UNIVERSITI PUTRA MALAYSIA

GROWTH, YIELD AND PHYTOCHEMICAL CONTENTS OF SABAH SNAKE GRASS [Clinacanthus nutans (Burm.f.) Lindau] IN RELATION TO PLANT AGE, HARVESTING INTERVALS AND POTASSIUM APPLICATIONS

NUR MARDHIATI AFIFA ABD SAMAT

FP 2018 62

GROWTH, YIELD AND PHYTOCHEMICAL CONTENTS OF SABAH SNAKE GRASS [*Clinacanthus nutans* (Burm.f.) Lindau] IN RELATION TO PLANT AGE, HARVESTING INTERVALS AND POTASSIUM APPLICATIONS

By

NUR MARDHIATI AFIFA ABD SAMAT

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

November 2017

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

GROWTH, YIELD AND PHYTOCHEMICAL CONTENTS OF SABAH SNAKE GRASS [*Clinacanthus nutans* (Burm.f.) Lindau] IN RELATION TO PLANT AGE, HARVESTING INTERVALS AND POTASSIUM APPLICATIONS

By

NUR MARDHIATI AFIFA ABD SAMAT

November 2017

Chairman : Associate Professor Yahya Bin Awang, PhD
Faculty : Agriculture

Clinacanthus nutans or Sabah snake grass is a well reputed medicinal herb among locals which therapeutically used to cure various ailments and diseases for its phytochemicals and antioxidants. Various factors including cultural practices may contribute to the changes in growth and phytochemical contents, hence determine the quantity, quality and efficacy of an herb. Current studies focusing on the harvesting (age and intervals) and fertilizer (potassium) were undertaken evaluating growth, yield and phytochemical content of *C. nutans*. Plants were cultivated through stem cuttings and were harvested at three different age (week 8, week 12 and week 16 after transplanting) and three harvesting intervals (every 8, 12 and 16 weeks, for respective harvesting age) for three consecutive harvests (harvest 1, 2 and 3). After the completion of the first experiment, plants were then treated with five different rates of potassium fertilizer (0, 50, 100, 150, 200 and 250 kg K_2O/ha) using muriate of potash (MOP). The experiments were conducted based on Randomized complete block design (RCBD) with appropriate replications.

The results show a significant interaction between plant age and harvesting intervals observed in plant height, leaf area, fresh and dry weight of leaves, phenolic content and ferric reducing antioxidant potential activity (FRAP). The highest leaf fresh yield was recorded at the 16-week-old plants (144.13 g) during third harvesting intervals (154.32 g). The leaf to stem ratio, however decreased with plant age while increased with harvesting interval indicating an increment in stem proportion as the plant grow older. The phytochemical contents were also found to be increased with plant age giving the highest total flavonoid content (TFC) and total phenolic content (TPC) accumulated at 16-week-old plant of 7.32 mg GAE/g DW and 10.84 mg quercetin/g DW respectively. The TFC and TPC decreased following the repetitive harvesting

with the lowest recorded at first harvesting interval (TFC: 7.13 mg GAE/g DW, TPC: 10.30 mg quercetin/g DW). The antioxidant activities also significantly increased with plant age while decreased in a number of harvesting intervals. Of all identified compounds, shaftoside was found to be the most abundant in *C. nutans* at any levels of treatments. The order of C-glycosyl flavone compounds detected under different plant age and harvesting intervals based on concentration from high to low were as follows: shaftoside > iso-orientin > orientin > vitexin > iso-vitexin. In second experiment, all plant growth attributes and yield except for the number of branches were increased with increment of potassium rates. Referring to the trend analysis, the growth and development of *C. nutans* improved gradually with potassium in a positive and quadratic trend from 0 kg K_2O/ha to 200 kg K_2O/ha before decline slowly at 250 K_2O/ha in respective shoot fresh and dry weight, leaf gas exchange, phytochemical contents and antioxidant activities. The optimum rate and the maximum value, however, varied with the parameters.

All detected C-glycosyl flavone compounds were highest at 200 kg K_2O/ha given shaftoside as the major compound identified. These results obtained in both experiments indicates that the yield and phytochemical quality of *C. nutans* can be enhanced by regulating the cultural practices. Harvesting at week 12 with one-time interval and applying would be appropriate harvesting method as growth, yield and phytochemicals content of *C. nutans* were enhanced.An optimum potassium level of 154.75 kg K_2O/ha could be the appropriate K application for the cultivation of *C. nutans* as yield were enhanced and 143 kg K_2O/ha of muriate of potash would be the appropriate optimum K rate that would improve the production of phytochemical content in *C. nutans*.

