UNIVERSITI PUTRA MALAYSIA

IMPROVED PROPAGATION, EARLY ESTABLISHMENT AND FRUIT DEVELOPMENT OF THE MIRACLE FRUIT, (SYNSEPALUM DULCIFICUM DANIELL.)

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FP 2013 41

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By

CHEN XINGWEI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

October 2013

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

IMPROVED PROPAGATION, EARLY ESTABLISHMENT AND FRUIT DEVELOPMENT OF THE MIRACLE FRUIT, (*SYNSEPALUM DULCIFICUM* DANIELL.)

By

CHEN XINGWEI

October 2013

Chairman: Associate Professor Thohirah Lee Abdullah, PhD
Faculty: Agriculture

Propagation of miracle fruit, *Synsepalum dulcificum* using cuttings has been investigated for early fruiting planting materials. However, there is very little information on the nutrient requirements during early establishment and growth of the species. Studies on its reproductive biology, fruit set and development are equally important to understand the flowering and fruiting behaviour. The objectives for this study are: (i) to improve the propagation of *Synsepalum dulcificum* through stem cutting using Indole-3-butyric acid (IBA); (ii) to establish seedlings under different shade levels and nitrogen (N) rates; (iii) to describe the flower and fruit development of *Synsepalum dulcificum*. Three experiments were conducted to achieve the objectives. In Experiment 1, rooting responses of softwood cuttings of *Synsepalum dulcificum* as affected by IBA concentrations were conducted**.** Soft wood stem cuttings were treated with 0 mg/L, 200 mg/L, 400 mg/L, 600 mg/L and 800 mg/L IBA concentrations and arranged in Randomized Complete Block Design (RCBD) with 5 replications. Callus formation started three weeks after sowing and adventitious roots emerged from the basal ends eight weeks after planting. High concentration of IBA (800 mgL^{-1}) increased rooting percentage to 23.64 ± 0.19%. The anatomy of stem cutting at day 0 showed the phloem being surrounded by 2-3 layers of fibers. Root primordial developed from secondary phloems and penetrated the fiber layers 5 weeks after planting. In Experiment 2, growth and physiological responses of miracle fruit seedlings to different shade levels and nitrogen (N) rates were recorded. Six months old seedlings were subjected to 0%, 45% and 75% shade and received 0, 300, 600 and 900 mg N $plant^{-1}$ $year^{-1}$. Treatments were arranged in Nested RCBD with 4 replications. Different levels of shades significantly affected plant height, dry weight, leaf area, specific leaf area, number of branches, root:shoot ratio, chlorophyll fluorescence and chlorophyll contents throughout the growing season. Miracle fruits seedlings under 75% shade were taller, had higher photosynthetic rate (1.82 ± 1.113 μ mol m^{-2} s^{-1}) than other treatments and had high relative growth rate (0.37 g $g^{-1}month^{-1}$) in the early establishment stage which suggest that this shade level is more suitable for establishment of young miracle fruit plants. Nitrogen fertilization was found to prevent photoinhibition in miracle fruit seedlings in the early establishment stages. Nitrogen rate at 300 mg N $plant^{-1}$ $year^{-1}$ was adequate for growth and development since the plant was more efficient in utilizing the available N in low N input (N utilization efficiency = 36.56 mg mg^{-1}). In Experiment 3, flower

ontogenesis and fruit development of *Synsepalum dulcificum* was observed. Flowers and flower buds were processed and observed under light microscope and scanning electron microscope. Miracle fruit flower takes 100 days to develop from reproductive meristem to full anthesis. The flower development can be divided into six stages based on the size and appearance of the flower bud. The fruit with persistence style developed and ripened 90 days after anthesis. Heavy fruit drop was observed at 40 – 60 days after anthesis which contributed to the final fruit set average of 5.06% per plant.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MENAMBAHBAIKKAN PEMBIAKAN, PERTUMBUHAN AWAL DAN PERKEMBANGAN BUAH PADA BUAH AJAIB, (*SYNSEPALUM DULCIFICUM* DANIELL.)

Oleh
CHEN XINGWEI
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Pembiakan buah ajaib, *Synsepalum dulcificum* melalui keratan telah dikaji untuk mendapatkan bahan tanaman yang boleh berbuah awal. Maklumat mengenai nutrisi yang diperlukan oleh spesis ini pada peringkat awal dan semasa pertumbuhan amat kurang. Kajian pada biologi pembiakan, pembentukan buah dan perkembangan buah pokok ini adalah sama penting untuk memahami tabiat pembungaan dan pembentukan buah. Objektif kajian ini adalah: (i) untuk menambahbaikkan pembiakan *Synsepalum dulcificum* melalui keratin batang dengan menggunakan Indole-3-butyric acid (IBA); (ii) untuk menanam anak benih di bawah tahap naungan dan kadar nitrogen yang berbeza; (iii) untuk mengetahui perkembangan pembentukan bunga dan buah *Synsepalum dulcificum*. Tiga eksperimen telah dijalankan untuk mencapai objektif tersebut. Dalam Eksperimen 1, tindak balas pembentukan akar pada keratan batang lembut *Synsepalum dulcificum* dipengaruhi oleh kepekatan IBA telah dijalankan. Keratan batng lembut telah dirawat dengan kepekatan IBA pada 0 mg/L, 200 mg/L, 400 mg/L, 600 mg/L and 800 mg/L dan disusun dalam Rekabentuk Rawak Berblok Lengkap (RCBD) dengan 5 replikasi. Kalus mula terbentuk tiga minggu selepas keratan disemai dan akar baharu muncul dari pangkal keratan lapan minggu selepas semaian dilakukan. IBA yang berkepekatan tinggi (800 mgL^{-1}) meningkatkan peratus pengakaran kepada 23.64 ± 0.19% apabila dibandingkan dengan rawatan lain. Anatomi keratin batang pada hari 0 menunjukkan phloem dikelilingi oleh 2-3 lapisan serat. Akar primordia berkembang dari phloem sekunder dan menembusi lapisan serat 5 minggu selepas semaian dilakukan. Dalam Eksperimen 2, pertumbuhan dan tindak balas fisiologi anak benih pokok buah ajaib terhadap tahap naungan dan kadar nitrogen (N) yang berbeza telah dicatat. Anak benih berumur enam bulan didedahkan kepada 0%, 45% and 75% naungan dan diberi 0, 300, 600 and 900 mg N $pokok^{-1}$ $tahun^{-1}$. Rawatan disusun dalam 'Nested RCBD' dengan 4 repikasi. Tahap naungan yang berbeza memberi kesan kepada ketinggian pokok, berat kering, luas permukaan daun, permukaan daun spesifik, bilangan dahan, ratio akar dan batang, klorofil floresen dan kandungan klorofil sepanjang musim pertumbuhan. Anak benih pokok buah ajaib di bawah naungan 75% adalah lebih tinggi, mempunyai kadar fotosintesis yang tinggi (1.82 ± 1.113 µ mol m^{-2} s^{-1}) berbanding rawatan lain dan mempunyai kadar pertumbuhan relatif yang tinggi (0.37 g $g^{-1}month^{-1}$) pada peringkat awal pertumbuhan. Perkara ini mencadangkan tahap naugan ini lebih sesuai digunakan pada anak benih pokok buah ajaib. Baja nitrogen didapati dapat mengurangkan

