**UNIVERSITI PUTRA MALAYSIA**

# *IMPROVED CUT FLOWER PRODUCTION, RHIZOME DORMANCY BREAKING AND FEASIBILITY STUDY OF Curcuma alismatifolia Gagnep. USING SOILLESS MEDIA CULTIVATION*

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**By**

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

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**IMPROVED CUT FLOWER PRODUCTION, RHIZOME DORMANCY BREAKING AND FEASIBILITY STUDY OF *Curcuma alismatifolia* Gagnep. USING SOILLESS MEDIA CULTIVATION**

By

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**May 2021**

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The effects of three soilless media (cocopeat: sand at 2:1 by volume, burnt rice husk: sand at 2:1 by volume and cocopeat: burnt rice husk: sand at 1:1:1 by volume) and three planting densities (9, 16 and 49 plants/$m^2$) on the growth, flower quality and rhizome yield of *Curcuma alismatifolia* were investigated. Cocopeat: burnt rice husk: sand (1:1:1 by volume) produced the largest flower (8.09±0.27 cm), highest mean number of flowers per clump (2.85±0.20 stalks) and highest mean number of rhizomes per $m^2$ (86.67±4.04 rhizomes/$m^2$). Planting density at 16 plants/$m^2$ produced high number of flowers per clump (2.92±0.19 stalks/clump) and high mean number of rhizomes per clump (2.95±0.67 rhizomes/clump). Although high planting density at 49 plants/$m^2$ produced the highest cut flower yield (62.42±7.24 stalks/$m^2$) and rhizome yield per $m^2$ (120.92±3.94 rhizomes/$m^2$) but the number of cut flowers per clump (1.28±0.15 stalks/clump) and rhizomes per clump (1.31±0.37 rhizomes/clump) were the lowest. The vase life, number of pink bracts, number of green bracts and flower stalk size were not affected by different types of soilless media and planting densities. The effects of storage duration (5, 10 and 15 weeks) and 6-Benzylaminopurine (BAP) application (0 and 100 mg/L) on the growth and flowering of *C. alismatifolia* were investigated. Rhizomes stored for 10 and 15 weeks started to germinate two weeks after planting while rhizomes stored for 5 weeks took 8 weeks to germinate regardless of the BAP treatments. Rhizome fresh weight, abscisic acid (ABA) level, starch content and total soluble sugar reduced with longer storage duration. Flower quality was not affected by storage duration and BAP treatment. Investigation on perception of consumer on flower quality and financial analysis of *C. alismatifolia* production in soilless trough system was carried out. *C. alismatifolia* flower obtained positive evaluation on its quality and rated as a very good cut flower. The highest gross profit was obtained from growing *C. alismatifolia* at planting density of 16 plants/$m^2$. The positive net present value (NPV), benefit-cost ratio (BCR) at 1.03, internal rate of return (IRR) at 13% and pay back period (PP) less than 2

years indicated that *C. alismatifolia* production in soilless trough system at planting density of 16 plants/$m^2$ is feasible.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PENAMBAHBAIKAN PENGELUARAN BUNGA KERATAN, PENGHAPUSAN KEDORMANAN RIZOM DAN KAJIAN KEBOLEHLAKSANAAN *Curcuma alismatifolia* Gagnep. MENGGUNAKAN MEDIA KULTUR TANPA TANAH**

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Kesan tiga media tanpa tanah (sabut kelapa: pasir pada 2:1 ukuran isipadu, sekam padi bakar: pasir pada 2:1 ukuran isipadu dan sabut kelapa: sekam padi bakar: pasir pada 1:1:1 ukuran isipadu) dan tiga kepadatan tanaman (9, 16 dan 49 pokok/$m^2$) pada pertumbuhan, kualiti bunga dan hasil rizom *Curcuma alismatifolia* telah dikaji. Sabut kelapa: sekam padi bakar: pasir (1:1:1 ukuran isipadu) menghasilkan bunga yang terbesar (8.09±0.27 cm), min bilangan keratan bunga dalam serumpun yang terbanyak (2.85±0.20 batang keratan) dan min bilangan rizom dalam satu $m^2$ yang terbanyak (86.67±4.04 rizom/$m^2$). Kepadatan tanaman pada 16 pokok/$m^2$ menghasilkan bilangan bunga dalam serumpun yang terbanyak (2.92±0.19 batang keratan serumpun) dan min bilangan rizom serumpun yang terbanyak (2.95±0.67 rizom serumpun). Walaupun kepadatan tanaman yang tinggi pada 49 pokok/$m^2$ mampu menghasilkan keratan bunga yang terbanyak (62.42±7.24 batang keratan/$m^2$) dan hasil rizom yang terbanyak dalam satu $m^2$ (120.92±3.94 rizom/$m^2$) tetapi penghasilan bilangan bunga keratan dalam serumpun (1.28±0.15 batang keratan serumpun) dan bilangan rizom dalam serumpun (1.31±0.37 rizom serumpun) adalah yang terendah. Jangka hayat jambangan, bilangan brakta bewarna merah jambu, bilangan brakta bewarna hijau dan saiz keratan batang bunga tidak dipengaruhi oleh jenis media tanpa tanah dan kepadatan tanaman yang berbeza. Kesan jangka waktu penyimpanan (5, 10 dan 15 minggu) dan rawatan 6-Benzylaminopurine (BAP) (0 dan 100 mg/L) pada pertumbuhan dan pembungan *C. alismatifolia* telah dikaji. Rizom disimpan selama 10 dan 15 minggu mula bercambah dua minggu selepas tanam manakala rizom yang disimpan selama 5 minggu mengambil masa 8 minggu untuk bercambah tidak kira rawatan BAP. Berat basah rizom, kandungan asid absisik (ABA), kandungan kanji dan jumlah kandungan gula larut menurun dengan pemanjangan jangka waktu penyimpanan. Kualiti bunga tidak dipengaruhi oleh jangka waktu penyimpanan dan rawatan BAP. Penyiasatan pada pesepsi pelanggan terhadap kualiti bunga dan analisis kewangan pada penghasilan *C. alismatifolia* dalam

