REFERANCES

Abl Biotechnologies Limited, 2009, **Beta-carotene** [Online], Available : http://www.ablbiotechnologies.com/Products.htm. [2009, December 10].

Al-Babili, S., Hugueney, P., Schledz, M., Frohnmeyer, H., Laule, O. and Beyer, P., 2000, Identification of a novel gene encoding for neoxanthin synthase from Sola tuberosum, **FEBS Lett**, Vol.485, pp.168–72.

Afreen, F., Zobayed, S.M.A., and Kozai, T., 2005, Spectral quality and UV-B stress stimulate glycyrrhizin concentration of Glycyrrhiza uralensis in hydroponic and pot system, **Plant Physiology and Biochemistry.** Vol. 43, pp. 1074–1081.

AOAC, 1990, **Official method of analysis of the association of official chemists**, Inc., Virginia, 1298 p.

AOAC, 2000, **Official method of analysis of the association of official chemists**. Inc., Virginia.

Aziz, Z.A., Davey, M.R., Power, J.B., Anthony, P., Smith, R.M. and Lowe, K.C., 2007, Production of asiaticoside and madecassocide in Centella asiatica in vitro and in vivo, **Biologia Plantarum**, Vol. 51, pp. 34–42.

Beam, J., 2009, **What is Beta Carotene?** [Online], Available : http://www.wisegeek.com/what-is-beta-carotene.htm [2009, July 29].

Bernáth, J. and Tétényi, P., 1978, Ecological factors - adaptibility relationship on investigation of examen two species, *Solanum laciniatum* Ait. and *S. dulcamara* L., **Acta Botanica Academiae Hungarica**, Vol. 24, No. 1-2, pp. 41-56.

Biddulph, O., 1953, **Translocation of radioactive mineral nutrients implants, Use of isotopes in plant and animal research**, US Atomic Energy Commission, TID-5098.

Bryant, J.P., 1987, Felt leaf willow-snowshoe hare interactions: plant carbon–nutrient balance and floodplains succession, **Ecology,** Vol. 68, No. 5, pp. 1319–1327.

Bryant, J.P., Chapin III, F.S. and Klein, D.R., 1983, Carbon/nutrient balance of boreal plants in relation to vertebrate herbivory, **Oikos**, Vol 40, pp. 357–368.

Bryant, J.P., Chapin III, F.S., Reichardt, P.B. and Clausen, T., 1985, Adaption to resource availability as a determinant of chemical defense strategies in woody plants, **Recent Advances in Phytochemistry**, Vol 19, pp. 219–237.

Bouvier, F., d'Harlingue, A., Backhaus, R.A., Kumagai, M.H. and Camara, B., 2000, Identification of neoxanthin synthase as a carotenoid cyclase paralog, **Eur J Biochem**, Vol. 267, pp. 6346–52.

Bouvier, F., d'Harlingue, A., Hugueney, P., Marin, E., Marion-Poll, A. and Camara, B., 1996, Xanthophyll biosynthesis, Cloning, expression, functional reconstitution, and regulation of beta-cyclohexenyl carotenoid epoxidase from pepper (*Capsicum annuum*). **Journal of Chemical Ecology**, Vol. 271, pp. 28861–7.

Change, Y.C. and Miller, W.B., 2005, The development of upper leaf necrosis in *Lilium* 'Star Gazer', **Journal of American Society for Horticultural Science**, Vol. 130, pp. 759-766.

Chauser-Volfson, E. and Gutterman, Y., 1998, Content and distribution of anthrone C-glycosides in the South African arid plant species Aloe mutabilis growing in the direct sunlight and the shade in the Negev Desert of Israel, **Journal of Arid Environments**, Vol. 40, pp. 441–451.

Chong, C., and Berard, L. 1983, Changes in glucosinolates during refrigerated storage of cabbage. , **Journal of American Society for Horticultural Science**, Vol. 108, pp. 688- 691.

Coelho, G.C., Rachwal, M.F.G., Dedecek, R.A., Curcio, G.R., Nietsche, K.and Schenkel, E.P., 2007, Effect of light intensity on methylxanthine contents of Ilex paraguariensis A. St. Hil. **Biochemical Systematic and Ecology**, Vol. 35, pp. 75–80.

Collin, D.J., Pilotti, C.A., and Wallis, A.F.A, 1992, Triterpene acids from Papua New Guinea Terminalia species, **Phytochemistry**, Vol. 31, pp. 881-884.

De Moura, R.S., Costa, S.S., Jansen, J.M., Silva, C.A., Lopes, C.S., Bernardo-Filho, M., Da Silva, VN., Criddle, D.N., Portela, N., Rubenich, L.M.S., Araujo, R.G. and Carvalho, L.C.R.M., 2002, Bronchodilator activity of *Mikania glomerata* Sprengel on human bronchi and guinea-pig trachea, **Journal of Pharmacy and Pharmacology**, Vol. 54, No. 2, pp. 249-256.

de Padua, L.S., Bunyapraphatsara, N., Lemmens, R.H.M.J. (eds). 1999. Medicinal and poisonous plants 1, **Plant Resources of South-East Asia** No. 12(1), Prosea Foundation, Indonesia, pp. 190-194.

Decoteau, D., 1988, Plant Physiology: Environmental Factors and Photosynthesis, **Greenhouse Glazing & Solar Radiation Transmission Workshop**, October 1998, pp. 1-6.

