Morphological Characterisation of Harumanis Mango (*Mangifera indica* Linn.) in Malaysia

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Abstract**—***Harumanis is a very popular green eating mango variety which has been planted commercially in the State of Perlis, Malaysia. However, several variations such as fruit shape and tree architecture which are apparent on field have caused confusing to the farmers as well as consumers of the 'genuine' Harumanis. This study was designed to observe the variation among Harumanis population at several locations in Malaysia. Samples were classified into two treatments based on their tree architecture: droop Harumanis and erect Harumanis. The samples were collected from six farmers' plot in Perlis, Kedah and Johor. Samples were subjected to fruit quality and branch strength analysis. Fruit quality characterisations and branch strength analysis revealed significant variation among treatments. Fruits harvested from droop Harumanis tree was bigger than erect Harumanis. Droop Harumanis fruit samples recorded higher value for relative water content, moisture content and modulus of elasticity while erect Harumanis recorded higher value for fresh-weight basis density and modulus of rupture. This study indicated that morphological characterisations play an important role in determining phenotypic variation in inter-variety population including Harumanis.*

Keywords**—*****branch strength analysis, fruit quality analysis, Harumanis, Mangifera indica L., modulus of rupture.***

I. INTRODUCTION

The mango (*Mangiferaindica* L.) is among the widely grown tropical and subtropical fruit of the world including Malaysia and is a diploid fruit tree with 2n = 40 chromosomes[1], [2]. Until 2016, there was about 5,816.4 hectare of mango cultivation in Malaysia with 17,429.7 metric tonne of production worth more than RM57 million [3]. There are several varieties of mango grown in Malaysia; the better known cultivars are Golek (MA 162), Masmuda (MA 204), Maha 65 (MA 165), Chok Anan (MA 224), Nam Dok Mai (MA 223), Sala and Harumanis. Harumanis among them, the most popular clone, which was registered as MA128 by the Department of Agriculture, Malaysia [4], [5], yielding at 2.69 tonne/ha in 2014 [6]. As described by JabatanPertanian Malaysia (2015), the fruit shape of Harumanis is oblong, has a prominent beak, the skin colour is green with a little bit of glossy and will turn to yellowish green when ripen, the fruit size varies ranging from 300 to 650 gram, has 16-17°Brix and the flesh is orange colour and sweet. Harumanis is very suitable for the export market as it has desirable colour and sweetness and good eating quality with good aroma [7].

Harumanis was believed to be originated from Indonesia and being domesticated in Malaysia ever since it was registered by the Department of Agriculture, Malaysia on May 28, 1971 [4]. Like many other cultivars derived from South East Asia, Harumanis is polyembryonic, i.e. the seeds have nucellar embryos that are genetically identical to the mother plant [8]. Because of this, polyembryonic cultivars have generally been propagated by seed and Harumanis is no exception to this rule. A viable zygotic embryo is also present in the seed of some polyembryonic mango cultivars [8]. As reported by Schnell & Knight (1992), the number of zygotic off types in seedling populations varied and can be as high as 64% in the cultivar Golek and as low as 0% in the Israeli cultivar 13-1.

Harumanis is well accepted by Malaysians and were planted by many as well as by commercial planters. In the state of Perlis alone, 1,037 hectare of land were planted with Harumanis [10]. However, a few reports by the growers of Harumanis in Perlis indicated that there are variations in term of fruit size, flesh colour and number of fruits per panicle (Mohd Azhar Hassan, personal communication, October 6, 2017). There are some cases where the growers found that the flesh colour of matured Harumanis fruits are yellow instead of orange. This phenomenon is not new in mango cultivation. There were reports of identification of intra-cultivar variation in mango such as in Sala [5], Chok Anan [11], Indian mango [12] and Kensington mango [8]. Khan, Ali, & Khan (2015) also reported that extensive differences exist among mango genotypes of the similar clones in any particular orchard, specifically with the respect to fruit shape, size, colour, aroma, flavour eating quality and texture in which, usually caused by either outcrossing or natural mutations. The presence of fruits in the evaluation of morphological variations in fruit crop is crucial. Nevertheless, in off fruiting season, breeders still need to identify dissimilarity among mango varieties/cultivars. Therefore, other morphological characteristics namely differences in tree architecture type need to be defined. A basic knowledge of the strength properties of mango wood such as moisture content, bending strength, elasticity and etc. are essential and interesting to explore. There is a need to study the variations in Harumanis population whether the variations, if any, could lead to economic and social importance, as well as to the scientific values. Morphological characters evaluation is the first step that should be carried out before advanced biochemical or molecular studies are carried out. Hence, justify the objective of this study.