sistem palung tanpa tanah telah dijalankan. Bunga *C. alismatifolia* mendapat penilaian yang positif pada qualiti bunganya dan dinilai sebagai bunga keratan yang sangat baik. Untung kasar yang paling tinggi diperolehi daripada penanaman *Curcuma alismatifolia* pada kepadatan pokok 16 pokok/$m^2$. Nilai kini bersih (*NPV*) yang positif, nisbah faedah-kos (*BCR*) pada 1.03, kadar pulang dalaman (*IRR*) pada 13% dan tempoh bayaran balik (*PP*) yang kurang daripada 2 tahun menunjukkan penghasilan *C. alismatifolia* tanpa tanah dalam sistem palung pada kepadatan tanaman 16 pokok/$m^2$ boleh dilaksanakan.

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I certify that a Thesis Examination Committee has met on 28 May 2021 to conduct the final examination of Chen XingWei on his thesis entitled "Improved Cut Flower Production, Rhizome Dormancy Breaking and Feasibility Study of *Curcuma alismatifolia* Gagnep. using Soilless Media Cultivation" 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 Doctor of Philosophy.

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**Declaration by Members of Supervisory Committee**

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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| | |
|---|---|
| **%** | Percentage |
| ˚C | Degree celsius |
| µl | Micro-liter |
| µmol/$m^2$/$s^1$ | Micro-mol per meter square per second |
| ABA | Abscisic acid |
| ANOVA | Analysis of variance |
| B | Boron |
| BAP | 6-Benzylaminopurine |
| BCR | Benefit-cost ratio |
| Ca | Calcium |
| cm | Centimeter |
| CEC | Cation exchange capacity |
| EC | Electrical conductivity |
| $CO_2$ | Carbon dioxide |
| DW | Dry weight |
| *et al*. | And friends |
| Fe | Iron |
| *F*m | maximum fluorescence |
| *F*v | Fluorescence |
| g | Gram |
| g/$cm^3$ | Gram per cubic centimeter |
| GLM | Generalized linear model |
| h | Hour |
| HCL | Hydrochloric acid |

| | |
|---|---|
| HPLC | High performance liquid chromatography |
| IRR | Internal rate of return |
| K | Potassium |
| m | Meter |
| M | Molarity |
| $m^2$ | Meter square |
| MCW | Methanol chloroform water |
| mg | Milligram |
| mg/L | Milligram per liter |
| Mg | Magnesium |
| Mn | Manganese |
| ml | Milliliter |
| Mo | Molybdenum |
| mS/cm | Mili-Siemens per centimeter |
| N | Nitrogen |
| n | Numbers of sample |
| ng | Nano-gram |
| nm | Nano-meter |
| NPV | Net present value |
| ns | Not significant |
| p | probability |
| P | Phosphorus |
| pH | Measurement of acidity and alkalinity |
| PP | Payback period |
| RCBD | Randomized complete block design |

| | |
|---|---|
| RH | Relative humidity |
| RM | Ringgit Malaysia |
| SAS | Statistical Analysis System |
| *t*-ZR | *trans*-Zeatin Riboside |
| USA | United States of America |
| v/v | Volume to volume |
| WAP | Weeks after planting |
| Zn | Zinc |

# CHAPTER 1

## INTRODUCTION

Floriculture is a discipline of ornamental horticulture dealing with production and marketing of flowering and foliage plants. Floriculture crops are listed as high value commodity that can benefit the national economy. According to the Department of Agriculture Malaysia, Malaysia had exported RM 514.83 million of floriculture products in year 2019. These products consists of landscape plant, potted plant and cut flower. Cut flowers are plants specifically grow for the purpose of harvesting the flowers, flower buds or leaves. The products are uses in vase display, wreath and garlands. The cut flower industry in Malaysia can be divided into three categories: (i) temperate flowers, (ii) orchid, and (iii) foliage. The highlands are the main production area for temperate cut flowers like chrysanthemum and roses while the low-lands are mainly focusing on orchid and foliage. Other low-land tropical cut flowers beside orchid are seldom seen in large scale production; therefore, ornamental ginger from the family Zingiberaceae has the potential to become a new low-land tropical cut flower in Malaysia. *Curcuma alismatifolia* (Siam Tulip) is a ginger plant originated from Thailand. It has colourful lotus shape inflorescence, comprising pink upper bracts and green lower bracts, with small purple colour true flowers. The inflorescence has long-lasting post harvest vase-life which can last for more than two weeks (Bunya-atichart *et al*., 2004). *C. alismatifolia* can be planted for cut flower, cultivated as potted ornamental plant and used in landscape. Demand for *C. alismatifolia* cut flower and rhizome is increasing. Thailand is the main producer of *C. alismatifolia* rhizome and exported to Japan, Europe, Netherland and United States as planting material (Ruamrungsri *et al.*, 2005).