Deng-Jye, Y. and Jau-Tien, Lin., 2008, Effects of different storage conditions on steroid saponins in yam (*Dioscorea pseudojaponica* Yamamoto) tubers, **Food Chemistry**, Vol. 110, pp. 670-677.

Department of Medical Sciences, 2004, Centella Asiatica Herba. *In*: **Supplement to Thai Herba Pharmacopeia**, Prachachon Co., Ltd., Bangkok. p. 9-17.

Division of Nutrition, 1992, **Table of nutrition of Thai food**, Department of Health. Ministry of Public Health, p. 26 (Thai language)

Earley, E.B., Miller, R.J., Reichert G.L., Hageman R.H. and Seif, R.D., 1966, Effect of shade on maize production under field conditions, **Crop Science**, Vol. 6, pp. 1-7.

Erfani, E., Hassandokht, M.R., Jabbari, A. and Barzegar, M., 2007, Effect of cultivar on chemical composition of some Iranian Spinach, **Pakistan Journal of Biological Science**, Vol 10, No. 4, pp. 602-606.

Evan, M., 2007, **Colouring** [Online], Available : http://www.chm.bris.ac.uk/motm/carotene/beta-carotene_colourings.html [July 29, 2009].

Farnsworth, E., 2004, Hormones and shifting ecology throughout plant development, **Ecology,** Vol. 85, pp. 5–15.

Frank, H.A. and Cogdell, R.J., 1996, Carotenoids in photosynthesis, **Phytochem Phytobiol**, Vol. 63, pp. 257–64.

Fricke, W., Hinde, P.S., Leigh, R.A. and Tomas, A.D., 1995, Vacuolar solutes in the upper epidermis of barley leaves; intercellular differences follow patterns, **Planta**, Vol. 196, pp. 40-49.

Gershenzon, J., 1994. Metabolic cost of terpenoid accumulation in higher plants, **Journal of Chemical Ecology**, Vol. 20, pp. 1281–2981.

Gershenzon, J. and Kreis, W., 1999, Biosynthesis of monoterpenes, sesquiterpenes, diterpenes, sterols, cardiac glycosides and steroid saponins, **Annual Plant Reviews**, Vol. 2, pp. 222–299.

Gregoriou, K., Pontikis, K. and Vemmos, S., 2007. Effects of reduced irradiance on leaf morphology, photosynthetic capacity, and fruit yield in olive (*Olea europaea* L.), **Photosynthetica,** Vol. 45, pp. 172–181.

GROSS, J., 1991, Pigments in vegetables: chlorophylls and carotenoids, Van Nostrand Reinhold, **New York**, 351 p.

Gupta, A.P., Gupta, M.M. and Kumar, S., 1999, High performance thin layer chromatography of asiaticoside in *Centella asiatica*. **Journal of India Chemical Society**, Vol. 76, pp. 321–322.

Gupta, S., Lakshmi, A.J., Manjunath, M.N. and Prakash, J., 2005, Analysis of nutrient and antinutrient content of underutilized green leafy vegetables, **LWT**, Vol. 38, pp. 339-345.

Hanson, J.R, 2003, The biosynthesis of secondary metabolites, In **Natural Products, the Secondary Metabolites**; The Royal Society of Chemistry: Cambridge, UK, 2003; pp. 112–121.

Havaux, M., 1998, Carotenoids as membrane stabilisers in chloroplasts, **Trends Plant Science**, Vol. 3, pp. 147–51.

Hettiarachchi, M.P., Rajapakse, W.D.J., Lakshman, P.L.N. and Subasinghe, S., 2005, Keeping quality of dried *Centella asiatica*, *Atternanthera sesilis* and *Cardiospermum halicacabum* for preparation of herbal drinks, Book of abstract, **APAC Symposium on Assuring Quality and Safety of fresh Produce**, August 1-3, 2005, Bangkok, Thailand, 76 pp.

Huang, W.D., Wu, L.K. and Zhan, J.C., 2004, Growth and photosynthesis adaptation of dwarf-type Chinese cherry (*Prunus pseudocerasus* L. cv. *Laiyang*) leaves to weak light stress, **Science Agricultural Singapore**, Vol. 37, pp. 1981–1985.

Josse, E.M., Simkin, A.J., Gaffe´, J., Laboure´, A.M., Kuntz, M. and Carol, P., 2000, A plastid terminal oxidase associated with carotenoid desaturation during chromoplast differentiation, **Plant Physiology**, Vol. 123, pp. 1427–36.

Karmas, E. and Harris, R.S., 1988, **Nutritional Evaluation of Food Processing**, New York, Van Nostrand Reinhold Company: 786 p.

Karting, T., 1988, Clinical Aplications of *Centella asiatica* (L.) Urb. In: Herbs, Spicies and Medicinal Plants, Recent Advances in Botany, **Hoticulture and Pharmacology**, Vol. 3. Ed. Craker L.E. Oryx Press, Phoenix.

Kılıç, S. and Köse, G., 2001, Ca in milk and the dairy products and female health, **World Food**, Vol. 5, pp 72-75. (in Turkish).

Kruse, S., Herrmann, A., Kornher, A., and Taube, F., 2008, Evaluation of genotype and environmental variation in fibre content of silage maize using a model-assisted approach, **European Journal of Agronomy**, Vol. 28, pp. 210-223.