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

PERTUMBUHAN, HASIL TANAMAN DAN KANDUNGAN FITOKIMIA BELALAI GAJAH [*Clinacanthus nutans* (Burm.f.) Lindau] BERHUBUNG DENGAN UMUR POKOK, SELANGAN PENUAIAN DAN PEMBAJAAN POTASSIUM

Oleh

NUR MARDHIATI AFIFA ABD SAMAT

November 2017

Pengerusi : Professor Madya Yahya Bin Awang, PhD
Fakulti : Pertanian

Clinacanthus nutans atau Belalai gajah adalah tanaman herba yang dikenali di antara penduduk tempatan dalam mengubati pelbagai penyakit oleh kerana adanya fitokimia dan antioksida. Pelbagai faktor termasuk amalan agronomi mungkin menyumbang kepada perubahan pertumbuhan dan kandungan fitokimia yang menentukan kuantiti, kualiti dan keberkesanan sesuatu tanaman herba. Kajian terkini yang menumpukan kepada penuaian (umur dan selang) dan pembajaan (potassium) telah dijalankan bagi menilai pertumbuhan, hasil tanaman dan kandungan fitokimia dalam Belalai gajah. Pokok telah ditanam menggunakan keratan batang dan telah dituai pada tiga umur yang berbeza (minggu 8, minggu 12 dan minggu 16 setelah transplant) dan tiga selang penuaian (setiap 8, 12 dan 16 minggu untuk umur masing-masing) untuk tiga kali penuaian berturut-turut (tuai 1, 2 dan 3). Setelah eksperimen pertama telah lengkap, pokok kemudiannya dibaja dengan lima kadar baja potassium yang berbeza (0, 50, 100, 150, 200 and 250 kg K_2O/ha) menggunakan muriate of potash (MOP). Eksperimen ini dijalankan dengan menggunakan reka bentuk blok lengkap rawak dengan replikasi yang sesuai.

Hasil kajian mendapati terdapat interaksi yang ketara di antara umur pokok dan selang penuaian pada tinggi pokok, luas daun, berat daun segar dan kering, kandungan fenolik dan aktiviti FRAP. Hasil berat daun yang segar telah direkodkan pada umur minggu ke-16 (144.13 g) pada selang penuaian yang ketiga (154.32 g). Walau bagaimanapun, nisbah daun kepada batang menurun mengikut umur pokok manakala ianya meningkat mengikut selang penuaian yang menunjukkan bahawa batang bertambah banyak apabila pokok semakin tua. Kandungan fitokimia juga didapati meningkat mengikut umur pokok dengan jumlah kandungan flavonoid (TFC) dan

jumlah kandungan fenolik (TPC) tertinggi terkumpul pada umur pokok ke-16 minggu dengan masing-masing 7.32 mg GAE/g DW dan 10.84 mg quercetin/g DW. TFC dan TPC menurun mengikut pengulangan penuaian dengan kadar terendah direkodkan pada selang penuaian pertama (TFC: 7.13 mg GAE/DW, TPC: 10.30 mg quercetin/DW). Aktiviti antioksida juga meningkat mengikut umur pokok dan menurun apabila kadar penuaian ditingkatkan. Diantara semua kandungan bioaktif, shaftoside banyak didapati dalam *C. nutans* pada mana-mana rawatan. Turutan C-glycosyl flavone pada umur pokok dan selang penuaian berdasarkan pada konsentrasi yang tinggi kepada rendah adalah yang tertera: shaftoside > iso-orientin > orientin > vitexin > iso-vitexin. Dalam kajian yang kedua, semua pertumbuhan dan hasil pokok kecuali bilangan cabang telah meningkat mengikut kadar pembajaan potassium. Berdasarkan kepada trend analisa, pertumbuhan dan perkembangan *C. nutans* meningkat mengikut kadar pembajaan potassium secara positif dan kuadratik bermula daripada 0 kg K_2O/ha kepada 200 kg K_2O/ha sebelum menurun secara perlahan pada 250 kg K_2O/ha yang dapat dilihat masing-masing pada berat basah dan kering tanaman, penukaran gas daun, kandungan fitokimia dan aktiviti antioksida. Akan tetapi, kadar pembajaan yang optima and maksimum adalah berbeza mengikut parameter.

Tambahan pula, semua kandungan C-glycosyl flavon tertinggi direkodkan pada 200 kg K_2O/ha dengan shaftoside sebagai konstitusi yang utama. Semua hasil kajian pada kedua-dua eksperimen menunjukkan bahawa hasil tanaman dan fetokimia *C. nutans* boleh ditingkatkan dengan memperbaiki amalan agronomi. Penuaian pada umur minggu ke-12 dengan sekali selang penuaian adalah teknik penuaian yang sesuai kerana pertumbuhan, hasil tanaman serta kandungan fitokimia meningkat pada tanaman *C. nutans*. Pembajaan potassium yang optima pada 154.75 kg K_2O/ha adalah pembajaan yang sesuai bagi penanaman *C. nutans* kerana hasil tanaman meningkat dan 143 kg K_2O/ha adalah kadar pembajaan potassium yang optima dalam meningkatkan kandungan fitokimia dalam *C. nutans*.