*Curcuma alismatifolia* undergoes dormancy after flowering. In normal cultural practice, the dormant rhizomes were stored until the next growing season (Ruamrungsri, 2015). Storage duration and rhizome dormancy breaking technique are crucial in commercial production. *C. alismatifolia* rhizomes are susceptible to rot cause by soil-borne bacterial (*Ralstonia solanacearum*). Some growers in Thailand had changed the cultivation methods of *C. alismatifolia* from conventional culture to soilless culture in order to overcome the soil-borne disease. The plant were grown in big polyethylene bag fill with rice husk: sand (1:1 by volume) to produce rhizomes for export (Ruamrungsri *et al*., 2006). Many floriculture crops had been successfully produced in soilless culture commercially despite the high initial investment cost (Van Os, Gieling and Lieth, 2008). High productivity with high quality product produced from soilless culture allowed the grower to make profit (Buwalda, Baas and Van Weel, 1994). Trough system is another possible soilless culture method where plants are grown in polyethylene sheet containing soilless media (Hochmuth and Hochmuth, 1993). This system allowed more flexibility on growing space, plants roots able to grow freely to search for water and only need simple drip line as fertigation system.

*Curcuma alismatifolia* is suitable to grow in Malaysia all year round. However it had not been commercially cultivated probably due to the high cost of planting material (average RM 2 per rhizome). Although new rhizomes can be produced locally for the next growing season but local growers are not familiar in cultivating and handling plants with dormancy. A rhizome dormancy breaking technique is needed to obtain a uniform plant growth. In order to prevent soil-borne diseases, a locally available soilless media suitable for *Curcuma alismatifolia* growth need to be identified. Although polyethylene bag planting is commonly used in Malaysia and Thailand, but the rhizome growth is restricted in the bag, preparation of growing bags in every season is labour intensive and the installation of fertigation system to individual plant is costly. Trough system is more suitable for plants with under-ground storage parts. The profitability of *C. alismatifolia* production would affected by planting density (Chang, 1996). When cultivate *C. alismatifolia* in trough, a planting density that allow optimum flower and rhizome yield with high profit has to be identified. The consumer perception and acceptance of new product is one of the important factor affecting the market demand. Growers are uncertain on the consumer preference towards the newly introduced *C. alismatifolia* cut flower.

A study was conducted to investigate the rhizome dormancy breaking techniques, flowering and rhizome yield under different soilless planting media and planting densities in association with the financial analysis of *Curcuma alismatifolia* production in soilless trough system. This study aimed to achieve these objectives: -

1. To investigate the effects of different soilless media and planting densities on the growth, flowering and rhizome yield of *C. alismatifolia.*
2. To determine the effects of storage time and plant growth regulator on breaking dormancy of *C. alismatifolia* rhizome.
3. To evaluate the economic aspect of *C. alismatifolia* in soilless media cultivation.

## REFERENCES


Abad, M., Noguera, P., Puchades, R., Maquieira, A. and Noguera, V. 2002. Physico-chemical and chemical properties of some coconut coir dusts for use as a peat substitute for containerised ornamental plants. Bioresource Technology 82(3): 241 – 245.

Alberty, C.A., Pellete, H.M. and Tylor, D.H. 1984. Characterization of soil compaction at construction sites and woody plant response. Journal of Environmental Horticulture 2(2): 48 – 53.

Apavatjrut, P., Anuntalabhoghai, S., Sirirugsa, P. and Alisi, G. 1999. Molecular markers in the identification of some early flowering *Curcuma* L. (Zingiberaceae) species. Ann. Bot. 84: 529-534.

Ariffin, D. 1993. Laboratory manual of soil samples. Kuala Lumpur: Palm Oil Research Institute of Malaysia.

B. Mahender, P. Syam, S.R., G. Thanuja, S., M. Balakrishna and B. Prathap. 2015. Effect of seed rhizome size and plant spacing on growth, yield and quality of ginger (*Zingiber officinale* Rosc.) under coconut cropping system. Plant Archives 15(2): 769 – 774.

Batt, P.J. and Pool, J. 2004. Consumer preference for cut flower in Western Australia. Acta Horticulturae 655: 81 – 88.

Becker, W.A., Behe, B.K., Johnson, J.L.,Townsend, C.D. and Litzenberg, K.K. 1997. Consumer perception on service qualiyt in the Texas retail floral industry. HortScience 32(2): 318 – 323.

Blok, C., Kreij, D.C., Baas, R. and Wever, G. 2008. Analytical methods used in soilless cultivation. In *Soilless culture theory and practice*, ed. M. Raviv and J.H. Lieth, pp. 245 – 289.Amsterdam: Elsevier.

Bolques, A., Duke, E.R., Knov, G.W. and Hewitt, T. 2004. Consumer acceptance of an organically grown ornamental. In *Proceedings of the Florida State Horticultural Society* 117: 326 – 328.