Generally, morphological characterisation is an evergreen methodology that uses the ocular estimate method with the help of several qualitative and quantitative measuring tools to score and distinguish tropical fruits including mangoes. The characters include tree height, growth habit, flowering pattern, disease resistant, inflorescence shape, colour and type of flowers, fruit shape and shape, shoulder position and type of seeds i.e. monoembryonic or polyembryonic.

II. MATERIAL AND METHOD

2.1 Plant Materials and Fruit Quality Analysis

Throughout this experiment, Harumanis plants were classified into two main category based on its tree architecture namely; droop and erect type (Fig. 1) as described by IPGRI (2006). Samples were collected from six farmers' plots in Perlis, Kedah and Johor. This experiment was divided to two sub-experiments which required two different types of samples. Sub-experiment 1 was conducted to evaluate fruit quality of selected Harumanis. Meanwhile in sub-experiment 2, the branch strength of selected Harumanis plants were studied.

FIGURE 1: TREE ARCHITECTURE OF TWO DIFFERENT TYPE OF HARUMANIS I.E. DROOP HARUMANIS (LEFT), AND ERECT HARUMANIS (RIGHT).

Matured fruits were harvested and artificially ripened by using calcium carbide prior to evaluation. Five fruits per plant were collected randomly and were analysed in the laboratory for various physico-chemical traits such as fruit weight (g), skin weight (g), flesh weight (g), fruit length (mm), fruit diameter (mm), fruit length-to-diameter ratio, flesh recovery (%) and total soluble solids (TSS) (°Brix) following standard analytical procedures. Fruit length to diameter ratio was defined by the length of the fruit divided by the diameter of the fruit. Flesh recovery was calculated by the weight of the flesh divided by total weight of the fruit multiplied by 100.

2.2 Branch Strength Analysis

Two separate sets of samples were obtained for static bending properties and basic density test. Samples were collected from various farmers' farms in Perlis, Kedah, and Johor. Both tests were done with the actual form of stems i.e. no moulding to the samples. For basic density test, 20 cm in length with diameter ranging from 15 to 20 mm test pieces, were harvested from selected live trees from different places for both types of tree architecture. Cut ends of the stems were coated with wax to prevent moisture loss. Moisture content and specific gravity of the test pieces was measured based on ASTM D1037-99 (1999). Specific gravity was computed from the weight and dimensions of the test pieces on a dry-weight basis. Moisture content and specific gravity were calculated as follows:

$$M = 100\left[\frac{(W-W_f)}{W_f}\right]. \quad (1)$$

where M is the moisture content (%), W is the initial weight (g) of the harvested branch measures on-site, and W_f is the weight of branch measures before the static bending test.

$$sp\ gr = \frac{KF}{L(\pi r^2)} \quad (2)$$

where F is the final weight when oven dry (g), L is the length of test specimen (mm), r is the radius of test specimen (mm) and K = 1, when SI units of weight and measurement are used.

Other parameter calculated in basic density test was relative water content, RWC, as mentioned by Kirkham (2014) and the formula is as follows:

$$RWC = \left[\frac{(fresh\ weight - dry\ weight)}{(turgid\ \ weight - dry\ weight)}\right] \times 100 \qquad (3)$$

Static bending properties was tested according to ASTM D 1037-99 (1999). Modulus of rupture (MOR) and modulus of elasticity (MOE) were determined in a static bending test on 20 cm in length and 15 to 20 mm diameter of fresh branches using Instron 5569 50kN Universal Testing Machine at a loading rate of 6.1 mm min^{-1}[16]. The test pieces were loaded to failure in a three-point loading over a span of 100 mm.

The MOR were calculated using Equation (4):

$$\sigma = \frac{3PL}{2(\pi d^3)} \qquad (4)$$

The MOE was calculated using Equation (5):

$$E = \frac{0.5PL^3}{\pi d^3} \qquad (5)$$

where P is the maximum load (N), L is the distance (mm) between the support span, and d is the branch diameter (mm).