Ledford, H.K. and Niyogi, K.K., 2005, Singlet oxygen and photo-oxidative stress management in plants and algae, **Plant Cell Environments**, Vol. 28, pp. 1037–45.

Lefsrud, M., Kopsell, D., Wenzel, A., and Sheehan, J., 2007, Changes in kale (*Brassica oleracea* L. var. *acephala*) carotenoid and chlorophyll pigment concentrations during leaf ontogeny, **Scientia Horticulturae**, Vol 112, pp. 136–141.

Liu, S.C., Lin, J.T, Yang, D.J., 2009, Determination of cis- and trans- a- and b-carotenoids in Taiwanese sweet potatoes (*Ipomoea batatas* (L.) Lam.) harvested at various times, **Food Chemistry**, Vol. 116, pp. 605–610.

Marin, E., Nussaume, L., Quesada, A., Gonneau, M., Sotta, B., and Hugueney, P.,1996, Molecular identification of zeaxanthin epoxidase of Nicotiana plumbaginifolia, a gene involved in abscisic acid biosynthesis and corresponding to the ABA locus of *Arabidopsis thaliana*, **EMBO J**, Vol. 15, pp. 2331–42.

Mathur, S., Verma, R.K., Gupta, M.M., Ram, M., Sharma, S., and Kumar, S., 2000, Screening of genetic resources of the medicinal-vegetable plant *Centella asiatica* for herb and asiaticoside yields under shaded and full sunlight condition, **Journal of Horticultural Science and Biotechnology**, Vol 75, pp. 551-554.

Montanaro, G., Dichio, B., Xiloyannis, C. and Celano G., 2006, Light influences transpiration and calcium accumulation infruit of kiwifruit plants (*Actinidia deliciosa* var. deliciosa), **Plant Science**, Vol 70, pp. 520-527.

Muangnoi, C., 2007, **Biosccessibility, cellular uptake, and angiotensin converting enzyme (ACE) inhibitory activity of triterpenoids from *Centella asiatica* (L.)** Urban, Master Thesis, Master of Science (Nutrition), Faculty of Graduate studied, Mahidol University, Thailand, 81pp.

Newall, C.V., Anderson, L.A. and Phillipson, J.D., 1996, **Herbal medicines**, London; Pharmaceutical Press.

Ndamba, J., Robertson, I., Lemmich, E., Chandiwana, S.K., Furu, P. and Molgaard, P., 1996, Berry productivity and molluscicidal saponin yield of *Phytolacca dodecandra* (Phytolaceae) under different sunlight, watering and nutrient conditions, **Economic Botany**, Vol. 50, pp. 151-166.

Odhave, B., Beekrum, S., Akula, Us and Baijnath, H., 2007, Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa, **Journal of Food Composition and Analysis**, Vol 20, pp. 430-435.

Oyama, H., Shinohara, Y. and Ito, T., 1999, Effect of air temperature and light intensity on β-carotene concentration in spinach and lettuce. **Journal of the Japanese Society for Horticultural Science**, Vol. 68, No. 2, pp. 414-420.

Pramongkit, K., 1995, **Active Constituents of *Centella asiatica* (L.) Urban. in Thailand**, Master Thesis, Master of Phamaceutical Science, Faculty of Pharmacy, Mahidol University, Nakhon Patom, Thailand. 152 p.

Qin, G., Gu, H., Ma, L., Peng, T. Deng, X.W., Chen, Z. and Qu, L.J., 2007, Disruption of phytoene desaturase gene results in albino and dwarf phenotypes in Arabidopsis by impairing chlorophyll, carotenoid, and gibberellin biosynthesis, **Cell Research**, Vol. 17, pp. 471–482.

Ralphs, M.H., Manners, G.D. and Gardner, D.R., 1998, Influence of light and photosynthesis on alkaloid concentration in larkspur, **Journal of Chemical Ecology**, Vol. 24, pp. 167–182.

Ramaswamy, A.S., Periyasamy, S.M. and Basu, N.k., 1970, Pharmacological studies on Centella asiatica, **Journal of Research and Education in India Medicine**, Vol 4, p. 160.

Randriamampionona, D., Diallo, B., Rakotoniriana, F., Rabemanantsoa, C., Cheuk, K., Corbisier, A.-M., Mahillion, J., Ratsimamanga, S. and Jaziri, M.E.J., 2007, Comparative analysis of active constituents in *Centella asiatica* samples from Madagascar: Application for ex situ conservation and clonal propagation, **Fitoterapia**, Vol. 78, pp. 482–489.

Rouillard-Guellec, F., Robin, J.R., Ratsimamanga, A.R., Ratsimamanga, S. and Rasaoanaivo, R., 1997, Comparative study of *Centella asiatica* of Madagascar origin and Indian origin, **Acta Botanica Gallica**, Vol. 144, pp. 489–493.

Ruban, A.V., Lee, P.J., Wentworth, M., Young, A.J. and Horton, P., 1999, Determination of the stoichiometry and strength of binding of xanthophylls to the photosystem II light harvesting complexes, **Journal of Chemical Ecology**, Vol. 274, pp. 10458–65.