Brascamp, W. 1996. Evaluation and measurment of consumer preferences on outdoor ornamental plants. PhD. Thesis, Massey University.

Bredmose, N.B. 1998. Growth, flowering, and postharvest performance of single-stemmed rose (*Rosa hybrida* L.) plants in response to light quantum integral and plant population density. Journal of the American Society for Horticultural Science 123(4): 569 – 576.

Bunt, A.C. and Oowel, M.C. 1982. Carnation yield patterns: the effects of plant density and planting date. Scientia Horticulturarae 17(2): 177 – 186.

Bunya-atichart, K., Ketsa, S. and van Doorn, W.G. 2004. Postharvest physiology of *Curcuma alismatifolia* flowers. Postharvest Biology and Technology 34: 219 – 226.

Buwalda, F., Baas, R. and Van Weel, P.A. 1994. A soilless ebb-and-flow system for all year round chrysanthemums. Acta Horticulturae 361: 123 – 132.

Cavalho, S.M.P and Heuvelink, E. 2003. Effect of assimilate availability on flower characteristics and plant height of cut chrysanthemum: An integrated study. Journal of Horticultural Science and Biotechnology 78(5): 711 – 720.

Cees, S. and Wim, V. 2009. Plant nutrition of greenhouse crops. Dordrecht: Springer.

Chang, C.S. 1996. The effect of planting density, shading level and corms size on the production of *Curcuma alismatifolia* (Gingeraceae). Research Report of Tainan District Agricultural Improvement Station 33: 34 – 44. (In Chinese)

Changeraja, R. 2009. Gene expression and factors affecting flowering of *Curcuma alismatifolia* Gagnep. Ph.D. Thesis, The Graduate School, Chiang Mai University. 120 pp.

Chidburee, A. 2008. Effects of day length and red light on growth of *Curcuma alismatifolia* Gagnep. rhizome. Ph.D. Thesis. The Graduate School, Chiang Mai University.

Christopher, T.B.S. and Jamal, T. 2006. Soil physic analysis volume 1. Selangor: Universiti Putra Malaysia Press.

Clark, D.C., Colquhoun, T.A. and Leonard, R.T. 2013. Identifying consumer preferences for essential elements of a flower product. Virginia: American floral Endowment.

Criley, R.A. 2013. Blueprint programming for year-round forcing of *Curcuma alismatifolia*. Acta Horticulturae 1000: 209 – 216.

D'Agostino, I.B. and Kieber, J.J. 1999. Molecular mechanisms of cytokinin action. Curr. Opin. Plant Biol. 2: 359 – 364.

Dai, Y.J., Shen, Z.G., Liu, Y., Wang, L.L., Hannaway, D. and Lu, H.F. 2009. Effects of shade treatments on the photosynthetic capacity, chlorophyll fluorescence, and chlorophyll content of *Tetrastigmahemsleyanum* Diels et Gilg. Environ. Exp. Bot. 65: 177 – 182.

Danh, L.T., Truong, P., Mammucari, R. and Foster, N. 2010. Economic incentive for applying vetiver grass to remediate lead, copper and zinc contaminated soils. International Journal of phytoremediation 13:1, 47– 60.

de BoonI, H.1990. A world perspective on more flowers for more people. Floriculture Indiana 4(2): 2 – 6.

De Visser, A.J. and Hendrix, A.T.M. 1986. Economic aspects of growing system for year round chrysanthemums. Acta Horticulturae 197: 111 – 114.

den Boer, B.G.W. and Murray, J.A.H. 2000. Control of plant growth and development through manipulation of cell-cycle genes. Curr. Opin. Biotechnol. 11: 138 – 145.

Deshmukh, G, Jhade, R.K. and Alawa, S.L. 2019. Economic feasibility of gerbera (*Gerbera jamisonii* L.) under protected cultivation with special reference to Chhindwara district of Madhya Pradesh. International Journal of Chemical Studies 7(2): 1765 – 1768.

Devitt, M.L. and Stafstrom, J.P. 1995. Cell cycle regulation during growth-dormancy cycles in pea axillary buds. Plant Mol. Biol. 29: 255 – 265.

Dimitrios, S., Giorgio, G., Yuksel, T. and Nazim, G. 2013.Soilless culture. In *Good Agriculture Practices for Greenhouse Vegetable Crops*, ed. W. Baodoin, R. Nono-Womdim, N. Lutaladio and A. Hodder, pp. 303 – 354.Rome: FAO.

Ding, X., Jiang, Y., Zhao, H., Guo, D., He, L., Liu, F. *et al*. 2018 Electrical conductivity of nutrient solution influenced photosynthesis, quality, and antioxidant enzyme activity of pakchoi (*Brassica campestris* L. ssp. Chinensis) in a hydroponic system. PLoS ONE 13(8): e0202090. https://doi. org/10.1371/journal.pone.0202090

Dufault, R.J., Philip, T.L. and Kelly, J.W. 1990. Nitrogen and potassium fertility and plant populations influencefield production of gerbera. HortScience 25(12): 1599 – 1602.

Evans,M.R, Konduru, S. and Stamps, R.H. 1996. Source variation in physical and chemical properties of coconut coir dust. HortScience 31(6): 965 – 967.