‘photoinhibition’ pada anak benih pokok buah ajaib pada peringkat awal penanaman. Kadar nitrogen pada 300 mg N pokok^{-1} tahun^{-1} adalah cukup untuk pertumbuhan dan perkembangan memandangkan pokok ini menggunakan N lebih cekap pada pemberian N berkadar rendah (kecekapan penggunaan N = 36.56 mg mg^{-1}). Dalam Eksperimen 3, pembungaan dan perkembangan buah pada *Synsepalum dulcificum* telah diperhatikan. Bunga dan kudup bunga diproses dan diperhatikan di bawah mikroskop cahaya dan imbasan mikroskop electron. Bunga buah ajaib mengambil masa 100 hari untuk berkembang dari meristem reproduktif ke antesis. Proses perkembangan bunga boleh dibahagikan kepada enam peringkat mengikut saiz dan rupa bentuk kudup bunga. Buah yang mempunyai stil berkembang dan masak pada hari 90 selepas antesis. Keguguran buah yang lebat didapati berlaku pada hari ke40 – 60 selepas antesis. Perkara ini menyumbangkan peratusan buah yang berjaya berkembang adalah kira-kira 5.06% sepokok.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my appreciation to my supervisor, Assoc. Prof. Dr. Thohirah Lee Abdullah for her guidance, advice and patience throughout the study. Thanks to my supervisory committee members Assoc. Prof. Dr. Siti Aishah Hassan and Dr. Nur Ashikin Psyquay Abdullah for their unreserved guidance and assistance.

I would like to express my warmest gratitude to my parents, my younger brother and my relatives for their support and encouragement. I also like to express my appreciation to all my friends Brian, Tan Siao Hue, Camellia, Wang Liang Hui, Goh Li Peng, Afifah, Teh Beng Leng, Eddison Chang, Catherine, Taweesak, Khairul, Salumiah, Shokrollah, Sima, Sarah, Seetha and Zulhilmi for their help and support towards the success of this research.

Thanks to En. Mat Yusof Suki, En. Mazlan Bangi, En. Daud Rustam, En. Suhaimi Aman and En. Mohd Khoiri Kandar from the Department of Crop Science; En. Shamsudin Bojang from the Department of Crop Protection and En. Jamil Omar from the Department of Land Management for their technical support and assistance. Thanks to everyone who had contributed direct or indirectly in making this research successful.

I certify that a Thesis Examination Committee has met on 7 October 2013 to conduct the final examination of Chen Xingwei on his thesis entitled "Improved Propagation, Early Establishment and Fruit Development of The Miracle Fruit, (*Synsepalum dulcificum* Daniell.)" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

CHEN XINGWEI

Date: 7 October 2013

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LIST OF ABBREVIATIONS

IBA	Indole-3-butyric acid
N	Nitrogen
IAA	Indole-3-acetic acid
NAA	α-naphthalene acetic acid
PAR	Photosynthetically active radiation
CO_2	Carbon dioxide
O_2	Oxygen
ATP	Adenosine triphosphate
NADPH	Nicotinamide adenine dinucleotide phosphate
PSI	Photosystem I
PSII	photosystem II
Rubisco	Ribulose 1,5-bisphosphate carboxylase-oxygenas
RuBP	Ribulose 1,5-bisphosphate
PGA	3-phosphoglyceric acid
P_{max}	Light saturated rate of photosynthesis
LHC I	Light harvesting complexes I
LHC II	light harvesting complexes II
Q_A	Plasmoquinone A
Q_B	plasmoquinone B
NH_4^+	Ammonium
NO_3^-	Nitrate

DNA	Deoxyribonucleic acid
RNA	Ribonucleic acid
$CO(NH_2)_2$	Urea
NH_3	Ammonia
NO_2^-	nitrite
SEM	Scanning electron microscopy
LM	Light microscope
CPD	Critical point drying
UPM	Universiti Putra Malaysia
RH	Relative humidity
FAA	Formalin-acitic acid-alcohol
TBA	Tertiary Butyl-Alcohol
RCBD	Randomized Complete Block Design
ANOVA	Analysis of variance
SAS	Statistical Analysis System
DMRT	Duncan Multiple Range Test
P	Phosphorous
K	Potassium
Ca	Calcium
Mg	Magnesium
SLA	Specific leaf area
RGR	Relative growth rate

*F*v	Fluorescence
*F*m	Maximum fluorescence
EU	Utilization efficiency
PE	Physiological efficiency
ARE	Apparent recovery efficiency
GLM	Generalized linear model
TE	Trace elements
FAA	Formalin-acitic acid-alcohol

