and efficacy are currently demanding (Kumar & Bhatia, 2014). The images of Harumanis mango were captured with a smartphone camera (Oukitel U20 Plus) at various distances (1, 2, and 3 m) and heights (0.5, 1, and 1.5 m) and saved in JPEG format for further image processing. Table 1 lists the smartphone camera technical specification. The study analysed images from an Oukitel U20 Plus smartphone camera without any pre-processing or filtering techniques. The images were captured in natural ambient light conditions without High Dynamic Range (HDR) or exposure modifications and without applying software noise reduction or geometric corrections. The chosen method maintains the device's inherent image properties but results in reduced measurement precision because correction techniques are not used.

Table 1. Oukitel U20 Plus camera technical specifications.

Sensor Model	Nominal Focal Length (mm)	Sensor Resolution (pixels)	Pixel Size (µm)	Physical Dimensions of the Sensor (mm)
Sony IMX135 Exmor RS	4	4160 × 3120	1.127	4.69 × 3.52

In this study, to eliminate potential perspective distortion, the smartphone camera was mounted on an adjustable stand, and the imaging plane was carefully aligned parallel to the plane of the fruit by adjusting the mount accordingly before capturing the image. The red colour scale paper with known dimensions of 10 × 10 cm was positioned in the same reference plane as the fruit to during image capture for real size calibration as shown in Figure 3. The effectiveness of this approach has been demonstrated in various studies of fruit size measurements (H. Cheng *et al.*, 2017; Neupane *et al.*, 2023; Wang *et al.*, 2018). The conversion of pixel measurements to real dimension units can be determined using Equation 1.

Scale ratio = known actual value in cm / known actual value in pixel (1)

Figure 3. Image of on-tree Harumanis mango with the red colour reference scale paper (10 × 10 cm).

The dimensions of Harumanis mango were measured using a digital vernier caliper, specifically in terms of length and width. The captured images of Harumanis mango were analysed using the MATLAB software. First, the image of Harumanis mango was transformed from RGB into HSV color space. The background was removed by color thresholding based on manually identified H, S and V values in the pre-processing steps (Park & Lu, 2015) as shown in Figure 4(a). The remaining branch and leaf were further removed using the 'bwareopen' function (Figure 4(b)). Then, the 'regionprops' function was used to measure the properties of image such as centroid area, bounding box, pixel list, eccentricity, orientation and solidity. The object's solidity was set to be more than 0.5 to further exclude image noise. Finally, red bounding boxes were displayed on the original image to indicate the detected fruits (Figure 4(c)).

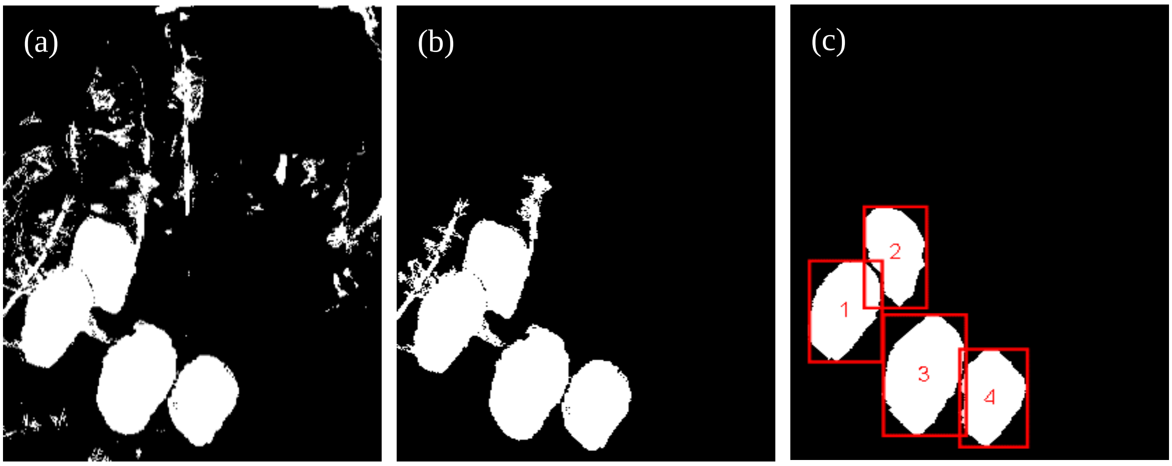

Figure 4. (a) Black and white image after background was removed; (b) after branch and leaf were removed using 'bwareaopen' function; (c) noise removal using 'regionprops' function and red bounding box was displayed on the detected fruits.