Farhat, N., Elkhouni, A., Zorrig, W. *et al.* 2016. Effects of magnesium deficiency on photosynthesis and carbohydrate partitioning. *Acta Physiol Plant* 38: 145.

Flora, C.L.S. 2007. Effects of light intensity and daylength on growth and flowering of Siam Tulip (Curcuma alismatifolia var Chiangmai Pink). Master Thesis. Universiti Putra Malaysia.

Francis, D. and Sorrell, D.A. 2001. The interface between the cell cycle and plant growth regulators: a mini review. Plant Growth Regul. 33: 1 – 12.

Freeman, D., Riou-Khamlichi, C., Oakenfull, E.A. and Murray, J.A. 2003. Isolation, characterization and expression of cyclin and cyclin-dependent kinase genes in Jerusalem artichoke (*Helianthus tuberosus* L.). J. Exp. Bot. 54: 303 – 308.

Ghaziani, M.V.F., Berimavandi, A.R., Torkashvand, A.M., Hashemabadi, D. and Kaviani, B. 2012. Influence of plant density and irrigation method on the growth,flowering and quantity of essential oil of *Calendula officinalis* L. Indian Journal of Fundamental and Applied Life Sciences 2(2): 184 – 490.

Girapunthong, N. and Ward, R.W. 2003. Demand drivers for fresh-cut flowers and their substitutes: An application of household expenditure allocation models. 2003 Anual meeting, July 27 – 30, Montreal, Canada.

Goody, J.1993. The culture of flowers, Woolnough Bookbinding, Irthlingborough, England.

Grafiadellis, I., Mattas, K., Maloupa, E., Tzouramani, I. and Galanopoulos, K. 2000. An economic analysis of soilless culture in gerbera production. HortScience 35(2): 300 – 303.

Hagiladi,A., Umiel, N. and Yang, X.H. 1997. *Curcuma alismatifolia* II.Effects of temperature and day length on the development of flowers and propagules. Acta Horticulturae 430: 755 – 761.

Hanna, N. and Wozniak, A. 2013. Consumer behavior: An applied approach 4th edition. Iowa: Kendall Hunt Publishing.

Heinen, M., Marcelis, L.F.M., Elings, A., Figueroa, R. and del Amor, F.M. 2001. Effects of EC and fertigation strategy on water and nutrient uptake of tomato plants. In *Proc. 4th IS on Cropmodels, ISHS 2002*. Eds. J.H. Lieth & L.R. Oki. Acta Hort. 593: 101 - 107.

Hansen, R. 1999. Chrysanthemums grown in hydroponics; toward development of cost effective, automated production system. Acta Horticulturae 481: 297 – 340.

Henry, A. 1996. Consumer behavior and marketing action 5th ed. Ohio: South-Western College Publishing.

Hochmuth, C. and Hochmuth, G.J. 1993. Use of plastic in greenhouse vegetable production in the United States. HortTecnology 3(1): 20 – 27.

Hongpakdee, P., Siritrakulsak, P., Ohtake, N., Sueyoshi, K., Ohayama, T. and Ruamrungsri, S. 2010. Changes in Endogenous Abscisic Acid, *trans*-Zeatin Riboside, Indole-3-Acetic Acid Levels and the Photosynthetic Rate during the Growth Cycle of *Curcuma alismatifolia* Gagnep. in Different Production Seasons. Europ. J. Hort. Sci. 75 (5): 204 – 213.

Horvath, D.P., Anderson, J.V., Chao, W.S. and Foley, M.E. 2003. Knowing when to grow: signals regulating bud dormancy. Trends in Plant Science 8 (11): 534 – 540.

Hossain, M.A., Ishimine, Y, Motomura, K. and Akamine, H. 2005. Effects of planting pattern and planting distance on growth and yield of turmeric (*Curcuma longa* L.). Plant Prod. Sci. 8 (1): 95 – 105.

Hu, Y., Bao, F. and Li, J. 2000. Promotive effect of brassinosteroids on cell division involves a distinct CycD3-induction pathway in Arabidopsis. Plant J. 24: 693 – 701.

Huang, L.C. 2005. Floral production and their influences of floral purchase frequency. HortTechnology 15(4): 766 – 771.

Huang, L.C and Yeh, T.F. 2009. Floral consumption values for consumer groups with different purchase choices of flowers. HortTechnology 19(3): 563 – 571.

Huang, Z., Liu, Q., An, B., Wu, X., Sun, L., Wu, P., Liu, B. and Ma, X. 2021. Effects of Planting Density on Morphological and Photosynthetic Characteristics of Leaves in Different Positions on *Cunninghamia lanceolata* Saplings. Forests 12: 853. DOI: 10.3390/f12070853

International Organization for Standardization. 2017. Geotechnical investigation and testing - identification and testing of soil - Part 1: Identification and description. ISO 14688-1: 2017.

Jafari, T., Rahikainen, M., Puljula, E., Sinkkonen, J. and Kangasjärvi, S. 2018. The impact of light intensity on metabolomic profifile of *Arabidopsis thaliana* wild type and *reticulata* mutant by NMR spectroscopy. Phytochem. Lett. 26*:* 170 – 178.

James, G.B., Kenneth, C. S., and Donal, D. O. 1986. *Principles of agribusiness management.* New Jersey, Prentice-Hall.