Ruban, A.V., Young, A.J., Pascal, A.A. and Horton, P., 1994, The effects of illumination on the xanthophyll composition of the photosystem II light-harvesting complexes of spinach thylakoid membranes, **Plant Physiology**, Vol. 104, pp. 227–34.

Sandmann, G., 1994, Carotenoid biosynthesis in micro-organisms and plants, **Eur J Biochem**, Vol. 223, pp: 7–24.

Sandmann, G., Römer, S. and Fraser, P.D., 2006, Understanding carotenoid metabolism as a necessity for genetic engineering of crop plants, **Metabolic Engineering**, Vol. 8. pp: 291–302.

Sandmann, G. and Böger, P., 1989, Inhibition of carotenoid biosynthesis by herbicides, In:, **Target sites of herbicides action**, Böger P, Sandmann G, Editors Boca Raton, FL: CRC Press. pp. 25–44.

Sapkoet, N., 2007, **Effects of processing and storage on phytochemical contents and free-radicale-scavenging activity in pennywort (*Centella asiatica* (Linn) Urban) beverages**, Master Thesis, Master of Science (Food and Nutrtion for Development), Mahidol University, Faculty of Graduate Studies, Thailand, 108 pp.

Schalch, W., Dayhaw-Barker, P. and Barker, F. M., 1999, The carotenoids of the human retina, *In* **Nutritional and Environmental Influences on the Eye**, Taylor, A.(Ed.), Boca Raton CRC Press, pp. 215–250.

Schwarzbach, A., Schreiner, M. and Knorr, D., 2006, Effect of cultivars and deep freeze storage on saponin content of white asparagus spears (*Asparagus officinalis* L.), **European Food Research and Technology**, Vol. 222, pp. 32-35, DOI 10.1007/s00114-005-0011-4

Shear, C.B., 1975, Calcium related disorders of fruits and vegetables, **Hortscience**, 10, pp. 361-365.

Shen, S.F., Chang, Z.D., Liu, J., Sun, X.H., Hua, X. and Liu, H.Z., 2007, Separation of glycyrrhizic acid and liquiritin from Glycyrrhiza uralensis Fisch extract by threeliquid-phase extraction systems, **Separation and Purification Technology**, Vol. 53, pp. 216–223.

Somwong, P., 2006, **Isolation, purification and quantitative, determination of asiaticoside, madecassoside, asiatci acid and madecassic acid in varieties of *Centella asiatica* (L.) Urban**, Master Thesis, Master of Science (Phamaceutical

Chemistry), Faculty of Pharmaceutical Science, Chulalongkorn University, Bangkok, Thailand, 130 pp.

Speek, A.J., Speek-Saichua, S., and Schreurs, W.H.P., 1988, Total carotenoid and β-carotene containsof Thai vegetables and the effect of processing, **Food Chemistry**, Vol. 27, 245-257 pp.

Swanson, C.A. and Whitney, J.B., 1953, Studies on the translocation of foliar-applied P-32 and other radioisotopes in bean plants, **American Journal of Botany**, Vol. 40, pp. 553-556.

Sung, T.V., Lavaud, C., Porzel, A., Steglich, W. and Adam, G., 1992, Triterpenoid and their glycosides from the bark of Schefflera octophylla, **Phytochemistry**, Volume 3, pp. 227-231.

Telfer, A., 2002, What is b-carotene doing in the photosystem II reaction centre, **Philos Trans R Soc Lond** , Vol. 357, pp. 1431–1440.

Thayer, S.S. and Björkman, O., 1992, Carotenoid distribution and de-epoxidationin thylakoid pigment–protein complexesfrom cotton leaves and bundle-sheath cells of maize, **Photosynth Res**, Vol. 33, pp. 213–25.

The Forest Herbalium, Royal Forest Department, 2001, **Thai Plant Names Tem Smitinand**, Royal Forest Department, Thailand, 810 p.

Tian, L., Musetti, V., Kim, J., Magallanes-Lundback, M. and DellaPenna, D., 2004, The rabidopsis LUT1 locus encodes a member of the cytochrome p450 family that is required for carotenoid epsilon-ring hydroxylation activity, **Proc Natl Acad Sci**, Vol. 6, No.101, pp. 402–407.

Wei, S.L., Wang, W.Q., Chen, X.H., Qin, S.Y., Chen, X.T., 2005. Studies on the shade-endurance capacity of Glycyrrhiza uralensis. **China J. Chin. Mater. Med**.Volume 30, pp. 100–104.

Westerfield R.R., 2008, When to Harvest Vegetables, **Circular 935** (Horticulture 3).

White, P.J., 2001, The pathways of calcium movement to the xylem. **Journal of Experimental Botany**, Volume 52, pp. 891-899.

White, P.J., and Broadley, M.R., 2003, Calcium in plants, **Annals of Botany**, Vol. 92, pp. 487-511.

Wills, R., McGlasson, B., Graham, D. and Joyce, D., 1998, **Postharvest:An Introduction to the physiology of fruit, Vegetables and Ornamentals**, UNSW Press, Sidney.

Wilson, D. and Cooper, J.P., 1969, Effect of light intensity during grown on leaf anatomy and subsequent light-saturated photosynthesis among contrasting Lolium genotypes, **New Phytol**, Vol. 68, pp. 1125–1135.