ACKNOWLEDGEMENTS

In the name of Allah S.W.T, for His most graciousness and most mercifulness;

I wish to express my deepest gratitude to everybody who is involved in this research project, regardless whether directly or indirectly.

First of all, I would like to express my deepest gratitude to my former supervisor, Assoc. Prof. Dr. Izham bin Ahmad and my new supervisor, Assoc. Prof. Dr. Yahya bin Awang for their guidance and contribution during the preparation of this master thesis. Their countless patience, encouragement and generosity cannot be over emphasized.

Special thanks to Tuan Haji Suhaimi Aman, Mr Mazlan Bangi and all staff of Department of Crop Science, Department of Soil Science, Institute of Tropical Agriculture (ITA) and Institute of Bio Science (IBS) who is involved directly or indirectly in this study. Special thanks also given to Kak Siti and all staff of Ladang 10. Thanks for your help, guidance and support for me to finish this project.

A very special gratitude to my parents, Abd Samat Bin Injau and NurHajaji Bte Mardjuni for being with me all the time from the beginning until the end of this study. Their generosity, encouragement, support and motivation are priceless and dearly appreciated.

Not to be forgotten, I would like to thanks to my friends, Stephanie, Nur Shuhamin, Nor Shariah Salleh, Zurafni binti Mat Daud and all other friends who have known me and always been very helpful to me.
Thank you so much.

This thesis was submitted to the Senate of the 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:

Yahya Bin Awang, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Syahida Ahmad, PhD
Senior Lecturer
Faculty of Biotechnology
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software

Signature: _____ Date: _____

Name and Matric No: Nur Mardhiati Afifa Abd Samat,.GS41566

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) were adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: Associate Professor Dr. Yahya Bin Awang

Signature: _____
Name of Member of Supervisory Committee: Dr. Syahida Ahmad

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

cm	Centimetre
ROS	Reactive oxygen species
AAPH	2,2'-azobis (2-amidinopropane) dihydrochloride
DPPH	α, α-diphenyl-β-picrylhydrazyl
ABTS	2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)
TLR	Toll-like receptor
%	Percentage
VZV	Varicella-zoster virus
HSV	Herpes simplex virus
ALS	Automatic liquid sampler
UHPLC	Ultra-high pressure liquid chromatography
HPLC	High pressure liquid chromatography
GC	Gas chromatography
GA	Gibberellic acid
kg	Kilogram
ha	Hectare
K^+	Potassium ion
K, K_2O	Potassium
mmol	Milimoles
L	Liter
CO_2	Carbon dioxide
PAL	Phenylalanine ammonia-lyase
µg	microgram

G	gram
CEC	Cation exchange capacity
N	Nitrogen
P, P_2O_5	Phosphorus
Ca	Calcium
Mg	Magnesium
Cu	Copper
Fe	Iron
Mn	Manganese
Zn	Zinc
TSP	Triple superphosphate
MOP	Muriate of potash
mm	Millimeter
^oC	Celcius
Na_2CO_3	Sodium carbonate
UV	Ultraviolet visible
GAE	Gallic acid equivalent
Nm	Nanometer
$NaNO_3$	Sodium nitrite
$AlCl_3$	Aluminium chloride
NaOH	Sodium hydroxide
mg	Milligram
mM	Millimolar
TPTZ	2,4,6- tri [2-pyridyl]-s- triazine
$FeCl_3$	Iron chloride

µM	Micromole
µL	Microlitre
Cm^2	Square centimeter
DW	Dry weight
FRAP	Ferric reducing antioxidant power
mmol m^{-2} s^{-1}	Millimole meter square per second
µmol m^{-2} s^{-1}	Micromole meter square per second

CHAPTER 1

INTRODUCTION

As herbal consist of a valuable source of bioactive compounds, it has been contributed significantly to human welfares which widely utilized across the world of nutraceuticals either traditionally, complementary and alternatively. More than 80% of the world population especially in developing countries has been appraised to rely predominantly on herbal remedies to fulfil healthcare necessity (WHO, 2002) and such medicines are acquired mostly from plant extracts. These plant extracts are known to be rich with phytochemicals which appear to be the antioxidant nature of aromatic phenolic acids and flavonoids structures. Flavonoids, as the largest family having low molecular structure of phenolic secondary metabolites are well known to be associated with great length of pharmacological activities which widely spread throughout the natural plants (Saxena et al., 2013). These compounds are receiving considerable attention due to documented protective role against many diseases which may attributed to the biological effects of antioxidant activity against reactive oxygen species (Schijlen et al., 2004).