Jowkar, M.M., Farshadfar, Z. and Rahmaniya, A.R. 2007. Predicting cut flower consumers' taste and preference for consumers' preference based selection in Shiraz, Iran. Acta Horticulturae 747, 75 – 80. DOI: 10.17660/ActaHortic.2007.747.6

Kahar, A. and Mahmud, T.M.M. 2005. Growth, flowering and cut flower quality of spray chrysanthemum (*Chrysanthemum morifolium* Ranmat) cv. Y720 at different planting densities. Journal of Tropical Agriculture and Food Science 33(2): 177 – 184.

Kazaz, S., Tekintas, F.E. and Askin, M.A. 2011. Effects of different planting systems and densities on yield and quality in standard carnation. Journal of Cell and Plant Sciences 2(1): 19 – 23.

Kim, H.H., Kyung, Y.J., Ohkawa, K., Pak, C.H. and Kwack, B.H. 1999. Flower industry in Korea. Acta Horticulturae 482: 407 – 414. DOI: 10.17660/ActaHortic.1999.482.59

Kipp, J.A., Weber, W. and De Kreij, C. 2000. International substrate manual. Amsterdam: Elsevier.

Khachatryan, H. and Choi, H.J. 2014. Factors affecting consumer preferences and demand for ornamental plants. Florida: University of Florida.

Khuankaew, T., Ito, S.,Ohtake, N., Sueyoshi, K.,Ohyma, T., Sato, T. and Ruamrungsri, S. 2011. Nitrogen and carbon translocation and distribbution in *Curcuma alismatifolia* Gagnep. by labelling experiment with $^{15}N$ and $^{13}C$. Proc. $X^{th}$ IS on Flower Bulbs and Herbaceous Perennials. Eds.: J.E. van den Ende et al. Acta Horticulturae 886: 131 – 138.

Kuehny, J.S., Sarmiento, M., Paz, M.P. and Branch, P.C. 2005. Effect of light intensity, photoperiod and plant growth retardants on production of zingiberacea as pot plants. Acta Hort. 683: 145-154.

Kyozuka, J. 2007. Control of shoot and root meristem function by cytokinin. Current Opinion Plant Biology 10: 442 – 446.

Lang, G.A., Early, J.D., Martin, G.C., Darnell, R.L. 1987. Endo-, para-, and eco-dormancy: physiological terminology and classification for dormancy research. Hortic. Sci. 22: 371 – 377.

Larsen, K. and Larsen, S.S. 2006. Gingers of Thailand (Chiang Mai: Queen Sirikit Botanic Garden). 184.

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

Lee, J.H., Heuvelink, E. and Challa,H. 2002. Effects of planting date and plant density on crop growth of cut chrysanthemum. Journal of Horticultural Science and Biotechnology 77(2): 238 – 247.

Lewis, J.D., Wang, X.Z., Griffin, K.L. and Tissue, D.T. 2002. Effects of age and ontogeny on photosynthetic responses of a determinate annual plant to elevated $CO^2$ concentrations. Plant, Cell and Environment 25: 359 – 36.

Lieth, J.H. and Oki, L.R. 2008. Irrigation in soilless production. In *Soilless Culture: Theory and Practice*, ed. M. Raviv and J.H. Lieth, pp. 117 – 156. Amsterdam: Elsevier.

Lucena, C.C.D., Siqueira, D.L.D., Martinez, H.E.P and Cecon, P.R. 2012. Salt stress change chlorophyll fluorescence in mango. Revista Brasileira de Fruticultura 34(4): 1245 – 1255.

Maher, M., Prasad, M. and Raviv, M. 2008. Organic soilless media components. In *Soilless Culture: Theory and Practice*, ed. M. Raviv and J.H. Lieth, pp. 459 – 504. Amsterdam: Elsevier.

Mckenzie, N.J., Jacquier, D.J., Isbell, R.F. and Brown, K.L. 2004. Australian soil and landscape: An illustrated compendium. CSIRO Publishing: Collingwood, Victoria.

Michael Cohen Group. 2005. Consumer attitudes and behaviors about floral purchasing study: Final analysis. Virginia: Society of American Florist.

Miller, W.B. and Langhans, R.W. 1989. Carbohydrate changes of ester lilies during growth in normal and reduced irradiance environments. Journal of American Society of Horticultural Science 114 (2): 310 – 315.

Mishra, A., Taing, K., Hall, M.W. and Shinogi, Y. 2017. Effects of rice husk and rice husk charcoal on soil physicochemical properties, rice growth and yield. Agricultural Sciences 8: 1014 – 1032.

Modupeola, T.O. and Olaniyi, J.O. 2015. Effects of Nitrogen (N) fertilizer and plant spacing on the growth and rhizome yield of turmeric (*Curcuma longa* L.) Ibadan South-west Nigeria. International of Plant Science and Ecology 1(4): 149 – 154.

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.

Morgan, J.V., Moustafa, A.T. and Groome, N. 1982. A technique for the production of spray chrysanthemums in hydroponics system on raised benches. Acta Horticulturae 125: 79 – 86.

Morison, J.I.L. and Lawlor, D.W. 1999. Interactions between increasing $CO_2$ concentration and temperature on plant growth. Plant, Cell and Environment 22: 659 – 682.