The size of bounding box in horizontal and vertical direction in pixels was converted to estimate width and length of fruit size (cm) respectively using predetermined scale ratio provided in Equation 2 and Equation 3.

$$FW\_size\ (cm) = D_{BB} \text{ in horizontal (pixel)} \times \text{Scale ratio (horizontal)} \quad (2)$$

$$FL\_size\ (cm) = D_{BB} \text{ in vertical (pixel)} \times \text{Scale ratio (vertical)} \quad (3)$$

where FW is fruit width, FL is fruit length and D_{BB} is distance of bounding box.

In this study, only one sample of on-tree Harumanis mango (labelled as No. 3), as depicted in Figure 4(c), was analysed weekly, as the other fruits were not clearly visible due to occlusion. To enhance measurement reliability and consistency, all images in this study were captured between 8:00 AM and 10:00 AM under natural ambient lighting, ensuring the most uniform illumination conditions possible.

3. Results and Discussions

3.1 Fruit Size Detection Accuracy

Figure 5(a) shows the percentage error in fruit length measurements, and Figure 5(b) shows the percentage error in width measurements, based on various camera heights and distances. The results emphasize the significant impact of camera placement on measurement precision. The minimum percentage error in length measurement, 1.16%, occurred when the camera was positioned 2 meters away and 1 meter above the actual fruits. The width measurement has a minimum percentage error of 0.22% using the identical camera arrangement. The results indicate that the precise placement of the camera is essential for improving the precision of fruit size identification. The low percentage of errors detected suggests that positioning the camera 2 m away and 1 m high from the fruits is effective. This setup probably offers the best view and clarity for accurately measuring fruit sizes in this work. The low percentage errors indicate the strength of the image processing method used in the detecting procedure.

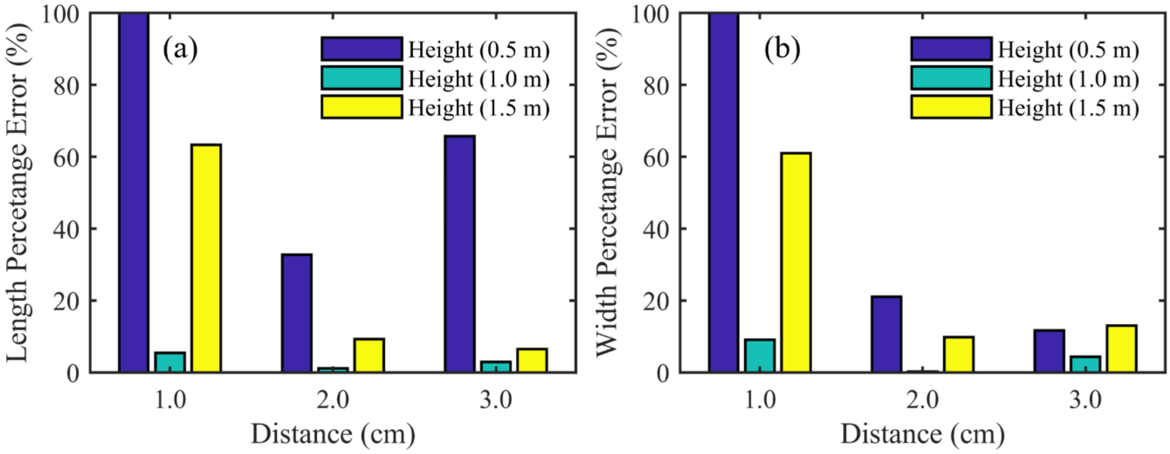

Figure 5. Percentage error between actual and detected fruits (a) length and (b) width respectively for various camera height and distance position from the actual fruits.

Figure 6 shows the fruit size in length and width estimated by using digital image analysis with the distance and height of camera from the fruits were 2 and 1 m respectively for about 5 weeks.