Until today, many intensive research and extensive studies are still carried out to exploit plants capabilities as alternative regiments against various ailments and diseases. To date, around 21,000 plant species have been identified to have medicinal potency and the number is still increasing (WHO, 2009). *Clinacanthus nutans* or commonly known as sabah snake grass has been recognized as one of the potent medicinal plants and highly reported to have a broad spectrum of pharmacological properties such as anti-inflammatory (Shyuprom, 2004), antioxidant (Wanakiat et al., 2007) and antiviral against (herpes simplex virus (HSV), varicalle-zoster virus, papillomavirus, and dengue virus) (Kunson et al., 2013). Native to tropical Asia countries, this herb is well reputed in Thai folklore medicine due to its ability to cure ailments such as skin inflammation, snake and insect bites. In Malaysia, *C. nutans* has attracted public interest recently for its high medicinal properties specifically as anticancer regimens due to the presence of natural antioxidant and anti-proliferative properties (Yong et al., 2013). Owing to the fact that this herb give significant economic benefits towards human health, the demand of this herb has been increasing in recent years.

Although these constituents offer many substantial effect in human well-being, the polyphenolic compounds attributed the biological activities may often modulated by various factors which includes cultivars, genotype, environmental condition such as light intensity, relative humidity and cultural practices. In all of these factors, cultural techniques considered to be the highly applicable long-term alternative practices which provide ample favourable circumstances to overcome difficulties inherited by medicinal plant including manipulating the genetic and phenotypic variation of polyphenolic compounds, contamination and toxicity of constituents as well as misidentification (Canter et al., 2005). Through a proper and controlled growing

condition, plant growth development may be enhanced and largen the biomass production with high and polyphenolic content consistency can be optimized (Mathe & Mathe, 2008). Considering these significant advantages, cultural techniques can be used as an alternative means to produce high quality herbage yield. These conditions cover plant age, harvesting interval, soil composition and fertilizer applications.

Fertilization or plant nutrient availability in particular, has been highlighted in countless number of studies to give a profound effect in plant performances as well as regulating the secondary metabolites and antioxidant activity within plants (Prange & Dell, 1997; Mudau, 2007; Strik, 2008; and Ibrahim et al., 2012). Potassium as one of the macronutrients plays a vital determinant for yield and quality in many crops (Cassman et al., 1990; Pettigrew, 2008 and Cakmak, 2010). In physiological aspect, potassium responsible in promoting the photosynthesis process and important mineral in phloem transportation and osmotic regulation (Ghazemsadeh et al., 2012). The development of photosynthesis process will improve the accumulation of primary metabolites (starch and soluble sugar) which then be devoted to secondary metabolites of aromatic phenolics and flavonoids. It has been found by Ibrahim et al. (2012) whose stated that enhancement of phytochemicals typically accompanied by an increment of potassium supplementation. Similar occurrence has been found related to plant maturity where upsurges in polyphenolic compounds and antioxidant activity is plant age and harvesting interval dependent (Ghazemsadeh et al., 2012 and Hue et al., 2012). The dynamic changes in secondary metabolites may be attributed to the levels of certain enzymes which are present in plants. As such, plant's progression and productivity have been seen to be vary with respect to plant maturity, harvesting intervals and fertilizer application.

Most of reported studies previously on *C. nutans* are more emphasized on phytochemistry, biological aspect and pharmaceutical quality but relatively few studies covering the agronomic attribution. Studies performed with different levels of nitrogen fertilization, plant density, and light intensity particularly on *C. nutans* are well demonstrated yet no documentation of plant development, yield and phytochemical responses in various plant maturity, harvesting intervals and fertilization, especially potassium, have been recorded (Khaulah, 2014 & Nasiri, 2016). It is desirable to gather relevant information through cultivation practices specifically in harvesting and fertilizer management as alternative ways to intensify the production while sustaining the medicinal potency of the plants. Therefore, current studies were undertaken to evaluate the effect of harvest age, harvest intervals and potassium on growth, yield and phytochemicals of *C. nutans*.

REFERENCES

Abdul Rahim, M. H., Zakaria, Z. A., Mohd Sani, M. H., Omar, M. H., Yakob, Y., Cheema, M. S., Ching, S. M., Ahmad, Z. and Abdul Kadir, A. (2016). Methanolic extract of *Clinacanthus nutans* exerts antinociceptive activity via the opioid/nitric oxide-mediated, but cgmp-independent, pathways. *Evidence-Based Complementary and Alternative Medicine*, 1–11.

Abdullah, T. (2013). Vegetative propagation [Powerpoint slides]. Universiti Putra Malaysia, Selangor Darul Ehsan, Malaysia.

Adnan, N. and Othman, N. (2012). The relationship between plants and the malay culture. *Procedia-Social and Behavioral Sciences, 42*, 231-241. Doi.org/10.1016/j.sbspro.2012.04.186.