Nicotra, A.B., Atkin, O.K., Bonser, S.P., Davidson, A.M., Finnegan, E.J., Mathesius, U., Poot, P., Purugganan, M.D., Richards, C.L., Valladares, F. et al. 2010. Plant phenotypic plasticity in a changing climate. Trends Plant Sci. 15: 684 – 692.

Ogawa, M., Hanada, A., Yamauchi, Y., Kuwahara, A., Kamiya, Y. and Yamaguchi, S. 2003. Gibberellin biosynthesis and response during Arabidopsis seed germination. Plant Cell 15: 1591 – 1604.

Özzambak,M.E., Zeybekoğlu, E., Tuncay, O., Başer, S., Haspolat, G. and Olgun, A. 2009. A survey of cut flower preferences and expectation. Acta Horticulturae 807: 771 – 776.

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.

Paz, M.P. 2003. Rhizome manipulation affects growth and development of ornamental gingers. Master of Science Thesis. Louisiana State University.

Pettijohn, F.J., Potter, P.E. and Siever, R. 1972. Sand and sandstone. New York: Springer.

Quintero, M.F., Gonzalez-Murillo, C.A., Florez, V.J. and Guzman, J.M. 2009. Physical evaluation of four substrates for cut-rose crops. Acta Horticulturae 843: 349 – 358.

Quintero, M.F.,Ortega, D.,Valenzuela, J.L. and Guzman, M. 2013. Variation of hydro-physical properties of burnt rice husk used for carnation crops: Improvement of fertigation criteria. Scientia Horticulturae 154: 82 – 87.

Raviv, M. and Lieth, J.H. 2008. Significance of soilless culture in agriculture. In *Soilless Culture: Theory and Practice*, ed. M. Raviv and J.H. Lieth, pp. 1 – 12. Amsterdam: Elsevier.

Robert, G.A. and Woods, T.A. 1997. An economic evaluation of single stem cut rose production. Acta Horticulturae (ISHS) 481: 629–634.

Roitsch, T. and Ehneβ, R. 2000. Regulation of source/sink relations by cytokinins. Plant Growth Regulator 32: 359 – 367.

Roychowdhury, N. 1989.Effect of plant spacing and growth regulators on growth and flower yield of gladiolus grown under polyethene tunnel. Acta Horticulturae 246; 259 -264.

Ruamrungsri, S. 2015. The physiology of *Curcuma alismatifolia* Gagnep. as a basis for the improvement of ornamental production. European Journal of Horticultural Science 80(6): 316 – 321.

Ruamrungsri, S. and Apavatjrut, P. 2003. Effect of nutrient deficiency on the growth and development of *Curcuma alismatifolia* Gagnep. Proc. 3rd Symposium on the family Zingiberaceae, Thailand, July, 7 – 12. P. 98 - 104.

Ruamrungsri, S., Ohtake, N., Kuni, S. Suwanthada, C., Apavatjrut, P. and Ohyama, T. 2001. Changes in Nitrogen compounds, carbohydrates and abscisic acid in *Curcuma alismatifolia* Gagnep. During dormancy. Journal of Horticultural Science and Biotechnology 76(1): 48 – 51.

Ruamrungsri, S., Ohtake, N., Sueyoshi, K. and Ohyama, T. 2006. Determination of the uptake and utilization of nitrogen in *Curcuma alismatifolia* Gagnep. using $^{15}N$ isotope. Soil Science and Plant Nutrition 52: 221 – 225.

Ruamrungsri, S., Suwanthada, C., Apavatjrut, P., Ohtake, N., Sueyoshi, K. and Ohyama, T. 2005. Effect of nitrogen and potassium on growth and development of *Curcuma alismatifolia* Gagnep. Acta Horticulturae 673: 443 – 448.

Ruamrungsri, S., Ohtake, N., Kuni, S., Suwanthada, C., Apavatjrut, P. and Ohyama, T. 2001. Changes in nitrogenous compounds, carbohydrates and abscisic acid in *Curcuma alismatifolia* Gagnep. during dormancy. Journal of Horticultural Science and Biotechnology 76 (1): 48 – 51.

Samoilă, C.M.S. 2012. Preliminary study of flower market research trough questionnaires. Bulletin of University of Agricultural Sciences and Vaterinary Medicine Cluj-Napoca Horticulture 69(2): 288 – 294.

Savvas, D., Gainquinto, G.P., Tuzel, Y. and Gruda, N., 2013. Soilless culture. In *Good Agricultural practices for greenhouse vegetable crops. Principles for Mediterranean climate areas*. ed, W. Baudoin, R. Nono-Womdim, N. Lutaladio, A. Hodder, N. Castilla, C. Leonardi, S. De Pascale, M. Qaryouti, R. Duffy, pp. 347 – 381.Rome: Food and Agriculture Organization of the United Nations.

Schimmenti, E., Asciuto, A., Galati, A. and Valenti, M. 2010. Consumers of flowers and ornamental plants: An exploratory survey in the Italian Mezzogiorno regions. New Medit 9: 36 – 46.

Shitaka, Y. and Hirose, T. 1999. Effects of shift in flowering time on the reproductive output of *Xanthium canadense* in a seasonal environment. Oecologia 114: 361 – 367.

Silber, A. and Bar-Tal, A. 2008. Nutrition of substrate-grown plants. In *Soilless Culture: Theory and Practice*, ed. M. Raviv and J.H. Lieth, pp. 291 – 339. Amsterdam: Elsevier.