Wong, K.C. and Tan, G.L., 1994, Essential oil of *Centella asiatica* (L.) Urb. Sch, **Journal of essential Oil Research**, Vol. 6, pp. 307.

World Health Organization, 1999, Herba Centellae, In: **WHO monographs on selected medicinal plants**, Vol. 1, pp. 77-85.

Ye, X., Al-Babili, S., Klöti, A., Zhang, J., Lucca, P., Beyer. P. and Potrykus, I., 2000, Engineering the Provitamin A (Beta-Carotene) Biosynthetic Pathway into (Carotenoid-Free) Rice Endosperm, **Science**, Vol. 287. no. 5451, pp. 303-305.

Zavala, J.A. and Ravetta, D.A., 2001, Allocation of photo assimilates to biomass, resin and carbohydrates in Grindelia chiloensis as affected by light intensity, **Field Crops Research**, Vol. 69, pp. 143–149.

Zhao, J., Li, G., Wang, B.M., Liu, W., Nan, T.G., Zhai, Z.X., Li, Z.H. and Li, Q.X., 2006, Development of a monoclonal antibody-based enzyme-linked immunosorbent assay for the analysis of glycyrrhizic acid, **Analytical and Bioanalytical Chemistry**, Vol. 386, pp. 1735–1740.

Zheng, C.J. and Qin, L.P, 2007, Chemical components of *Centella asiatica* and their bioactivities, **Chinese Journal of Integrative Medicine**, Vol. 5, pp. 348–351.

APPENDIX A

Table A.1 The leaf area of three accessions of Bua Bok that harvested in different age leaves.

Treatments	Leaf area (cm^2)
Accessions (A)	
Nahkon Si Thammarat	9.73 a[1/]
Rayong	5.67 b
Ubon Ratchathani	5.81 b
F-test	*
Leaf age (G) (days after emerging)	
7	5.08 d
14	5.90 c
21	7.50 b
28	8.44 a
35	8.44 a
F-test	*
A x G	*
C.V. (%)	16.57

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test).

Table A.2 The interaction between accessions of Bua Bok and age leaves on leaf area.

Accessions (A)	Leaf age (G)	Leaf area (cm^2)
Nahkon Si Thammarat	7	6.50 ±1.51 cd[1/]
	14	7.71 ±0.96 b
	21	11.01 ±1.13 a
	28	11.70±1.35 a
	35	11.71±1.40 a
Rayong	7	3.91±1.13f
	14	4.92±0.66 ef
	21	5.95±0.57 cde
	28	6.79±1.03 bc
	35	6.79±0.72 bc
Ubon Ratchathani	7	4.83±1.41ef
	14	5.06±0.95 e
	21	5.54±1.16 de
	28	6.82±1.62 bc
	35	6.82±1.39 bc
Accessions (A)		*
Leaf age (G)		*
A x G		*
C.V. (%)		16.57

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.3 Fiber, protein, calcium and beta-carotene content in Bua Bok accessions that harvested different age leaf

Treatment	Fiber (g/100g dry weight)	Protein (g/100g dry weight)	Calcium (g/100g dry weight)	Beta-carotene (μg/100g dry weight)
Accessions (A)				
Nakhon Si Thammarat	24.53 a[1/]	14.25 b	1.29 b	231.88 b
Rayong	22.92 c	13.85 c	1.12 c	236.32 a
Ubon Ratchathani	24.44 b	14.83 a	1.41 a	225.36 c
F-test	*	*	*	*
Leaf age (G) (days after emerging)				
7	24.16 b	14.38 b	1.27 b	224.59 c
14	23.13 d	14.52 a	1.29 b	234.34 a
21	23.94 c	14.02 d	1.23 b	229.76 b
28	24.62 a	14.33 c	1.42 a	236.45 a
F-test	*	*	*	*
A × G	*	*	*	*
C.V. (%)	0.18	0.27	5.3	1.34

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.4 The interaction between accession of Bua Bok and age leaf on fiber, protein, calcium and beta-carotene contents.

Accessions	Leaf age (days)	Fiber (g/100g dry weight)	Protein (g/100g dry weight)	Calcium (g/100g dry weight)	Beta-carotene (μg/100g dry weight)
Nakhon Si Thammarat	7	24.87±0.10e[1/]	14.56±0.00c	1.34±0.02bc	220.05±0.03g
	14	20.81±0.04l	14.19±0.00f	1.15±0.11d	235.41±0.02bc
	21	26.33±0.04a	14.10±0.04g	1.13±0.08d	230.82±0.01bc
	28	26.07±0.06c	14.15±0.03fg	1.54±0.05a	241.23±0.01a
Rayong	7	21.39±0.02k	13.46±0.03 h	1.08±0.01d	229.54±0.02de
	14	22.61±0.04i	14.17±0.03fg	1.29±0.12c	241.57±0.03a
	21	23.60±0.01h	1.348±0.03h	1.17±0.08d	236.41±0.03ab
	28	24.07±0.02f	14.29±0.03e	1.30±0.02c	238.97±0.02ab
Ubon Ratchathani	7	26.21±0.02b	15.10±0.04b	1.38±0.08bc	224.20±0.03efg
	14	25.96±0.01d	15.21±0.03a	1.42±0.02abc	226.06±0.02def
	21	21.87±0.02j	14.48±0.04d	1.40± 0.01bc	222.04±0.03fg
	28	23.71±0.02g	14.54±0.03cd	1.44±0.04ab	229.15±0.03de
Accessions (A)		*	*	*	*
Leaf age (G)		*	*	*	*
A × G		*	*	*	*
C.V. (%)		0.18	0.27	5.3	1.34