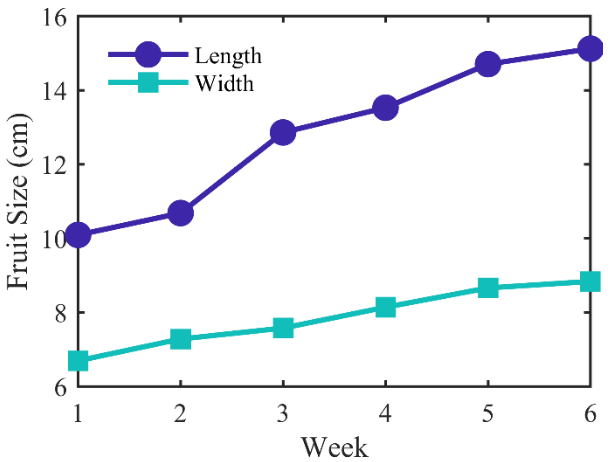

Figure 6. Fruit size length and width against number of weeks.

The result shows that the length and width size has increased over the number of weeks. The average growth rate of width and length estimated by using digital image analysis for a week is around 1 and 0.44 cm respectively. This finding is consistent with the results reported by Weng *et al.* (2018), although some variation in growth parameters was observed.

In the present study, the average fruit growth rate was 1.43 mm/day in width and 0.63 mm/day in length, whereas Weng *et al.* (2018) reported growth rates of 0.9 mm/day for width and 1.0 mm/day for length. This variation is maybe due to differences in mango variety between the two studies.

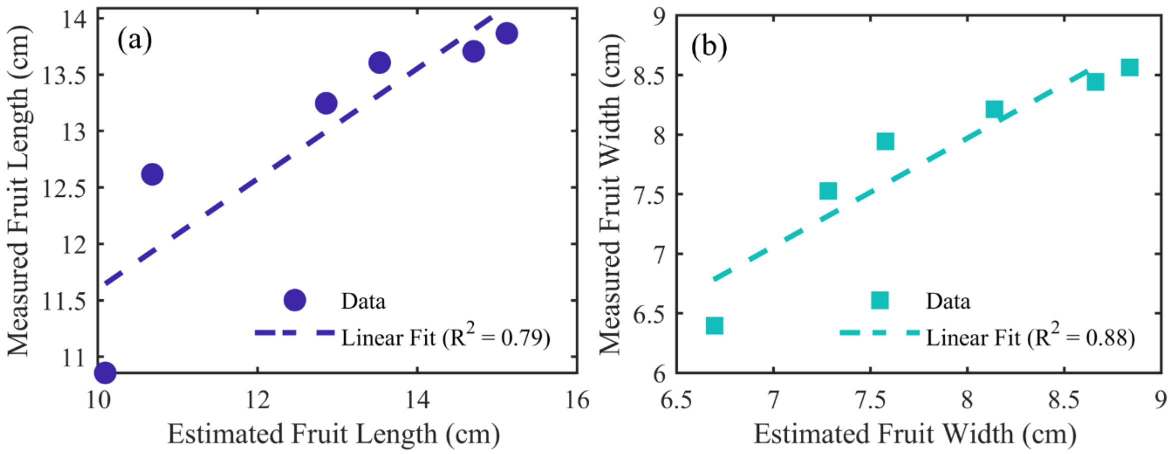

Figure 7. (a) Relationship between measured fruit length and estimated fruit length; (b) Relationship between measured fruit width and estimated fruit width.

The comparisons between the measured (manual measurement) and estimated (digital image analysis) length and width of Harumanis fruit size are illustrated in Figure 7(a) and Figure 7(b) respectively. The coefficient of determination (R^2) values for the fruits length and width is 0.79 and 0.88, respectively, suggesting that the estimated results are acceptable. This implies that the digital image analysis technique produces reasonably accurate assessments of the Harumanis fruits' dimensions. The R^2 obtained in this study is slightly lower than those reported in similar studies estimating on-tree mango fruit size using smartphone cameras. The referenced studies reported R^2 values of 0.92 and 0.90 for fruit length and width, respectively (Wang *et al.*, 2018). However, those studies were conducted at shorter camera-to-fruit distances, typically between 12 and 30 cm, under ambient lighting conditions. In contrast, our study was performed at a significantly longer distance of 2 meters, which may have contributed to the reduced accuracy.

However, this study's findings have reduced broader applicability because they are based on tests using only one smartphone model (Oukitel U20 Plus). The proposed measurement method proves effective and feasible under controlled conditions but its application to additional smartphone models is still unconfirmed. Measurement accuracy and segmentation performance can be affected by differences in camera specifications including sensor resolution and internal image processing algorithms along with lens geometry. This study establishes a preliminary evaluation framework for the proposed method; however, further research is necessary to assess its robustness and generalizability across different smartphone models. Furthermore, enhancing the accuracy of this technique could be achieved by ensuring uniform illumination conditions during image collecting, as emphasized by Wang *et al.* (2017). Furthermore, larger sample sizes in future may enhance the robustness of the analysis.