CHAPTER 1

INTRODUCTION

Miracle fruit or miracle berry plant (*Synsepalum dulcificum* Daniell.) from the family Sapotaceae is a tropical evergreen shrub or small tree growing 2 m – 5 m tall (Keay, 1992; Duke and duCellier, 1993). This plant is indigenous to tropical West Africa (Opeke, 1982) and commonly found growing in the wild in virgin forest, costal area and in mountainous forest (Duke and duCellier, 1993). Miracle fruit plant produces small creamy white flowers which measured around 0.5 cm on the axillary buds throughout the year. The plant produces small ellipsoid red berries (2 to 3 cm long) with a single seed. After eaten the fruit and allowed the fleshy pulp to coat the taste buds of the tongue, every sour or acidic food eaten or drunk afterwards will taste very sweet. The taste modifying effect will last for 30 minutes. Daniell was the first to describe scientifically the unusual quality of this fruit, which he called it "miraculous berry" (Daniell, 1852). The sweetening property is due to the presence of glycoprotein in the pulp of the berry called miraculin (Kant, 2005). The fruit could possibly help diabetic people eating less calorie food without taking in sugar. Miracle fruit has been investigated as a food additive and a possible source for a natural food sweetener (Kant, 2005).

Miracle fruit has been cultivated not only for its fruit but also as an ornamental plant. The tree form of *Synsepalum dulcificum* is cone or pyramid shape. The moderate growth rate and free branching characteristic of this plant make it a potential ornamental small tree or shrub, hedges and potted plant for urban planting. Pruning is not necessary for this plant since it is bushy and forms a beautiful tree form naturally. Besides that, the miracle fruit plant also can be trained into a bonsai or topiary. *Synsepalum dulcificum* has red to orange colour young leaves which adds to the esthetic value of the plant. The plant produces fragrant flowers and edible fruits all year round; thus it is a good candidate for a fragrance garden or edible garden. The miracle berries turn bright red when ripen and makes the tree a stunning and attractive ornamental plant. The plant also attracts birds to feed on its berries.

Despite the need of large-scale production of miracle berry to exploit its potential and enhance its improvement, commercial production of the plant has been a constraint. The plant is recalcitrant to propagation both by seeds and cuttings (Ogunsola and Ilori, 2008). The seeds dry very quickly after harvest and loses viability after drying while rooting of the cuttings have been very difficult and it takes long time to establish (Joyner, 2006). Large scale production of miracle fruit plants is still rely on seeds (Joyner, 2006). The growth of the seedlings is slow in the nursery stage (Duke and duCellier, 1993). Plants begin to bear fruit 3 to 4 years after seeding in the nursery. Fully regeneration of miracle berry through tissue culture using nodal explants from mature plants and young seedlings was not very successful (Ogunsola and Ilori, 2008). A technique for propagation by cuttings needs to be devised so that plants will begin to bear fruits earlier

(Duke, 1993). There is lack of scientific literature on propagation miracle fruit through stem cuttings and the origin of adventitious root development is unknown.
For the miracle fruit production practices, shading will be given to the young seedlings and will be thinned out as the plant begins bearing (Duke and duCellier, 1993). Miracle fruit is a shade plant, adapted to the under storey of forests in its native habitat and is able to tolerate full sunshine when the plant grew bigger (Duke and duCellier, 1993). However, there is very little information on the growth of miracle fruit seedlings under different shade levels and N rates for successfully produce the planting materials. The effects of different shade level on miracle fruit seedlings during early establishment have not been reported. There is also lack of information on the nutrient requirement for miracle fruit during early growth. Despite the economical importance of the berry of *Synsepalum dulcificum*, interest has been drawn to investigate the development of the flower and fruit of this plant. There is still lack of study on fruit set and development of *Synsepalum dulcificum*. Hence, three studies had been carried out to investigate the problems stated with the general objectives:

1. To improve the propagation of *Synsepalum dulcificum* through stem cutting using Indole-3-butyric acid (IBA)
2. To successfully establish the miracle fruit seedlings under different shade levels and nitrogen (N) rates
3. To describe the flower and fruit development of *Synsepalum dulcificum*

REFERENCES

Adir, N., Showchat, S. and Ohad, I. 1990. Light dependent D1 protein synthesis and translocation is regulated by reaction center II: reaction center II serves as an acceptor for the D1 precursor. *J. Biol. Chem.* 265: 12563-12568.

Albrechtova, J. T. P., Dueggelin, M., Duerrenberger, M. and Wagner, E. 2004. Changes in the geometry of the apical meristem and concomitant changes in cell wall properties during photoperiodic induction of flowering in *Chenopodium rubrum*. *New phytol*. 163: 263-269.

Alves, P. L. da C. A., Magalhaes, A. C. N. and Barja, P. R. 2002. The phenomenon of photoinhibition of photosynthesis and its importance in reforestation. *Bot. Rev.* 68 (2): 193-208.

Amissah, J. N., Paolillo, Jr. D. J. and Bassuk, N. 2008. Adventitious root formation in stem cuttings of *Quercus bicolor* and *Quercus macrocarpa* and its relationship to stem anatomy. *J. Amer. Soc. Hort. Sci.* 133: 479-486.

Anandacoomaraswamy, A., DeCosta, W. A. J. M., Tennakoon, P. L. K. and VanDerWerf, A. 2002. The physiological basis of increased biomass partitioning to roots upon nitrogen deprivation in young clonal tea (*Camellia sinensis* (L.) O. Kuntz). *Plant Soil* 238: 1-9.

Anderson, T. F. 1951. Techniques for the preservation of three dimensional structures in preparing specimens for the electron microscope. *Transactions of the New York Academy of Sciences* 13: 130.

Araujo, J. C., Teran, F. C., Oliveira, R. A., Nour, E. A. A., Montenegro, M. A. P., Campos, J.R. and Vazoller, R.F. 2003. Comparison of hexamethyldisilazane and critical point drying treatments for SEM analysis of anaerobic biofilms and granular sludge, *Journal of Electron Microscopy* 52: 429–433.

Ayensu, E. S. 1972. Morphology and anatomy of *Synsepalum dulcificum* (Sapotaceae). *Bot. J. Linn Soc.* 65: 179-187.

Baillon, H. E. 1891. *Synsepalum dulcificum*. *Hist. Plantarum* 11: 286.