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.5 Asiaticoside content on accessions of Bua Bok.that harvested from different leaf age

Factors	Asiaticoside (% dry weight)
Accessions (A)	
Nakhon Si Thammarat	3.38 b[1/]
Rayong	3.25 b
Ubon Ratchathani	3.94 a
F-test	*
Leaf age (G) (days after emerging)	
7	3.00 c
14	3.57 b
21	3.77 ab
28	3.89 a
F-test	*
A x G	*
C.V. (%)	7.45

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test)

Table A.6 The interaction between accession of Bua Bok and leaf age on asiaticoside content

Accessions	Leaf age (days)	Asiaticoside (% dry weight
Nakhon Si Thammarat	7	3.01±0.10 ef[1/]
	14	3.66±0.10 de
	21	3.39 ±0.10fg
	28	3.85±0.20dc
Rayong	7	3.25±0.10 g
	14	3.03±0.20 h
	21	3.24±0.12 g
	28	3.51±0.13 ef
Ubon Ratchathani	7	2.73±0.21 i
	14	4.04±0.10 c
	21	4.46±0.17 a
	28	4.32±0.10 b
Accessions (A)		*
Leaf age (G)		*
A x G		*
C.V. (%)		7.46

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test).

Table A.7 The chlorophyll content of three accessions of Bua Bok in different light intensity.

Factors	Chlorophyll content (mg/g fresh weight)
Accessions (A)	
Nakhon Si Thammarat	2.80 b[1/]
Rayong	4.03 b
Ubon Ratchathani	24.07 a
F-test	*
Light intensity (L) ($\mu mol/m^2/s$)	
933.07	4.11 a
362.55	12.48 a
93.30	14.32 a
F-test	ns
A x L	ns
C.V. (%)	42.4

[1/] Values within columns followed by the same letter are not significantly different to each other at P ≤0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P≤ 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.8 The interaction between accessions of Bua Bok and light intensity on chlorophyll contents.

Accessions (A)	Light intensity (L) ($\mu mol/m^2/s$)	Chlorophyll content (mg/g fresh weight)
Nakhon Si Thammarat	933.07	1.79±2.54 b[1/]
	362.55	2.31±1.38 b
	93.30	4.28±2.42 ab
Rayong	933.07	1.23±1.11 b
	362.55	4.37±6.35 ab
	93.30	6.48±5.47 ab
Ubon Ratchathani	933.07	9.29±12.19 ab
	362.55	10.74±30.0 a
	93.30	12.19±28.3 a
Accessions (A)		*
Light intensity (L)		ns
A x L		ns
C.V. (%)		42.4

[1/] Values within columns followed by the same letter are not significantly different to each other at P ≤0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P≤ 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.9 The leaf area and petiole length of three accessions of Bua Bok that growth under different light intensity

Treatment	Leaf area (cm^2)	Petiole length (cm)
Accessions (A)		
Nakhon Si Thammarat	13.08 a[1/]	6.94 c
Rayong	9.27 b	10.6 a
Ubon Ratchathani	9.77 b	8.34 b
F-test	*	*
Light intensity (L) ($\mu mol/m^2/s$)		
933.07	8.44 c	5.52 c
362.55	10.58 b	8.37 b
93.30	13.05 a	12.00 a
F-test	*	*
A x L	*	*
C.V. (%)	21.87	23.19

[1/] Values within columns followed by the same letter are not significantly different to each other at P ≤0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P≤ 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.10 The interaction between accessions of Bua Bok and light intensity on leaf area and petiole length.

Accessions (A)	Light intensity (L) ($\mu mol/m^2/s$)	Leaf area (cm^2)	Petiole length (cm)
Nakhon Si Thammarat	933.07	11.70±1.35 bc[1/]	3.94±0.38 d
	362.55	12.66±3.36 abc	5.75±1.13 c
	93.30	14.72±2.15 a	11.15±2.35 b
Rayong	933.07	6.79±1.03 e	7.33±1.15 c
	362.55	8.65±1.91 de	9.80± 2.99 b
	93.30	10.56±2.91 cd	14.7±2.85 a
Ubon Ratchathani	933.07	9.82±1.68 e	5.30±1.37 d
	362.55	10.42±1.61 cd	9.56±2.50 b
	93.30	13.87±3.60 ab	10.16±1.56 b
Accessions (A)		*	*
Light intensity (L)		*	*
A x L		*	*
C.V. (%)		21.87	23.19

[1/] Values within columns followed by the same letter are not significantly different to each other at P ≤0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P≤ 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.11 The fresh and dry weight of three accessions of Bua Bok that growth under different light intensity

Treatment	Fresh weight (kg/m^2)	Dry weight (g/kg fresh weight)
Accessions (A)		
Nakhon Si Thammarat	1.68 b[1/]	141.101
Rayong	1.31 c	136.21
Ubon Ratchathani	2.00 a	135.83
F-test	*	ns
Light intensity (L) ($\mu mol\ m^{-2}\ s^{-1}$)		
933.07	2.76 a	152.31 a
362.55	1.44 b	139.91 b
93.30	0.79 c	120.92 c
F-test	*	*
A x L	ns	4.47
C.V. (%)	23.87	