Density for static bending test was calculated on a fresh-weight basis using formula as follows [17]:

$$\rho = \frac{m}{V} \qquad (6)$$

where m is the mass of test specimen (g) and V is the volume of test specimen (cm^3).

2.3 Statistical Analysis

Data were analysed by using the SAS® University software version 9.4 and were subjected to one-way analysis of variance (ANOVA) and means were separated by Student-Newman-Keuls (SNK).

III. RESULTS AND DISCUSSION

3.1 Fruit Quality Analysis

All fruit samples from both type of droop and erect Harumanis were subjected to physico-chemical traits i.e. fruit weight, skin weight, flesh weight, fruit length, fruit diameter, fruit length-to-diameter ratio, flesh recovery and TSS. The analysis of variance showed no significant different between the treatments with fruit weight, skin weight, flesh weight, flesh recovery and TSS. However, significant differences were observed between treatments for fruit length and fruit length-to-diameter ratio (Table 1).

TABLE 1
MEAN SQUARES FROM ANOVA FOR FRUIT QUALITY ATTRIBUTES IN HARUMANIS POPULATION

Sources	Df	Fruit Weight (g)	Skin Weight (g)	Flesh Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit Length-to-Diameter Ratio	Flesh Recovery (%)	TSS (°Brix)
Variants	1	8847.90	206.08	5557.13	3598.57 **	1.95	0.48 **	1.51	2.68
Rep	25	6248.51	180.84	4175.30	165.18	17.23	0.02	7.27	2.80
Mean		478.02	89.21	344.39	126.88	83.19	1.53	71.96	19.38
CV		14.53	17.94	14.59	13.41	5.58	12.11	4.07	8.86

*****Significantly different at P≤0.01***

Results on mean of studied pyhsico-chemical traits are shown in Table 2. It shows that there was variation in fruit size of Harumanis. Based on description by IPGRI (2006), fruits from droop Harumanis is in obovoid shape while fruits from erect

Harumanis is roundish shape (Fig. 2) as reflected from the findings of fruit length and fruit length-to-diameter ratio. Fruit length-to-diameter ratio was used as a referral to fruit shape. Droop Harumanis' fruits are longer (135.20 mm) than fruits from erect type (118.56 mm). The most prominent feature of Harumanis mango is the formation of a slight projection which develops laterally at proximal end of the fruit, usually known as the "beak" by the locals. Both droop and erect Harumanis have this beak (Fig. 2). The topic of fruit growth and development may be influenced by genes, proteins as well as agronomic practices, climate and other mechanical processes that specify or affect the fruit formation and development. Plants compromised in photosynthesis, phloem transport, floral initiation and development, or male or female fertility either cannot produce fruit or are abnormal in their fruit production i.e. parthenocarpic fruit, reduced fruit size, or reduced fruit load [18]. Khan et al. (2015) also reported that even if a variety of mango being grown in the same region, its quality will be affected by different environmental.

TABLE 2
MEANS OF FRUIT WEIGHT, SKIN WEIGHT, FLESH WEIGHT, FRUIT LENGTH, FRUIT DIAMETER, FRUIT-LENGTH-TO-DIAMETER RATIO, FLESH RECOVERY AND TSS IN HARUMANIS POPULATION

Tree Architecture Type	Fruit Weight (g)	Skin Weight (g)	Flesh Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit Length-to-Diameter Ratio	Flesh Recovery (%)	TSS (°Brix)
Droop	491.06a	91.20a	354.73a	135.20a	83.39a	1.62a	72.13a	19.16a
Erect	464.97a	87.22a	334.06a	118.56b	82.99a	1.43b	71.79a	19.61a

Means within column followed by the same letters are not significantly different at p=0.05.