Baker, N. R. 1996. Environmental constraints on photosynthesis. An overview of some future prospects. In *Photosynthesis and the environment*, ed. N. R. Baker, pp. 469-476. Dordrecht: Kluwer Academic Publishers.

Baker, N. R. and Bowyer, J. R. 1994. *Photoinhibition of photosynthesis, from molecular mechanism to the field*. Oxford, UK: Bios Scientific Publishers.

Beakbane, B. 1961. Structure of the plant stem in relation to adventitious rooting. *Nature* 192 954-955.

Bendall, D.S. 2007. Light reactions in photosynthesis. In *Handbook of plant science, Vol. 2*, ed. K. Roberts, pp. 1188-1195. England: John Wiley & Sons Ltd.

Bernier, G., Havelange, A., Houssa, C., Petitjean, A. and Lejeune, P. 1993. Physiological signals that induce flowering. *The Plant cell* 5 (10): 1147-1155.

Björkman, O. 1981. Responses to different quantum flux densities. In *Physiological Plant Ecology I. Responses to the Physical Environment, Encyclopedia of Plant Physiology, New Series, Vol. 12A*, eds O.L. Lange, P.S. Nobel, C.B. Osmond and H. Ziegler. pp. 57–107. Berlin: Springer-Verlag.

Boyde, A. 1972. Biological specimen preparation for the scanning electron microscope: an overview. In *Proceedings of the Fifth Annual Electron Microscopy Symposium*, eds. O. Johari and I. Corvin, Chicago.

Boyde, A. and Wood, C. 1969. Preparation of animal tissues for surface scanning electron microscopy. *Journal of Microscopy* 90: 221.

Brouwer, R. 1962. Distribution of dry matter in the plant. *Netherlands Journal of Agricultural Sciences* 10, 361–376.

Candolle, A. de. 1844. *Sideroxylon dulcificum. Prodromus Syst. Nat. Veg.* 8: 183.

Carr, M. K. V. and Stephens, W. 1992. Climate, weather and the yield of tea. In Tea - cultivation to consumption, eds. K. C. Wilson and M. N. Clifford, pp. 87–135. London: Chapman and Hall.

Chase, M. W. *et al*. 1993. Phylogenetics of seed plants: an analysis of nucleotide sequences from the plastic gene *rbc*L. *Annals of the Missouri Botanical Garden* 80: 528–580.

Chitnis, P.R. 2001. Photosystem I: Function and physiology. *Annu. Rev. Plant, Physiol. Plant Mol. Biol.* 52: 593-626.

Chong, S. T. and Chai T. B. 1991. Recent development of some tropical fruits trees. Prociding Buah-buahan Kebangsaan. MARDI, Serdang, Selangor.

Chung, G.C., Rowe, R.N. and Field, R.J. 1982. Relationship between shoot and roots of cucumber plants under nutritional stress. Ann. Bot., 50: 859-861.

Cline, M. N., and Neely, D. 1983. The histology and histochemistry of the wound healing process in geranium cuttings. *J. Amer. Soc. Hort. Sci.* 108: 452 – 496.

Coombs , R.C. 1987. Analytic Techniques. In Coombs, J., D.O. Hall, S.P. Long and J.M.O. Scurlock. *Techniques in bioproductivity and photosynthesis.* Robert Maxwell, United kingdom : 223-224

Dai, Y., Shen, Z., Liu, Y., Wang, L., Hannaway, D. and Lu, H. 2009. Effects of shade treatments on the photosynthetic capacity, chlorophyll fluorescence, and chlorophyll content of *Tetrastigma hemsleyanum* Diels et Gilg. *Environmental and Experimental Botany* 65: 177-182.

Daniell, W. F. 1852. The *Synsepalum dulcificum*, De Cand.; or, miraculous berry of Western Africa. *Pharmaceutical Journal* 11: 445 – 448.

Darwin, C. R. 1880. The Power of Movement in Plants. London: Murray.

Davies, F. T., Jr. Lazarte, J. E. and Joiner, J. N.. 1982. Initiation and development of roots in juvenile and mature leafbud cuttings of *Ficus pumila* L. *Amer. J. Bot.* 69: 804 – 811.

Demming-Adams, B. and Adams III, W.W. 1992. Photoprotection and other responses of plants to high light stress. *Annu. Rev. Plant Physiol. Plant. Mol. Biol.* 43: 599-626.

Dennis, E. S., Helliwell, C. A. and Peacock, W. J. 2006. Vernalization: Spring into flowering. *Dev. Cell* 11: 1-7.

Duke, A. J. and duCellier, J. L. 1993. *CRC Handbook of Alternative Cash Crops*. 536 pp. Boca Raton, Florida: CRC Press.

Edson, J. L. 1991. Propagation of western larch by stem cuttings. *Western Journal of Applied Forestry* 6 (2): 115 – 125.

Edwards, R. A. and Thomas, M. B. 1980. Observations on physical barriers to root formation in cuttings. *Plant Propagator* 26: 6-8.

Elkhalifa, K. F. and Al-Mufarrij, H. 2006. Propagation of *Cordia mixa* L. by stem cuttings. *Pakistan Journal of Biological Sciences* 9: 176-178.

Esau, K. 1953. *Plant anatomy*. New York: John Wiley & Sons, Inc.

Esumi, T., Tao, R. and Yonemori, K. 2007. Comparison of early inflorescence development between Japanese pear (*Pyrus pyrifolia* Nakai) and quince (*Cydonia oblonga* Mill.). *J. jap. Soc. Hortic. Sci.* 73 (3): 210-216.

Evans, G. C. 1972. The quantitative analysis of plant growth. Oxford: Blackwell Scientific.

Evans, J. R. and Poorter, H. 2001. Photosynthetic acclimation of plants to growth irradiance: the relative importance of specific leaf area and nitrogen partitioning in maximizing carbon gain. *Plant, Cell and Environment* 24: 755–767

Evans, L. J., Goodwin, R. M. and McBrydie, H. M. 2010. Factors affecting 'Hass' avocado (*Persea americana*) fruit set in New Zealand. *New Zealand Plant Protection* 63: 214-218.