4. Conclusions

In this work, distance and height of the camera from the fruits were determined to be 2 meters and 1 meter respectively, with a percentage error of 1.16% for length and 0.22% for width. The average growth rate of length and width, determined using digital image analysis over a week, is around 1 and 0.44 cm, respectively. The correlation coefficient for fruit size length and width between the conventional approach and digital image analysis was found to be 0.79 and 0.88 respectively. This method can be utilized to monitor the fruit's dimensions, effectively replacing the tedious manual measuring procedure.

Author Contributions: "Conceptualization, Muhammad Firdaus Abdul Muttalib.; methodology, N. A. Zulkifli.; validation and formal analysis, Muhammad Firdaus Abdul Muttalib, N. A. Zulkifli., S.R.S. Kamaruzaman, A.A. Nordin, F.A. Azizan and Mohd Fauzie Jusoh.; resources, Muhammad Firdaus Abdul Muttalib.; writing—original draft preparation, N. A. Zulkifli.; writing—review and editing, Muhammad Firdaus Abdul Muttalib, M.N.A. Uda, Z.A. Arsat, F. Abdullah, M.K.R. Hashim and Mohd Fauzie Jusoh.

Funding: "External funding was provided for this research"

Acknowledgments: The author would like to acknowledge the support from the Fundamental Research Grant Scheme (FRGS) under a grant number of FRGS/1/2021/WAB04/UNIMAP/02/1 from the Ministry of Higher Education Malaysia.

Conflicts of Interest: "The authors declare no conflict of interest."

References

Ahmad, N. A., Muttalib, M. F. A., Uda, M. N. A., *et al.* (2023). Measurement of leaf chlorophyll content in Harumanis mango cultivated in a greenhouse using SPAD meter. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2023.01.174

Cheng, H. D., Jiang, X. H., Sun, Y., *et al.* (2001). Color image segmentation: Advances and prospects. *Pattern Recognition*, *34*(12). https://doi.org/10.1016/S0031-3203(00)00149-7

Cheng, H., Damerow, L., Sun, Y., *et al.* (2017). Early yield prediction using image analysis of apple fruit and tree canopy features with neural networks. *Journal of Imaging*, *3*(1). https://doi.org/10.3390/jimaging3010006

Cohen, M., Savé, R., Biel, C., *et al.* (1998). Simultaneous measurements of water stress with LVDT sensors and electrotensiometers: application in pepper plants grown in two types of perlites. *Acta Horticulturae*, *421*, 193–200. https://doi.org/10.17660/ActaHortic.1998.421.20

Durán Zuazo, V. H., Tarifa, D. F., Rodríguez, B. C., *et al.* (2021). Mango fruit quality improvements in response to water stress: Implications for adaptation under environmental constraints. *Horticultural Science*, *48*(1), 1–11. https://doi.org/10.17221/45/2020-HORTSCI

Farook, R. S. M., Hallis, A., Aziz, A., *et al.* (2012). *Data Mining on Climatic Factors for Harumanis Mango Yield Prediction*. 115–119. https://doi.org/10.1109/ISMS.2012.51

Ganiron, T. U. (2014). Size properties of mangoes using image analysis. *International Journal of Bio-Science and Bio-Technology*, *6*(2). https://doi.org/10.14257/ijbsbt.2014.6.2.03

Hsu, T. S., & Wang, T. C. (2015). An improvement stereo vision images processing for object distance measurement. *International Journal of Automation and Smart Technology*, *5*(2). https://doi.org/10.5875/ausmt.v5i2.460

Kumar, G., & Bhatia, P. K. (2014). A detailed review of feature extraction in image processing systems. *International Conference on Advanced Computing and Communication Technologies, ACCT*. https://doi.org/10.1109/ACCT.2014.74

Link, S. O., Thiede, M. E., & Van Bavel, M. G. (1998). An improved strain-gauge device for continuous field measurement of stem and fruit diameter. In *Journal of Experimental Botany* (Vol. 49, Issue 326). https://academic.oup.com/jxb/article/49/326/1583/532161

Mohd Aziz, R., Shaidatul, A. A. T., Fauzi, J., *et al*. (2019). Physiological responses, nutrient content and fruit quality of mango (*Mangifera indica L.*) cv. Harumanis at different agro-climatic zones. *28th Malaysian Society of Plant Physiology Conference (MSPPC 2018), Challenges and Strategies for Plant Productivity and Resilience, Kelantan, Malaysia, 28-30 August 2018, January*.