Aladakatti, Y. R., Palled, Y. B., Chetti, M. B., Halikatti, S. I., Alagundagi, S. C., Patil, P. L., Patil, V. C. and Janawade, A. D. (2012). Effect of nitrogen, phosphorus and potassium levels on growth and yield of stevia (*Stevia rebaudiana* Bertoni.). *Karnataka Journal of Agricultural Science, 25* (1), 25-29.

Alam, A., Ferdosh, S., Ghafor, K., Hakim, A., Juraimi, A. S., Khatib, A. and Sarker, Z. I. (2016). *Clinacanthus nutans*: A review of the medicinal uses, pharmacology and phytochemistry. *Asian Pacific Journal of Tropical Medicine, 9* (4), 402-409.

Amaglo, N. K., Timpo, G. M., Ellis, W. O. and Bennett, R. N. (2006). Effect of spacing and harvest frequency on the growth and leaf yield of moringa (*Moringa oleifera* Lam), a leafy vegetable crop. *Ghana Journal of Horticulture*, 33-40.

Amtmann, A., Troufflard, S. and Armengaud, P. (2008). The effect of potassium nutrition on pest and disease resistance in plants. *Physiologia Plantarum, 133*, 682–691.

Ariffin, Z., Mamat, W. Z. W., Hussain, Y. and Yaacob, M. (2006). Manual penanaman hempedu bumi. Kuala Lumpur, Malaysia: Institut Penyelidikan dan Kemajuan Pertanian Malaysia (MARDI).

Arullappan, S., Rajamanickam, P., Thevar, N. and Kodimani, C. C. (2014). In vitro screening of cytotoxic, antimicrobial and antioxidant activities of *Clinacanthus nutans* (Acanthaceae) leaf extracts. *Tropical Journal of Pharmaceutical Research, 13* (9), 1455-1461. Doi.org/10.4314/tjpr. v13i9.11.

Ashley, M. K., Grant, M. and Grabov, A. (2006). Plant responses to potassium deficiencies: A role for potassium transport proteins. *Journal of Experimental Botany, 57*, 425–436.

Ayub, M., Nadeem, A., Tahir, M., Ibrahim, M. and Aslam, M. N. (2009). Effect of nitrogen application and harvesting intervals on forage yield and quality of pearl millet (*Pennisetum americanum* L.). *Pakistan Journal of Life and Social Sciences, 7* (2), 185-189.

Ayub, M., Nadeem, M. A., Tanveer, A. and Husnain, A. (2002). Effect of different levels of nitrogen and harvesting times on growth, yield and quality of sorghum fodder. *Asian Journal Plant Sciences, 4*, 304-307.

Barku, V. Y. A., Boye, A. and Ayaba, S. (2013). Phytochemical screening and assessment of wound healing activity of the leaves of *Anogeissus leiocarpus*. *European Journal of Experimental Biology, 3* (4), 18-25.

Beemnet, M. K., Solomon, A., and Texeria, D. S. (2011). Agronomic characters, leaf and essential oil yield of peppermint (*Mentha piperiata* l.) as influenced by harvesting age and row spacing. *Medicinal and Aromatic Plant Science and Biotechnology, 5* (1), 49-53.

Benlloch-Gonzalez, M., Arquero, O., Fournier, J.M., Barranco, D. and Benlloch, M. (2008). K+ starvation inhibits water-stress-induced stomatal closure. *Journal of Plant Physiology, 165*, 623–630.

Benlloch-Gonzalez, M., Romera, J., Cristescu, S., Harren, F., Fournier, J.M. and Benlloch, M. (2010). K+ starvation inhibits water-stress-induced stomatal closure via ethylene synthesis in sunflower plants. *Journal of Experimental Botany, 61*, 1139–1145.

Benzie, I. F. F. and Strain, J. J. (1996). The ferric reducing ability of plasma (frap) as a measure of ‘‘antioxidant power’’: The frap assay. *Analytical Biochemistry, 239*, 70-76.

Benzie, IFF and Wachtel-Galor, S. (2011). Herbal medicine: An introduction to its history, usage, regulation, current trends and research needs. In IFF Benzie and S. Wachtel-Galor (Eds), *Herbal Medicine: Raton (FL): CRC Press/Taylor and Francis*, chapter 1. Available from: https://www.ncbi.nlm.nh.gov/books/NBK92773.

Beveridge, C. A. (2006) Axillary bud outgrowth: Sending a message. *Current Opinion Plant Biology., 9*, 35–40.

Bon, P. V. and Harwood, C. E. (2016). Effects of stock plant age and fertiliser application at planting on growth and form of clonal *Acacia* hybrid. *Journal of Tropical Forest Science, 28* (2), 182-189.