Fageria, N. K., and Baligar, V. C. 2005. Enhancing nitrogen use efficiency in crop plants. *Advances in Agronomy* 88: 97–185.

Formaggio, E., Cinque, G. and Bassi, R. 2001. Functional architecture of the major light harvesting complex from higher plants. *J. Mol. Biol.* 314: 1157-1166.

Foster, T., Johnston, R. and Seleznyova, A. 2003. A morphological and quantitative characterization of early floral development in apple (*Malus* x *domestica* Borkh.). *Ann. Bot.* 92 (2): 199-206.

Foyer, C. H. and Paul, M. J. 2007. Source-sink relationships. . In *Handbook of plant science, Vol. 2*, ed. K. Roberts, pp. 831-841. England: John Wiley & Sons Ltd.

Fredeen, A. L., Raab, T. K., Rao, I. M. and Terry, N. 1990. Effects of phosphorus nutrition on photosynthesis of Glycine max. (L.) Merr. *Planta (Berl.)* 181: 399-405.

Fretz, T. A., Read, P. E. and Peele, M. C. 1979. *Plant propagation lab manual*. Burgess Publishing, Minneapolis MN.

Fujita, Y. 2007. Chlorophylls. In *Handbook of plant science, Vol. 2*, ed. K. Roberts, pp. 1212-1223. England: John Wiley & Sons Ltd.

Gordon, D. M., Grey, K. A., Chase, S. C. and Simpson, C. J. 1994. Change to the structure and productivity of a *Posidonia sinuosa* meadow during and after imposed shading. *Aquatic Botany* 47: 265 – 275.

Grace, S. C. 2007. Plant bioenergetics. In *Handbook of plant science, Vol. 2*, ed. K. Roberts, pp. 825-831. England: John Wiley & Sons Ltd.

Grusak, M. A. 2007. Plant macro- and micronutrient minerals. In *Handbook of plant science, Vol. 2*, ed. K. Roberts, pp. 842-845. England: John Wiley & Sons Ltd.

Hankamer, B., Barber, J. and Boekema, E. J. 1997. Structure and membrane organization of photosystem II in green plants. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 48: 641-671.

Hanson, H.C. 1917. Leaf-structure as related to environment. *Amer. J. Bot.* 4: 533–560.

Hartmann, H. T., Kester, D. E., Davies, Jr. F. T. and Geneve, R. L. 2002. Plant propagation: principles and practices seventh edition, Pearson Education Inc., Upper Saddle River, New Jersey.

Havaux, M., Bonfies, J.P., Lutz, C. and Niyogi, K.K. 2000. Photodamage of the photosynthetic apparatus and its dependence on the leaf developmental stage in the *npq*1 Arabidopsis mutant deficient in the xanthophylls cycle enzyme violaxanthein de-epoxidase. *Plant Physiol.* 124: 273-284.

Havlin, J. L., Beaton, J. D., Tisdale, S. L. and Nelson, W. R. 1999. *Soil fertility and fertilizers, an introduction to nutrient management 6th edition*. New Jersey: Prentice Hall.

Hawkesford, M., Horst, W., Kichey, T., Lambers, H., Schjoering, J., Møller, I.S. and White, P. 2012. Functions of macronutrients. In *Marschner's Mineral nutrition of Higher Plants*, ed. P. Marschner, pp. 135-189. USA: Elsevier Ltd.

Henrique, A., Campinhos, E. N., Ono, E. O. and de Pinho, S. Z. 2006. Effect of plant growth regulators in rooting of *Pinus* cuttings. *Braz. Arch. Biol. Tech.* 49: 189 – 196.

Hess, W.M., 1966. Fixation and staining of fungus hyphae and host plant root tissues for electron microscopy, *Stain Technology* 41: 27–35.

Hillier, W. and Babcock, G. T. 2001. Photosynthetic reaction centers. *Plant Physiol.* 125: 33 – 37.

Hoffmann, W. A. and Poorter, H. 2002. Avoiding bias in calculations of relative growth rate. *Annals of Botany* 80: 37-42.

Holloway, P. J. and Baker, E. A. 1974. The aerial surfaces of higher plants. In *Principles and Techniques of Scanning Electron Microscopy*, ed. M. Hayat, pp. 181–205. New York: Van Norstrand Reinhold.

Honsho, C., Yonemori, K., Somsri, S., Subhadrabandhu, S. and Sugiura, A. 2004. Marked improvement of fruit set in Thai durian by artificial cross-pollination. *Scientia Horticulturae* 101: 399-406.

Horton, P., Ruban, A.V. and Walters, R.G. 1996. Regulation of light harvesting in green plants. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 47: 655-684.

Horton, P., Ruban, A.V. and Young, J.A. 1999. Regulation of the structure and function of the light harvesting complexes of photosystem II by the xanthophylls cycle. In: *Advances in Photosynthesis Vol. 8*, ed. H.A. Frank, A.J. Young, G. Britton, R.J. Cogdell, pp. 271-291. Dordercht: Kluwer Academic Publishers.

Huner, N.P.A., Oquist, G. and Sachan, F. 1998. Energy balance and acclimation to light and cold. *Trends Plant Sci.* 3: 224-230.

Hunt, R. 1982. *Plant growth curves*. London: Edward Arnold.

Hurry, V., Anderson, J. M., Chow, W.S. and Osmond, C. B. 1997. Accumulation of zeaxanthin in abscisic acid-deficient mutants of *Arabidopsis* does not affect chlorophyll fluorescence quenching or sensitivity to photoinhibition in vivo. *Plant Physiol.* 113: 639-648.

Ingrouille, M. 2007a. Sepals. In *Handbook of plant science, Vol. 1*, ed. K. Roberts, pp. 110- 111. England: John Wiley & Sons Ltd.

Ingrouille, M. 2007b. Flowers. In *Handbook of plant science, Vol. 1*, ed. K. Roberts, pp. 104-110. England: John Wiley & Sons Ltd.