[1/] Values within columns followed by the same letter are not significantly different to each other at P ≤0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P≤ 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.12 The interaction between accessions and light intensity on fresh and dry weight of Bua Bok

Accessions	Light intensity ($\mu mol/m^2/s$)	Fresh weight (kg/m^2)	Dry weight (g/kg fresh weight)
Nakhon Si Thammarat	933.07	2.78±0.69 b[1/]	154.93±5.42 a
	362.55	1.45±0.37 d	147.50±6.50 ab
	93.30	0.83±0.16 e	120.86±2.24 d
Rayong	933.07	2.02±0.33 c	151.45±6.35 a
	362.55	1.22±0.23 de	137.82±9.68 bc
	93.30	0.69±0.25 e	119.36±6.66 d
Ubon Ratchathani	933.07	3.50±0.58 a	150.56±6.19 a
	362.55	1.66±0.42 cd	134.42±4.58 c
	93.30	0.85±0.09 e	122.53±5.43 d
Accessions		*	ns
Light intensity		*	*
Accessions x Light intensity		ns	ns
C.V. (%)		23.87	4.47

[1/] Values within columns followed by the same letter are not significantly different to each other at P ≤0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P≤ 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.13 The fiber, protein, calcium and beta-carotene of three accessions of Bua Bok that growth under different light intensity

Treatment	Fiber (g/100g dry weight)	Protein (g/100g dry weight)	Calcium (g/100g dry weight)	Beta-carotene (µg/100g dry weight)
Accessions (A)				
Nakhon Si Thammarat	11.15 c[1/]	18.63 a	1.37 c	15.58 c
Rayong	11.91 a	18.02 c	1.58 b	18.56 a
Ubon Ratchathani	11.71 b	18.86 b	1.78 a	16.87 b
F-test	*	*	*	*
Light intensity (L) (µmol/m^2/s)				
933.07	11.68	16.77 a	1.47 c	16.84 b
362.55	11.55	19.27 b	1.52 b	16.67 c
93.30	11.53	19.48 c	1.74 a	17.50 a
F-test	ns	*	*	*
A × L	*	*	*	*
C.V. (%)	1.73	0.22	2.18	0.07

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.14 The interaction between accessions of Bua Bok and light intensity on fiber, protein, calcium and beta-carotene contents.

Accessions	Light intensity ($\mu mol/m^2/s$)	Fiber (g/100g dry weight)	Protein (g/100g dry weight)	Calcium (g/100g dry weight)	Beta-carotene (μg/100g dry weight)
Nakhon Si Thammarat	933.07	11.22 ± 0.09 d[1/]	17.78 ± 0.03g	1.25 ± 0.03 f	15.76 ± 0.00 g
	362.55	11.59 ± 0.09 bcd	18.26 ± 0.03 e	1.35 ± 0.01 e	14.91 ± 0.01 i
	93.30	10.63 ± 0.38 e	19.84 ± 0.03 b	1.48 ± 0.01d	16.08 ± 0.01e
Rayong	933.07	12.19 ± 0.03a	14.67 ± 0.09h	1.42 ± 0.06e	18.95 ± 0.01c
	362.55	11.44 ± 0.09 cd	20.09 ± 0.03a	1.76 ± 0.01b	20.12 ± 0.02a
	93.30	12.11 ± 0.20a	19.28 ± 0.03d	1.56 ± 0.01c	16.16 ± 0.01d
Ubon Ratchathani	933.07	11.63 ± 0.16 bc	17.87 ± 0.01f	1.75 ± 0.39b	15.82 ± 0.01f
	362.55	11.59 ± 0.32bcd	19.41 ± 0.03c	1.42 ± 0.01 e	14.99 ± 0.00h
	93.30	11.91 ± 0.11ab	19.31 ± 0.00d	2.17 ± 0.56a	19.80 ± 0.01b
Accessions (A)		*	*	*	*
Light intensity (L)		ns	*	*	*
A × L		*	*	*	*
CV. (%)		1.73	0.22	2.18	0.07

[1/] Values within columns followed by the same letter are not significantly different to each other at P ≤0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P≤ 0.05 (Duncan's Multiple Range test).

ns = Not significantly different

Table A.15 The asiaticoside content of three accessions of Bua Bok that growth under different light intensity

Factors	Asiaticoside (%w/w)
Accessions (A)	
Nakhon Si Thammarat	2.67 c[1/]
Rayong	3.44 b
Ubon Ratchathani	3.65 a
F-test	*
Light intensity (L) (μmol/m^2/s)	
933.07	3.90 a
362.	3.16 b
93.30	2.69 c
F-test	*
A x L	*
C.V. (%)	5.32

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test)

Table A.16 The interaction between accessions of Bua Bok and light intensity on asiaticoside content.

Accessions	Light intensity ($\mu mol/m^2/s$)	Asiaticoside (%w/w)
Nakhon Si Thammarat	933.07	3.36±0.04 c[1/]
	362.55	2.43±0.09 ed
	93.30	2.22±0.01 e
Rayong	933.07	4.38±0.39 a
	362.55	3.38±0.12 c
	93.30	2.56±0.22 d
Ubon Ratchathani	933.07	3.95±0.08 b
	362.55	3.88±0.16 b
	93.30	3.10±0.07 c
Accessions (A)		*
Light intensity (L)		*
A x L		*
C.V. (%)		5.32

[1/] Values within columns followed by the same letter are not significantly different to each other at P =0.05 (Duncan's Multiple Range test).