Brown, G. D. (2010). The biosynthesis of *artemisinin* (Qinghaosu) and the phytochemistry of *Artemisia annua* l. (Qinghao). *Molecules, 15*, 7603-7698.

Brum, O. B., Lopez, S., Garcia, R., Andres, S. and Calleja, A. (2009). Influence of harvest season, cutting frequency and nitrogen fertilization of mountain meadows on yield, floristic composition and protein content of herbage. *Revista Brasileira de Zootecnia, 38* (4). Doi.org/10.1590/S1516-35982009000400002.

Buba, T. (2013). Relationships between stem diameter at breast height (dbh), tree height, crown length, and crown ratio of *Vitellaria paradoxa* C.F. Gaertn in the Nigerian guinea savanna. *African Journal of Biotechnology, 12* (22), 3441-3446. Doi: 10.5897/AJB12.463.

Bukhari, M.A. (2009) Effect of different harvesting intervals on growth, forage yield and quality of pearl millet (*Pennisetum americanum* L.) cultivars. (M.sc., Thesis, University of Agriculture, Faisalabad, Pakistan, 2009).

Buriro, M., Hussain, F., Talpur, G. H., Gandahi, A. W. and Buriro, B. (2015). Growth and yield response of mungbean varieties to various potassium levels. *Pakistan Journal Agriculture, Agricultural Engineering and Veterinary Sciences, 31* (2), 203-210.

Cakmak, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. *Journal of Plant Nutrition and Soil Science, 168*, 521-530.

Cakmak, I. (2010). Potassium for better crop production and quality. *Plant Soil, 335*, 1–2.

Canter, P. H., Thomas, H. and Ernst, E. (2005). Bringing medicinal plants into cultivation: Oppurtunities and challenges for biotechnology. *TRENDS in Biotechnology,* 23 (4). Doi:10.1016/j.tibtech.2005.02.002.

Cassman, K. G., Kerby, T. A., Roberts, B. A., Bryant, D. C. and Higashi, S. L. (1990). Potassium nutrition effects on lint yield and fiber quality of acala cotton. *Crop Science, 30*, 672–677.

Chatfield, S. P., Stirnberg, P., Forde, B. G. and Leyser, O. (2000). The hormonal regulation of axillary bud growth in *Arabidopsis*. *The Plant Journal, 24*, 159–169. Doi:10.1046/j.1365-313x.2000.00862.x.

Chelyn, J. L., Omar, M. H., Yousuf, N. S. A. M., Ranggasamy, R., Wasiman, M. I. and Ismail, Z. (2014). Analysis of flavone c-glycosides in the leaves of *Clinacanthus nutans* (Burm. f.) lindau by HPTLC and HPLC-UV/DAD. *The scientific World Journal*, Vol. pages:6. Doi.org/10.1155/2014/724267.

Chomnawang, M. T., Surassmo, S., Wongsariya, K. and Bunyapraphatsara, N. (2009). Antibacterial activity of thai medicinal plants against methicillin-resistant staphylococcus aureus. *Fitoterapia, 80*, 102–104.

Cochrane, T. T. and Cochrane, T. A. (2009). Differences in the way potassium chloride and sucrose solutions effect osmotic potential of significance to stomata aperture modulation. *Plant Physiology and Biochemistry, 47* (3), 205-209. Doi: org/10.1016/j.plaphy.2008.11.006.

Dampawan, P. (1976). Studies of the chemical constituents of the *Clinacanthus nutans* (acanthaceae) and *Zingiber Cassumunar* Roxb. (M.S. Thesis, Mahidol University, 1976).

Dampawan, P., Huntrakul, C. and Reutrakul, V. (1977). Constituents of *Clinacanthus nutans* and the crystal structure of Lup-20-ene-3-one. *Journal of the Science Society of Thailand, 3*, 14-26.

Davies, P. J. (2004). Plant hormones: Biosynthesis, signal transduction and action. Kluwer Academic Publishers.

Day, M. E., Greenwood, M. G. and White, A. S. (2001). Age-related changes in foliar morphology and physiology in red spruce and their influence on declining photosynthetic rates and productivity with tree age. *Tree Physiology, 21*, 1195-1204.

Deeken, R., Geiger, D., Fromm, J., Koroleva, O., Ache, P., Langenfeld-Heyser, R., Sauer, N., May, S. T. and Hedrich, R. (2002). Loss of the AKT2/3 potassium channel affects sugar loading into the phloem of *Arabidopsis*. *Planta, 216*, 334–344.

Devi, B. S. R., Kim, Y. J., Selvi, S. K., Gayathri, S., Altanzul, K., Parvin, S., Yang, D. U. and Yang, D. C. (2012). Influence of potassium nitrate on antioxidant level and secondary metabolite genes under cold stress in *Panax ginseng*. *Russian Journal Plant Physiology, 59*, 318–332.