Isaac, M. E., Ulzen-Appiah, F., Timmer, V. R. and Quashie-Sam, S. J. 2007. Early growth and nutritional response to resource competition in cocoa-shade intercropped systems. Plant Soil 298: 243-254.

Jaeger, K. E., Graf, A. and Wigge, P. A. 2006. The control of flowering in time and space. *J. Exp. Bot.* 57: 3415-3418.

Johansen, D. A. 1940. *Plant microtechnique*. New York, London: McGraw-Hill Book Company inc.

Johnson, G. 2007. Photosynthesis: Ecology. In *Handbook of plant science, Vol. 2*, ed. K. Roberts pp. 1206-1212. England: John Wiley & Sons Ltd.

Joyner, G. 2006. The miracle fruit. In: *Quandong magazine of the West Australian Nut & Tree Crop Association, vol. 32*, ed. P. Scott, pp: 15. Subiaco, West Australia: West Australian Nut & Tree Crop Association (Inc).

Juniper, B. E. and Jeffree, C. E. 1983. *Plant Surfaces*. London: Edward Arnold Limited.

Kant, R. 2005. Sweet proteins – Potential replacement for artificial low calorie sweeteners. *Nutrition Journal* 4.

Kassel, R. G. and Shih, C. Y. 1974. *Scanning Electron Microscopy in biology: A students' atlas on biological organization*. Berlin Heidelberg, New York: Springer-Verlag. 368 pp.

Kätterer, T. 2007. Nitrogen budgets. In *Handbook of plant science, Vol. 2*, ed. K. Roberts, pp. 923-930. England: John Wiley & Sons Ltd.

Ke, B. 2000a. Role of carotenoids in photosynthesis. In *Advance in photosynthesis, Vol. 10*, ed. Gorindjee, pp. 229-250. Dordrecht: Kluwer Academic Publishers.

Ke, B. 2000b. The stable primary electron acceptor Q_A and the secondary electron acceptor Q_B. In *Advance in photosynthesis, vol. 10*, ed. Govindjee, pp. 289-304. Dordrecht: Kluwer Academic Publishers.

Keay, R. W. J. 1992. *Trees of Nigeria*. United Kingdom: Oxford University Press.

Kesari, V., Krishnamachari, A. and Rangan, L. 2008. Effect of auxins on adventitious rooting from stem cuttings of candidate plus tree *Pongamia pinnata* (L.), a potential biodiesel plant. *Trees – Structure and Function*.

Kibbler, H., Jhonston, M. E. and Williams, R. R. 2004. Adventitious root formation in cuttings of *Backhousia citriodora* F. Muell: 1. Plant genotype, juvenility and characteristics of cuttings. *Scientia Horticulturae* 102(1): 133-143.

Kochhar, V. K., Singh, S.P., Katiyar, R. S. and Pushpangadan, P. 2005. Differential rooting and sprouting behaviour of two Jatropha species and associated physiological and biochemical changes, *Current Science* 89 (6): 936-939.

Kok, B. 1956. On the inhibition of photosynthesis by intense light. *Biochim. Biophys. Acta* 21: 234-244.

Krause, G. H. 1988. Photoinhibition of photosynthesis. An evaluation of damaging and protecting machanisms. *Physiol. Plant* 74: 566-574.

Krauß, N. and Saenger, W. 2007. Photosystem I. Light reactions in photosynthesis. In *Handbook of plant science, vol. 2*, ed. K. Roberts, pp. 1239-1244. England: John Wiley & Sons Ltd.

Krisantini, S., Johnston, M., Williams, R. R., and Beveridge, C. 2006. Adventitious root formation in *Grevillea* (Proteaceae), an Australian native species. *Sci. Hortic.* 107: 171 – 175.

Kura-Hotta, R., Satoh, K. and Kato, S. 1987. Chlorophyll concentration and its changes in leaves of spinach raised under different light levels. *Plant Cell Physiol.* 87: 12-19.

Kurokura, T., Inaba, Y., Neri, D. and Sugiyama, N. 2005. A morphological study of the development of the second inflorescences in strawberry (*Fagaria* x *ananassa* Dush.). *Ann. Applied Biol.* 146 (4): 511-515.

Kwiatkowska, D. 2006. Flower primordium formation at the Arabidopsis shoot apex: Quantitative analysis of surface geometry and growth. *J. Exp. Bot.* 57 (3): 571-580.

Lawlor, D. W. 2001. *Photosynthesis: molecular, physiological and environment processes, 3rd edn*. Oxford, UK: Bios Scientific Publishers.

Lei, T. T., Tabuchi, R., Kitao, M. and koike, T. 1996. The functional relationship between chlorophyll content, leaf reflectance, and light capturing efficiency of Japanese forest species under natural shade and open light regimes. *Physiol. Planta* 96: 411-418.

Lemay, V., Gâteblé, G. and McCoy, S. 2008. Vegetative propagation of two endemic species of *Cloezia* Brongn. & Gris for conservation and mining revegetation activities in New Caledonia. *New Forests* 37: 1-8.

Lips, S. H., Leidi, E. O., Silberbush, M., Soares, M. I. M. and Lewis, O. E. M. 1990. Physiological aspects of ammonium and nitrate fertilization. *J. Plant Nutrition* 13: 1271-1289.

Long, S. P., Humphries, S. and Falkowski, P. G. 1994. Photoinhibition of photosynthesis in nature. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 45: 633-622.

Ludwig-Müller, J. 2000. Indole-3-butyric acid in plant growth and development. *Plant Growth Regul.* 32: 219-230.

Marschner, H. and Cakmak, I. 1989. High light intensity enhances chlorosis and necrosis in leaves of zinc, potassium and magnesium deficient bean (*Phaseolus vulgaris*) plants. *J. Plant Physiol.* 134: 308-315.

Mc Calla, A. G., Wei, J. R. and Neatby, K. W. 1939. Effects of temperature and sunlight on the rate of elongation of maize and gladiolus. *Can. J. Biol.* 17: 388 – 409.

Melis, A. 1996. Excitation energy transfer, function and dynamic aspect of LHC (cab) proteins. In *Advances in photosynthesis, vol. 4*, ed. D.R. Ort, and C.F. Yocum, pp. 523-538. Netherlands: Kluwer Academic Publishers.