Momin, M. A., Rahman, M. T., Sultana, M. S., *et al.* (2017). Geometry-based mass grading of mango fruits using image processing. *Information Processing in Agriculture*, *4*(2). https://doi.org/10.1016/j.inpa.2017.03.003

Morandi, B., Manfrini, L., Zibordi, M., *et al.* (2007). A low-cost device for accurate and continuous measurements of fruit diameter. *HortScience*, *42*(6). https://doi.org/10.21273/hortsci.42.6.1380

Nasron, N., Ghazali, N. S., Shahidin, N. M., *et al*. (2021). Soil suitability assessment for harumanis mango cultivation in UiTM Arau, Perlis. *IOP Conference Series: Earth and Environmental Science*, *620*(1). https://doi.org/10.1088/1755-1315/620/1/012007

Neupane, C., Pereira, M., Koirala, A., *et al*. (2023). Fruit Sizing in Orchard: A Review from Caliper to Machine Vision with Deep Learning. *Sensors*, *23*(8), 3868. https://doi.org/10.3390/s23083868

Pal, N. R., & Pal, S. K. (1993). A review on image segmentation techniques. *Pattern Recognition*, *26*(9). https://doi.org/10.1016/0031-3203(93)90135-J

Park, B. & Lu, R. (2015). Hyperspectral imaging technology in food and agriculture. In *Hyperspectral Imaging Technology in Food and Agriculture*. https://doi.org/10.1007/978-1-4939-2836-1

Sa, I., Ge, Z., Dayoub, F., *et al*. (2016). Deepfruits: A fruit detection system using deep neural networks. *Sensors (Switzerland)*, *16*(8). https://doi.org/10.3390/s16081222

Sani, M. A., Abbas, H., Jaafar, M. N., *et al*. (2018). Morphological Characterisation of Harumanis Mango (*Mangifera indica Linn*.) in Malaysia. *International Journal of Environmental & Agriculture Research*, *4*(1).

Spreer, W., & Müller, J. (2011). Estimating the mass of mango fruit (*Mangifera indica*, cv. Chok Anan) from its geometric dimensions by optical measurement. *Computers and Electronics in Agriculture*, *75*(1). https://doi.org/10.1016/j.compag.2010.10.007

Stein, M., Bargoti, S., & Underwood, J. (2016). Image based mango fruit detection, localisation and yield estimation using multiple view geometry. *Sensors (Switzerland)*, *16*(11). https://doi.org/10.3390/s16111915

Talib, S. A. A., Hassan, M. H. M., Rashid, M. A., *et al.* (2020). Effects of Environmental Temperature and Precipitation Pattern on Growth Stages of *Magnifera indica* cv. Harumanis Mango. *Journal of Agricultural Science*, *12*(12), 26. https://doi.org/10.5539/jas.v12n12p26

Uda, M. N. A., Gopinath, S. C. B., Hashim, U., *et al.* (2020). Harumanis Mango: Perspectives in Disease Management and Advancement using Interdigitated Electrodes (IDE) Nano-Biosensor. *IOP Conference Series: Materials Science and Engineering*, *864*(1). https://doi.org/10.1088/1757-899X/864/1/012180

Wang, Z., Koirala, A., Walsh, K., *et al.* (2018). In field fruit sizing using a smart phone application. *Sensors (Switzerland)*, *18*(10). https://doi.org/10.3390/S18103331

Wang, Z., Walsh, K. B., & Verma, B. (2017). On-tree mango fruit size estimation using RGB-D images. *Sensors (Switzerland)*, *17*(12). https://doi.org/10.3390/s17122738

Yusuf, S. N. A., Rahman, A. M. A., Zakaria, Z., *et al.* (2020). Morphological variability identification of harumanis mango (*Mangifera indica l.*) harvested from different location and tree age. *Tropical Life Sciences Research*, *31*(2). https://doi.org/10.21315/tlsr2020.31.2.6