* Significantly different to each other at P= 0.05 (Duncan's Multiple Range test)

CURRICULUM VITAE

NAME	:	Miss Jirapan Srithongkul
DATE OF BIRTH	:	4 September 1976
EDUCATION RECORD		
HIGH SCHOOL	:	Suratthani School, 1995
BACHELOR'S DEGREE	:	Bachelor of Science (Agriculture) Naresuan University, 1999
MASTER'S DEGREE	:	Master of Science (Horticulture) Kasetsart University, 2003
DOCTORAL DEGREE	:	Doctor of Philosophy (Postharvest Technology) King Mongkut's University of Technology Thonburi, 2010
SCHOLARSHIP/ RESEARCH GRANT	:	King Mongkut's Diamond Scholarship
EMPLOYMENT RECORD	:	Thailand Institute of Scientific and Technological Research
PUBLICATIONS	:	Sritongkul, J., Srilaong, V., Uthairatanakij, A., Kanlayanarat, S. and Chalermglin, P. 2009, Effect of light intensity on chemical composition of Asiatic pennywort (*Centella asiatica* (L.)Urban), **Acta Hort. (ISHS),** 837:87-93
		Sritongkul, J., Srilaong, V., Uthairutanakij, A., Kanlayanarat, S. and Chalermglin, P. 2008, Effects of leaf maturity on asiaticoside, beta-carotene and calcium of India pennywort (*Centella asiatica* (L.)Urban), **Acta Hort (ISHS),** 804:367-372
		Sritongkul, J., Kanlayanarat, S., Srilaong, V., Uthairutanakij, A., and Chalermglin, P., 2011, Effects of light intensity on growth and accumulation of triterpenoids in three ccessions of Asiatic pennywort (*Centella asiatica* (L.) Urb.), **Journal of Food Agriculture & Environment,** 9(1):360-363

King Mongkut's University of Technology Thonburi

Agreement on Intellectual Property Rights Transfer for Postgraduate Students

Date 30 April 2010

Name JIRAPAN

Surname/Family Name SRITHONGKUL

Student Number 48530102 who is a student of King's Mongkut's University of Technology Thonburi (KMUTT) in ○ Graduate Diploma ○ Master Degree ○ Doctoral Degree

Program Doctor of Philosophy Field of Study Postharvest Technology

Faculty/School School of Bioresources and Technology

Home Address 19 Moo 4 Lipanoi, Koh Samui, Suratthani

Postal Code 84140 Country Thailand

I, as 'Transferer', hereby transfer the ownership of my thesis copyright to King's Mongkut's University of Technology Thonburi who has appointed (Dean's name) Assoc. Prof. Narumon Jeyahoke Dean of Faculty of School of Bioresources and Technology to be 'Transferee' of copyright ownership under the 'Agreement' as follows.

1. I am the author of the thesis entitled Effects of leaf maturity, light intensity and temperature on changing of asiaticoside and quality of Asiatic Pennywort (*Centella asiatica* (L.) Urb.) under the supervision of Assoc. Prof. Dr. Sirichai Kanlayanarat who is my supervisor, and Chief Expert Dr. Piya Chalermglin who is my co-supervisor, in accordance with the Thai Copyright Act B.E. 2537. The thesis is a part of the curriculum of KMUTT.

2. I hereby transfer the copyright ownership of all my works in the thesis to KMUTT throughout the copyright protection period in accordance with the Thai Copyright Act B.E. 2537, effective on the approval date of thesis proposal consented by KMUTT.

3. To have the thesis distributed in any form of media, I shall in each and every case stipulate the thesis as the work of KMUTT.

4. For my own distribution of thesis or the reproduction, adjustment, or distribution of thesis by the third party in accordance with the Thai Copyright Act B.E. 2537 with remuneration in return, I am subject to obtain a prior written permission from KMUTT.

5. To use any information from my thesis to make an invention or create any intellectual property works within ten (10) years from the date of signing this Agreement, I am subject to obtain prior written permission from KMUTT, and KMUTT is entitled to have intellectual property rights on such inventions or intellectual property works, including entitling to take royalty from licensing together with the distribution of any benefit deriving partly or wholly from the works in the future, conforming with the Regulation of King Mongkut's Institute of Technology Thonburi *Re* the Administration of Benefits deriving from Intellectual Property B.E. 2538.

6. If the benefits arise from my thesis or my intellectual property works owned by KMUTT, I shall be entitled to gain the benefits according to the allocation rate stated in the Regulation of King Mongkut's Institute of Technology Thonburi *Re* the Administration of Benefits deriving from Intellectual Property B.E. 2538.

Signature Jirapan Srithongkul Transferor

(Miss Jirapan Srithongkul)

Signature Narumon Jeyahoke Transferee

(Assoc. Prof. Narumon Jeyahoke)

Signature Sirichai Kanlayanarat Witness

(Assoc. Prof. Dr.Sirichai Kanlayanarat)

Signature Varit Srilaong Witness

(Assist. Dr. Varit Srilaong)