Melis, A. 1999. Photosystem II damage and repair cycle in chloroplasts: what modulates the rate of photodamage in vivo. *Trends in Plant Science* 4: 130–135.

Mesen, F., Newton, A. C. and Leakey, R. R. B. 1997. Vegetative propagation of *Cordia allidora* (Ruiz and Pavon) Oken: the effects of IBA concentration, propagation medium and cutting origin. *For. Ecol. Manage.* 92: 45 – 54.

Mohotti, A. J. and Lawlor, D. W. 2002. Diurnal variation of photosynthesis and photoinhibition in tea: effects of irradiance and nitrogen supply during growth in the field. *Journal of Experimental Botany* 53: 313 – 322.

Most, B. H., Summerfield, R. J. and Boxall, M. 1979. Tropical plants with sweetening properties. Physiology and agronomic problems of protected cropping 2. *Thaumacoccus danielli*. *Econ. Bot.* 32: 321 – 335.

Mullineaux, P. and Karpinski, S. 2002. Signal transduction in response to excess light: Getting out of the chloroplast. *Curr. Opin. Plant Biol.* 5: 43-48.

Nunes, M. A., Ramalho, J. D. C. and Dias, M. A. 1993. Effect of nitrogen supply on the photosynthetic performance of leaves from coffee plants exposed to bright light. *Journal of Experimental Botany* 44: 893–899.

Ogunsola, K.E. and Ilori, C.O. 2008. *In vitro* propagation of miracle berry (*Synsepalum dulcificum* Daniel) through embryo and nodal cultures. *African Journal of Biotechnology* 7: 244-248.

Ohad, I., Kyle, D. J. and Arntzen, C. J. 1984. Membrane protein damage and repair removal and replacement of inactivated 32.kDa polypeptide in chloroplast membranes. *J. Cell Biol.* 99: 481-485.

Oke, S.O. 1985. Effect of soil texture nutrient stress and water stress on yield of *Andropogon gayanus*. knuth and *Schizchyrium sanguineum* (Rertz) alston. M.Sc. Thesis, University of Ife (Now Obafemi Awolowo University), Nigeria.

Okoli, P. S. O. and Wilson, G. F. 1986. Response of Cassava (*Manihot esculenta* Crantz) to shade under field conditions. *Field Crops Research* 14: 349 – 359.

Opeke, L.K. 1982. *Tropical tree crops*, pp. 298 – 300. United Kingdom: John Wiley and Sons Ltd.

Ort, D. R. 2001. When there is too much light. *Plant Physiol.*125: 29-32.

Ort, D. R. and Whitmarsh, J. 2007. Photosynthesis. In *Handbook of plant science, Vol. 2*, ed. K. Roberts, pp. 1174-1180. England: John Wiley & Sons Ltd.

Osmond, C. B. 1994. What is photoinhibition: some insights from comparison of shade and sun plants. In *Photoinhibition of photosynthesis – from molecular mechanism to the* field, ed. N.R. Baker and J.R. Bowyer pp. 1-24. Oxford: Bios Scientific Publishers.

Owens, T.G. 1994. Excitation energy transfer between chlorophylls and carotenoids. Proposed molecular mechanism for non photochemical quenching. In *Photoinhibition of photosynthesis – from molecular mechanism to the field*, ed. N.R. Baker, and J.R. Bowyer, pp. 95-109. Oxford: Bios Scientific Publishers.

Owens, T.G. 1996. Processing of excitation energy by antennae pigments. In *Photosynthesis and the Environment*, ed. N.R. Baker, pp. 1-23. The Netherlands: Kluwer Academic Publishers.

Owuor, P. O., Wanyoko, J. K. and Othieno, C.O. 1990. High rates of N on tea. I. Response and distribution of yields of clonal tea. *Tea* 11, 78–89.

Palanisamy, K., Ansari, S. A., Pramod, K., and Gupta, B. N. 1998. Adventitious rooting in shoot cuttings of *Azardirachta indica* and *Pongamia pinnata*. *New For.* 16: 81 – 88.

Pathan, A. K., Bond, J. and Gaskin, R. E. 2008. Sample preparation for scanning electron microscopy of plant surfaces—Horses for courses. *Micron* 39: 1049 – 1061.

Patricio, H. P., Castañeto, Y. T., Vallesteros, A. P. and Castañeto , E. T. 2006. Macropropagation of *Shorea guiso* using stem cuttings. *Journal of Tropical Forest Science* 18: 198-201.

Paul, M. J. and Driscoll, S. P. 1997. Sugar repression of photosynthesis: the role of carbohydrates in signalling nitrogen deficiency through source: sink imbalance, *Plant, Cell and Environment* 20, 110–116.

Paulsen, H. 1995. Chlorophyll *a*/*b* – binding proteins. *Photochem. Photobiol.* 62: 367-382.

Peace, W.J.H. and Grubb, P.J. 1982. Interraction of light and mineral nutrient supply in the growth of *Impatients parviflora*. New Phytol., 90: 127-150.

Pichersky, E. and Jansson, S. 1996. The light harvesting chlorophyll *a*/*b* binding polypeptides and their genes in angiosperm and gymnosperm species. In *Advances in photosynthesis, vol. 4*, ed. D.R. Ort, and C.F. Yocum, pp. 507-521. Netherlands: Kluwer Academic Publishers.

Poorter, H. 2007. Plant growth and carbon economy. In *Handbook of plant science, vol. 2*, ed. K. Roberts, pp. 936-941. England: John Wiley & Sons Ltd.

Poorter, H. and Nagel, O.W. 2000 The role of biomass allocation in the growth response of plants to different levels of light, CO2, nutrients and water: a quantitative review. *Australian Journal of Plant Physiology* 27: 595–607.

Poupard, C., Chauviere, M. and Monteuuis, O. 1994. Rooting *Acacia mangium* cuttings: effects of age, within-shoot position and auxin treatment. *Silvae Genet* 43: 226 – 231.

Powles, S. B. 1984. Photoinhibition of photosynthesis induced by visible light. *Annu. Rev. Plant Physiol.* 35: 15-44.