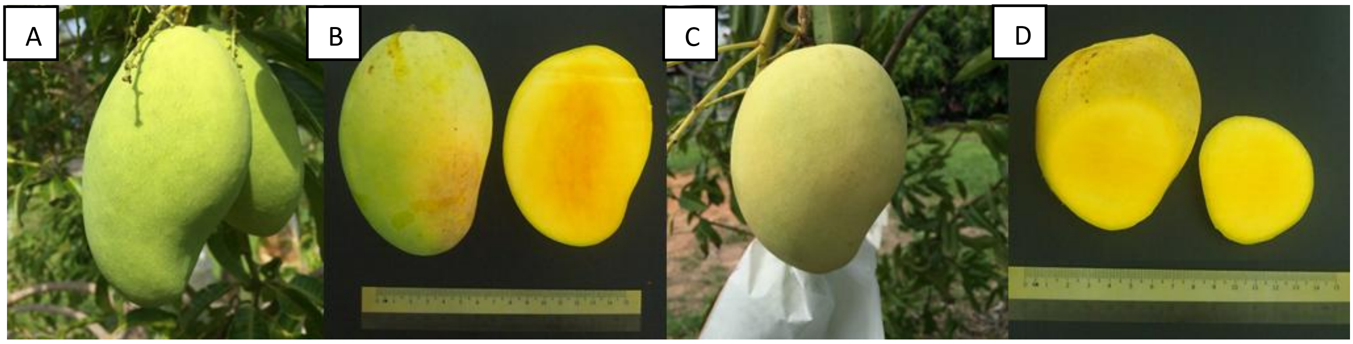

FIGURE 2: FRUIT FROM TWO DIFFERENT TYPE OF HARUMANIS I.E. DROOP HARUMANIS (A) & (B), AND ERECT HARUMANIS (C) & (D).

3.2 Branch Strength Analysis

Stem traits emerge as important plant functional traits, even for fruit trees, because of their role for stability, defence, architecture, hydraulics, carbon gain and growth potential, hence justify this experiment. Two sub-experiments were conducted to study branch strength of droop and erect Harumanis i.e. basic density test and static bending properties. Branch strength analysis were divided into those sub-experiments because they involved destructive analysis.

Data from ANOVA showed that for basic density test, there was no significant different for stem diameter and specific gravity, but significant differences were observed between treatments in relative water content (RWC) and moisture content (Table 3). Results on mean of stem diameter, RWC, specific gravity and moisture content are shown in Table 4. Droop Harumanis recorded higher percentage of RWC and moisture content (17.23% and 177.87% respectively) than erect Harumanis (17.05% and 151.31% respectively). RWC compares the water content of a stem with the maximum water content at full turgor and take into consideration the quantity of water in the plant. However, two different species may have the same RWC values with different amounts of water in their leaves (Ceccato et al.,2001). Malavasi et al. (2016) noted that variations in wood stem water content are generally related to environment such as rainfall factor as well as agricultural practices. Zziwa et al. (2016) and Malavasi et al. (2016) reported that the biological properties of biological materials such as wood and mechanisms of internal water influx regulation, vary within and among tree and species. This is attributed partly to differences in phenotypic and genetic composition.

TABLE 3
MEAN SQUARES FROM ANOVA FOR STEM DIAMETER, RWC, SPECIFIC GRAVITY AND MOISTURE CONTENT OF SELECTED HARUMANIS ACCESSIONS.

Sources	df	Stem Diameter (mm)	RWC(%)	Specific Gravity	Moisture Content (%)
Treatments	1	2.28	172.01**	0.0019	5641.61**
Rep	15	0.68	19.45	0.0011	217.28
Mean		16.34	91.23	0.51	164.59
CV		5.83	4.17	13.28	11.89

***** Significantly different at p≤0.01***

TABLE 4
MEANS FOR STEM DIAMETER, RWC, SPECIFIC GRAVITY AND MOISTURE CONTENT OF SELECTED HARUMANIS ACCESSIONS.

Treatment	Stem Diameter (mm)	RWC(%)	Specific Gravity	Moisture Content(%)
Droop	16.61a	17.23a	0.52a	177.87a
Erect	16.08a	17.05b	0.50a	151.31b

Means within column followed by the same letters are not significantly different at p=0.05.