Dewdar, M. D. H. (2013). Return of soil and foliar applications of potassium fertilization on potential and fiber quality traits for two *Gossypium barbadense* (L.) varieties in Egypt. *Scholarly Journal of Agricultural Science, 3*, 94-98.

Djeridane, A., Yousfi, M., Nadjemi, B., Boutassouna, D., Stocker, P. and Vidal, N. (2006). Antioxidant activity of some algerian medicinal plants extracts containing phenolic compounds. *Food chemistry, 97* (4), 654-660.

Dkhil, B. B., Denden, M. and Aboud, S. (2011). Foliar potassium fertilization and its effect on growth, yield and quality of potato grown under loam-sandy soil and semi-arid conditions. *International Journal of Agricultural Research, 6* (7), 593-600.

Domagalska, M. A. and Leyser, O. (2011). Signal integration in the control of shoot branching. *Natural Reviews, Molecular Cell Biology, 12* (4), 211-21. Doi: 10.1038/nrm3088.

Doust, A. N. (2007). Grass architecture: Genetic and environmental control of branching. *Current Opinion Plant Biology*, *10*, 21–25.

Du Toit, J. T., Bryant, J. P. and Frisby, K. (1990). Regrowth and palatability of *Acacia* shoots following pruning by African savanna browsers. *Ecology*, *71*, 149-154.

Ebinger, K. and Weller, H. N. (2013). Comparison of chromatographic techniques for diastereomer separation of a diverse set of drug-like compounds. *Journal of Chromatography A, 1272*, 150-154. Doi.org/10.1016/j.chroma.2012.11.065.

Farrokh, A. R. and Farrokh, A. (2012). Effect of nitrogen and potassium on yield, agronomy efficiency, physiological efficiency and recovery efficiency of nitrogen and potassium in flue cured tobacco. *International Journal of Agriculture and Crop Sciences, 4* (12), 770-778.

Ferguson, B. J. and Beveridge, C. A. (2009). Roles for auxin, cytokinin, and strigolactone in regulating shoot branching. *Plant Physiology*, *149* (4), 1929-1944.

Ferreyra, M. L. F., Rius, S. P. and Casati, P. (2012). Flavonoids: Biosynthesis, biological functions, and biotechnological applications. *Frontiers in Plant Science, 3*.

Filho, A. C. D. A. C., Crusciol, C. A. C., Nascente, A. S., Mauad, M. and Garcia, R. A. (2017). Influence of potassium levels on root growth and nutrient uptake of upland rice cultivars. *Revista Caatinga, 30* (1). Doi.org/10.1590/1983-21252017v30n104rc.

Fong, S. Y. (2015). *Genetic, phytochemical and bioactivity studies of Clinacanthus nutans (Burm.f.) Lindau (acanthaceae)*. (Doctor of Philosophy, RMIT University, 2015).

Gajdanowicz, P., Michard, E., Sandmann, M., Rocha, M., Correa, L. G., Ramirez-Aquilar, S. J., Gomez-Porras, J. L., Gonzalez, W., Thibaud, J. B., Van Dongen, J. T. and Dreyer, I. (2011). Potassium (K+) gradient serve as a mobile energy source in plant vascular tissues. *Proceeding of the National Academy of Sciences of the United Stated of America, 108* (2), 864-9. Doi: 10.1073/pnas.1009777108.

Gebremeskel, H. and Woldetsadik, K. (2015). Effect of plant spacing and harvesting age on growth, biomass and oil yield of rose-scented geranium (*Pelargonium Graveolens* L. Herit). *Basic Research Journals, 4* (3), 094-101.

Geng, Y-P., Pan, X-Y., Xu, C-Y., Zhang, W-J. and Li, B. (2007). Phenotypic plasticity rather than locally adapted ecotypes allows the invasive alligator weed to colonize a wide range of habitats. *Biological Invasions, 9*, 245–256.

Ghasemzadeh, A., Nasiri, A., Jaafar, H. Z. E., Baghdadi, A. and Ahmad, I. (2014). Changes in phytochemical synthesis, chalcone synthase activity and pharmaceutical qualities of Sabah snake grass (*Clinacanthus nutans* L.) in relation to plant age. *Molecules, 19,* 17632-17648. Doi:10.3390/molecules191117632.

Gholizadeh, R., Roshan, N. M., Sadeghi, S. M. and Dorodian, H. (2012). Study effects of different nitrogen and potassium fertilizers application amounts on quantitative and qualitative characteristics of tobacco (male sterile variety, PVH19) in Talesh region. *Annals of Biological Research, 3* (11), 5323-5349.

Global information hub on integrated medicine (Globinmed) (2010-2015). *Clinacanthus nutans* (Burm.f.) Lindau. Retrieved July 9, 2017, from http://www.globinmed.com/index.php?option=com_content&view=article&id=79320:clinacanthus-nutans-burmf-lindau.