Sirirungsa, P., Larsen, K. and Maknoi, C. 2007. The genus *Curcuma* L.(Zingeberaceae): distribution and classification with reference to species diversity in Thailand.Gardens' Bulletin Singapore 59(1/2): 203 - 220.

Song, Q., Zhang, G. and Zhu, X.G. 2013. Optimal crop canopy architecture to maximise canopy photosynthetic $CO_2$ uptake under elevated $CO_2$ – a theoretical study using a mechanistic model of canopy photosynthesis. Funct. Plant Biol. 40:109 – 124.

Tang, H., Hu, Y.Y., Yu, W.W., Song, L.L. and Wu, J.S. 2015. Growth, photosynthetic and physiological responses of *Torreya grandis* seedlings to varied light environments. Trees 29: 1011 – 1022.

Taweesak, V., Abdullah, T.L., Hassan, S.A., Kamarulzaman, N.H. and Wan Yusof, W.A. 2014. Growth and flowering response of cut chrysanthemums grown in restricted root conditions. Journal of Food, Agriculture & Environment 12(2): 1240-1243.

Thohirah, L.A., Flora, C.L.S. and Kamalakshi, N. 2010. Breaking bud dormancy and different shade levels for production of pot and cut *Curcuma alismatifolia*. American Journal of Agricultural and Biological Sciences 5 (3): 385 – 388.

Tsukamoto, Y. and Ando, T. 1973. The changes of amount of inhibitors inducing dormancy in the Dutch iris bulb. Proceedings of the Japanese Academy 49, 627 – 632.

Urquhart, L.C. 1959. Civil engineering handbook. New York: McGraw-Hill Book.

Van Os, E.A., Gieling, T.H. and Lieth, J.H. 2008. Technical equiepment in soilless production systems. In *Soilless Culture: Theory and Practice*, ed. M. Raviv and J.H. Lieth, pp. 157 – 207. Amsterdam: Elsevier.

Varela Milla, O., Rivera, E.B., Huang, W.J., Chien, C. and Wang, Y.M. 2013. Agronomic properties and characterization of rice husk and wood biochars and their effect on the growth of water spinach in a field test. Journal of Soil Science and Plant Nutrition 13(2): 251 – 266.

Walker-Simmons, M.K., Roes, P.A., Hogge, L.R. and Abbrams, S.R. 2000. Abscisic acid, ABA immunoassay and gas chromatography/ mass spectrometry verification. In *Plant hormone prtocols (Methods in Molecular Biology)*, ed. G.A. Tucker and J.A. Robberts. Human Press, New Jersey. 33 – 47.

Wallach, R. 2008. Physical characteristic of soilless media. In *Soilless Culture: Theory and Practice*, ed. M. Raviv and J.H. Lieth, pp. 41 – 116. Amsterdam: Elsevier.

Wang, H., Fowke, L.C. and Crosby, W.L. 1997. A plant cyclin dependent kinase inhibitor gene. Nature 386: 451 – 452.

Werner, T., Motyka, V., Strnad, M. and Schmülling, T. 2001. Regulation of plant growth by cytokinin. Proceedings of the National Academy of Sciences of the United States of America 98 (18): 10487 – 10492.

Wilson, D.P. and Finlay,A.R. 1995. Hydroponic system for the production of all year round chrysanthemum. Acta Horticulturae 40: 185 – 192.

Wu, L., Deng, Z., Cao, L. and Meng L. 2020. Effect of plant density on yield and Quality of perilla sprouts. Scientific Reports 10: 9937. DOI: 10.1038/s41598-020-67106-2

Yahya, A., Anieza, S.S., Rosli, B.M. and Ahmad, S. 2009. Chemical and physical characteristics of cocopeat-base media mixtures and their effects on the growth and development of *Celosia cristata*. American Journal of Agricultural and biological Sciences 4(1): 63 – 71.

Yahya, A., Safie, H. and Kahar, S.A. 1997. Properties of cocopeat-based growing media and their effects on two annual ornamentals. Journal of Tropical Agriculture and Food Science 25(2): 151 – 157.

Yao, H., Zhang, Y., Yi, X. *et al*. 2016. Cotton responds to different plant population densities by adjusting specific leaf area to optimize canopy photosynthetic use efficiency of light and nitrogen. Field Crop Res.188:10 – 6.

Zhang, J.T. and Mu, C.S. 2009. Effects of saline and alkaline stresses on the germination, growth, photosynthesis, ionic balance and anti-oxidant system in an alkali-tolerant leguminous forage *Lathyrus quinquenervius.* Soil Science and Plant Nutrition, 55:5, 685 – 697, DOI: 10.1111/j.1747-0765.2009.00411.x

Zhang, W. F., Wang, Z. L., Yu, S. L., Li, S. K., Fang, J. and Tong, W. S. 2004. Effects of planting density on canopy photosynthesis, canopy structure and yield formation of high-yielded cotton in Xinjiang, China. Acta Phytoecologica Sinica 28: 164 – 171. (in Chinese)

Zeithaml, V. A. 1988. Consumer perceptions of price, quality and value: A means-end model and synthesis of evidence. The Journal of Marketing 52(3): 2 – 22.