Rahman, F. 1988. Physiology of the tea bush. *Two and a Bud* 35, 1–14.

Rama Das, V. S. 2004. *Photosynthesis: Regulation under varying light regimes*. USA: Science Publishers, Inc.

Ramalho, J. C., Pons, T. L., Groeneveld, H. W. and Nunes, M. A. 1997. Photosynthetic responses of *Coffea arabica* leaves to a short-term high light exposure in relation to N availability. *Physiologia Plantarum* 101: 229–239.

Rao, I. M., Fredeen, A. L. and Terry, N. 1990. Leaf phosphate status, photosynthesis and carbohydrate partitioning in sugar beet. III. Diurnal changes in carbon partitioning and carbon export. *Plant Physiol.* 92: 29-36.

Richard-Molard, C., Krapp, A., Brun, F., Ney, B., Daniel-Vedelo, F. and Chaillous, S. 2008. Plant response to nitrate starvation is determined by N storage capacity matched by nitrate uptake capacity in two Arabidopsis genotypes. *J. Exp. Bot.* 59: 779-791.

Ronse Decraene, L. P. and Smets, E. F. 1995. The distribution and systematic relevance of the androecial character oligomery. *Bot. J. Linn. Soc.* 118: 193-247.

Ronse Decraene, L. P. and Smets, E. F. 2001. Staminodes: Their morphological and evolutionary significance. *The Botanical Review* 67: 351-402.

Ryugo, K. 1988. Fruit Culture. *Its Science and Art*. New York: Wiley.

Scheller, M.V., Jensen, P.E., Haldrup, A., Lunde, C. and Knoetzel, J. 2001. Role of subunits in eukaryotic photosystem I. *Biochim. Biophys. Acta* 1507: 41-60.

Schneitz, K. and Balasubramanian, S. 2007. Floral meristems. In *Handbook of plant science, Vol. 1*, ed. K. Roberts, pp. 40-47. England: John Wiley & Sons Ltd.

Schreiber, U., Bilger, W., Hormann, H. and Neubauer, C. 1998. Chlorophyll fluorescence as a diagnostic tool: basics and some aspects of practical relevance. In *Photosynthesis: A comprehensive guide*, ed. A. S. Raghavendra, pp. 320-336. Cambridge.

Simpson, D.V. and Knoetzel, J. 1996. Light harvesting complexes of plants and algae: Introduction, survey and nomenclature. In *Advances in photosynthesis, Vol. 4*, ed. D.R. Ort, and C.F. Yocum, pp. 493-506. Netherlands: Kluwer Academic Publishers.

Sims, D.A. and Pearcy, R.W. 1994 Scaling sun and shade photosynthetic acclimation of *Alocasia macrorrhiza* to wholeplant performance – I. Carbon balance and allocation at different daily photon flux densities. *Plant, Cell and Environment* 17: 881–887.

Smith, B. G., Stephens, W., Burgess, P. J. and Carr, M. K. V. 1993. Effects of light, temperature, irrigation and fertilizer on photosynthetic rate in tea (*Camellia sinensis* L.). *Experimental Agriculture* 29: 291–306.

Somashekar, B. S. and Sharma, M. 2002. Propagation techniques of commercially important medicinal plants. Training manual, FRLHT, Bangalore, pp 118.

Stewart, G. R., Mann, A. F. and Fentem, P. A. 1980. Enzymes of glutamate formation: Glutamate dehydrogenase, glutamine synthetase, and glutamine synthase. In *The Biochemistry of Plants*, ed. B. J. Miflin, pp. 271-327. New York: Academic Press, Inc.

Tchoundjeu, Z., Ngo Mpeck, M.L., Asaah, E., and Amougou, A. 2004. The role of vegetative propagation in the domestication of *Pausinystalia johimbe* (K. Schum), a highly threatened medicinal species of West and Central Africa. *For. Ecol. Manage.* 188: 175 – 183.

Teeri, T. H., Uimari, A., Kotilainen, M., Laitinen, R., Help, H. Elomaa, P. and Albert, V. A. 2006. Reproductive meristem fates in *Gerbera*. *J. Exp. Bot.* 57: 3445-3455.

Temussi, P. A. 2006. Natural sweet macromolecules: how sweet proteins work. *Cellular and Molecular Life Sciences* 63: 1876-1888.

Thompson, W.A., G.C. Stocker and P.E. Kriedemann, 1988. Growth and photosynthetic response to light and nutrients of *Flindersia brayleyana* F. Muell., a rainforest tree with broad tolerance to sun and stade. Aust. J. Plant Physiol., 15: 299-315.

Tromp, J. 2000. Flower-bud formation in pome fruits as affected by fruit thinning. *Plant Growth Reg.* 31: 27-34.

Valiente, J. I. and Albrigo, L. G. 2004. Flower bud induction of sweet orange trees (*Citrus sinensis* Osbeck): Effect of low temperatures, crop load and bud age. *J. Am. Soc. Hortic. Sci.* 129: 158-164.

Vink, W. 1995. Revision of *Magodendron* (Sapotaceae) with observations on floral development and morphology. *Blumea* 40: 91-107.

Walker-Larsen, J. and Harder, L. D. 2000. The evolution of staminodes in Angiosperms: patterns of stamen reduction, loss, and functional re-invention. *American Journal of Botany* 87: 1367 – 1384.

Whitmarsh, J. and Govindjee. 2007. Photosystem II. In *Handbook of plant science, Vol. 2*, ed. K. Roberts, pp. 1245-1256. England: John Wiley & Sons Ltd.

Wittmann, C., Aschan, G. and Pfanz, H. 2000. Leaf and twig photosynthesis of young beech (*Fagus sylvatica*) and aspen (*Populus tremula*) trees grown under different light regime. *Basic and Applied Ecology* 2: 145 -154.

Yoder, L.M., Cole, A.G. and Sension, R.J. 2002. Structure and function in theisolated reaction center complex of photosystem II: energy and charge transfer dynamics and mechanism. *Photosynth. Res.* 72: 147-158.