Zziwa et al. (2016) noted that wood density is a measure of the cell wall material per unit volume and there it is a very good indicator of the strength properties. However, density alone is not a reasonable basis for estimating strength properties of wood, hence MOR and MOE needed to be examined. For static bending test properties, results from ANOVA showed that significant differences were observed between treatments and density, modulus of rupture (MOR) and modulus of elasticity (MOE) (*Table 5*). The results of Student-Newman-Keuls tests indicated significant differences (P< 0.05) in density, MOR and MOE of droop and erect Harumanis. Erect type of Harumanis showed higher value in density and MOR but less elasticity than droop type of Harumanis (*Table 6*). The mean density and MOR for erect Harumanis was 1.33 g/cm^3 and 58.92 MPa while 1.24g/cm3 and 48.28 MPa were recorded for droop Harumanis' density and MOR. Interestingly, droop Harumanis showed higher value for MOE (7926.50 MPa) compared to erect Harumanis (5723.75 MPa). Malavasi et al. (2016) reported that plants with high wood density have xylem conduits less susceptible to cavitation. The extent in which wood plant species can conduct water and resist xylem cavitation in the stem is determined by vessel adaptation. Failure of the conductive tissue to resist high negative pressures can result in collapse of the conduit walls resulting in cavitation. Joly & Zaerr (1987) in their report said that increased in cell-wall water content may modify the viscoelasticity properties of cell wall explaining our findings on droop and erect Harumanis. Furthermore, the elastic modulus of the wood decreases with water content, such that excessive water withdrawal from the stem could affect mechanical stability [22].

TABLE 5
MEAN SQUARES FROM ANOVA FOR DIAMETER, DENSITY, WEIGHT TO DIAMETER RATIO, MODULUS OF RUPTURE, AND MODULUS OF ELASTICITY OF SELECTED HARUMANIS ACCESSIONS.

Sources	df	Stem Diameter (mm)	Density (g/cm^3)	Weight to Diameter Ratio	Modulus of Rupture (MPa)	Modulus of Elasticity (MPa)
Treatments	1	2.63	0.07*	0.10	9059194.08*	38816992.70**
Rep	15	4.81	0.03	0.28	984060.10	7505152.30
Mean		18.61	1.29	2.82	53.61	6825.13
CV		13.35	9.55	17.38	25.53	34.60

**** Significantly different at p≤0.05***

TABLE 6
MEANS FOR DIAMETER, DENSITY, WEIGHT TO DIAMETER RATIO, MODULUS OF RUPTURE, FLEXURE STRESS AND MODULUS OF ELASTICITY OF SELECTED HARUMANIS ACCESSIONS.

Treatment	Stem Diameter (mm)	Density (g/cm^3)	Weight to Diameter Ratio	Modulus of Rupture (MPa)	Modulus of Elasticity (Mpa)
Droop	18.90a	1.24b	2.77a	48.28b	7926.50a
Erect	18.32a	1.33a	2.88a	58.92a	5723.75b

Means within column followed by the same letters are not significantly different at p=0.05.

IV. CONCLUSION

A conclusion section must be included and should indicate clearly the advantages, limitations, and possible applications of the paper. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.There are rooms for Harumanis improvement through breeding as there are a good collection of variants that could be used as parents or shall be introduced as new variant in Harumanis cultivation. Although identification and evaluation of mango varieties/cultivars is quite possible with morphological characterisation, but the markers also have certain limitation especially in such cases when the cultivars are differentiated on the basis of growth habit, panicle, fruit characteristics [13]. In this study, significant differences were observed for fruit length, fruit-length-to-diameter ratio, stem RWC and moisture content, fresh-weight basis stem density, stem MOR and MOE. Morphological characters alone cannot really define whether the variation among cultivars/varieties exist at DNA level as phenotypic traits may affected by different environmental and growing conditions. In conclusion, droop and erect Harumanis showed a little variation phenotypically. However, thorough evaluation with modern approaches such as the use of Chroma meter to record flesh and skin colour, and molecular markers to differentiate variants at DNA level should be used in future.

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REFERENCES

[1] D. N. Kuhn *et al.*, "Genetic Map of Mango: A Tool for Mango Breeding.," *Front. Plant Sci.*, vol. 8, p. 577, 2017.
[2] S. K. Mukherjee, "Origin of mango (*Mangifera indica*)," *Econ. Bot.*, 1972.
[3] Department of Agriculture, *Fruit Crops Statistic of Malaysia*. Putrajaya, Malaysia, 2016.
[4] Jabatan Pertanian Malaysia, *Senarai klon buah-buahan yang didaftarkan oleh Jabatan Pertanian Semenanjung Malaysia*. Kuala Lumpur, Malaysia: Jabatan Pertanian Malaysia, 1995.
[5] J. Sarip, "Pembaikan mangga (*Mangifera indica*) var. Sala dari populasi pokok pendebungaan terbuka," in *National Horticulture Conference*, 1999, pp. 123–131.
[6] Jabatan Audit Negara Malaysia, "Laporan Ketua Audit Negara," Putrajaya, Malaysia, 2014.
[7] M. F. Mohd Mokhtar, "Mango (Harum Manis) Quality Grading System," Tun Hussein Onn University of Malaysia, 2014.
[8] I. S. E. Bally, G. C. Graham, and R. J. Henry, "Genetic diversity of Kensington mango in Australia," *Aust. J. Exp. Agric.*, vol. 36, no. 2, pp. 243–247, 1996.
[9] R. J. Schnell and R. J. Knight, "Frequency of Zygotic Seedlings from Five Polyembryonic Mango Rootstocks," *Hort. Sci.*, vol. 27, no. 2, pp. 174–176, 1992.
[10] Universiti Malaysia Perlis, "Sistem Pemantauan PSPM 2015," 2017. [Online]. Available: http://epspm.unimap.edu.my/EPSPM_V1/PSPM_ini_viewinitiative_luar.jsp?indikatorid=2&indidesc=KDNK Sektor Pertanian. [Accessed: 26-Nov-2017].
[11] H. Mohd Azhar, S. Mohd Asrul, J. Sarip, and T. A. M. Tengku Maamun, "Variation study on morphological characters among mangifera indica L. 'Chok Anan' for development of superior mango clone," *Acta Hortic.*, vol. 1012, pp. 305–314, 2013.
[12] S. Singh, A. B. Gaikwad, and J. L. Karihaloo, "Morphological and Molecular Analysis of Intracultivar Variation in Indian Mango (*Mangifera indica* L.) Cultivars," in *Proc. VIth IS on In Vitro Cult. and Hort. Breed.*, 2009, pp. 205–212.
[13] A. S. Khan, S. Ali, and I. A. Khan, "Morphological and molecular characterization and evaluation of mango germplasm: An overview," *Sci. Hortic. (Amsterdam).*, vol. 194, pp. 353–366, 2015.
[14] IPGRI, *Descriptors for Mango*. Rome, Italy: International Plant Genetic Resources Institute, 2006.
[15] M. B. Kirkham, *Principles of Soil and Plant Water Relations*. MA, USA: Elsevier Academic Press, 2014.

[16] A. Zziwa, R. K. Kambugu, S. Kizito, A. Mugisha, O. Sseremba, and A. Syofuna, "Evaluation Of Basic Strength Indicators Of Mangifera indica Timber To Ascertain Its Suitability For Furniture Construction," vol. 4, no. 1, pp. 1–9, 2016.

[17] L. Oliva Carrasco *et al.*, "Water storage dynamics in the main stem of subtropical tree species differing in wood density, growth rate and life history traits," *Tree Physiol.*, vol. 35, no. 4, pp. 354–365, Apr. 2015.

[18] S. D. Tanksley, "The Genetic, Developmental, and Molecular Bases of Fruit Size in Tomato and Shape Variation," *Plant Cell*, vol. 16, no. Supplement 2004, pp. 181–190, 2009.

[19] P. Ceccato, S. Flasse, S. Tarantola, S. Jacquemoud, and J.-M. Grégoire, "Detecting vegetation leaf water content using reflectance in the optical domain," *Remote Sens. Environ.*, vol. 77, pp. 22–33, 2001.

[20] U. C. Malavasi, A. S. Davis, M. de M. Malavasi, U. C. Malavasi, A. S. Davis, and M. de M. Malavasi, "Estimating Water in Living Woody Stems - A Review," *CERNE*, vol. 22, no. 4, pp. 415–422, Dec. 2016.

[21] R. J. Joly and J. B. Zaerr, "Alteration of Cell-Wall Water Content and Elasticity in Douglas-Fir during Periods of Water Deficit.," *Plant Physiol.*, vol. 83, no. 2, pp. 418–22, Feb. 1987.

[22] S. M. Chapotin, J. H. Razanamehararizaka, and N. M. Holbrook, "a Biomechanical Perspective on the Role of Large Stem," *Am. J. Bot.*, vol. 93, no. 9, pp. 1251–1264, 2006.