Golpavar, A. R. (2011). Determination of the best harvesting times to obtain maximum dry herbage, essential oil and thymol yield in garden thyme (*Thymus vulgaris* L.). *International Journal of Life Science and Medical Research, 1* (1), 1-4.

Greenwood, M. S., Ward, M. H., Day, M. E., Adams, S. L. and Bond, B. J. (2008). Age-related trends in red spruce foliar plasticity in relation to declining productivity. *Tree Physiology, 28*, 225-232.

Guo, W., Nazim, H., Liang, Z. and Yang, D. (2016). Magnesium deficiency in plants: An urgent problem. *The Crop Journal, 4*, 83-91. Doi.org/10.1016/j.cj.2015.11.003.

Gupta, R. and Chakrabarty, S. K. (2013). Gibberellic acid in plant: Still a mystery unresolved. *Plant Signalling and Behaviour, 8*, 9. E25504.

Hagos, H., Worku, W. and Takele, A. (2014). Effect of drying off period and harvest age on quality and yield of ratoon cane (*Saccharium officinarium* L.). *Advances in Crop Science and Technology, 2* (3). Doi: org/10.4172/2329-8863.1000133.

Haq, I. (2004). Safety of medicinal plants. *Pakistan Journal of Medical Reserach, 43* (4), 203-10.

He, J. X. and Li, Q. F. (2013) Mechanism of signalling crosstalk between brassinosteroids and gibberelins. *Plant signalling behaviour, 8*,7 e 2486.

Hegazi, E. S., Mohamed, S. M., El-Sonbaty, M. R., El-Naby, S. K. M. and El-Sharony, T. F. (2011). Effect of potassium nitrate on vegetative growth, nutritional status, yield and fruit quality of olive cv. "Picual". *Journal of Horticultural Science and Ornamental Plants, 3* (3), 252-258.

Herman, C., Hammond, J. P., White, P. J. and Verbruggen, N. (2004). How do plants respond to nutrient shortage by biomass allocation? *Trends in Plant Science*, *11*, 610–617.

Hermans, C. and Verbruggen, N. (2005). Physiological characterization of Mg deficiency in *Arabidopsis thaliana*. *Journal of Experimental Botany, 56*, 2153–2161.

Hossain, M. D., Musa, M. H., Talib, J. and Jol, H. (2010). Effects of nitrogen, phosphorus and potassium levels on kenaf (*Hibiscus cannabinus* L.) growth and photosynthesis under nutrient solution. *Journal of Agricultural Science*, *2* (2).

Hu, J. and Daniel, F. (2011). *Acanthaceae*. In Wu et al. (eds) Flora or China. Vol. 19 (Cucurbitaceae through valerianaceae with annonaceae and berberisaceae), Science Press, Beijing and Missouri Botanical Garden Press, Missouri (442-474).

Huang, Z. A., Zhao, T., Fan, H. J., Wang, N., Zheng, S. S. and Ling, H. Q. (2012). The up-regulation on ntan2 expression at low temperature in required for anthocyanin accumulation in juvenile leaves of ic-transgenic tobacco (*Nicotiana tabacum* L.) J. *Genet. Genomics, 20*, 149-156.

Hue, K. T., Van, D. T. T., Ledin, I., Wredle, E. and Sporndly, E. (2012). Effect of harvesting frequency, variety and leaf maturity on nutrient composition, hydrogen cyanide content and cassava foliage yield. *Asian-Australasian Journal of animal Sciences, 25* (12), 1691-1700. doi.org/10.5713/ajas.2012.12052.

Ibrahim, M. H., Jaafar, H. Z. E., Karimi, E. and Ghasemzadeh, A. (2012). Primary, secondary metabolites, photosynthetic capacity and antioxidant activity of the malaysian herb Kacip fatimah (*Labisia Pumila* Benth) exposed to potassium fertilization under greenhouse conditions. *International Journal of Molecular Science*, *13*, 15321-15342. doi:10.3390/ijms131115321.

Isnard, S., Speck, T. and Rowe, N. P. (2003). Mechanical architecture and development in clematis: implications for canalised evolution of growth forms. *New Physiologist*, *158*, 543-559.

Jahan, S. A., Alim, M. A., Hasan, M. M., Kabiraj, U. K. and Hossain, M. B. (2009). Effect of potassium levels on the growth, yield and yield attributes of lentil. *International Journal of Sustainable Crop Production, 4* (6), 1-6.

Jenkins, G.I. (2009). Signal transduction in responses to UV-b radiation. *Annual Review of Plant Biology*, *60*, 407–413.

Jin, S.H., Huang, J.Q., Li, X.Q., Zheng, B.S., Wu, J.S., Wang, Z.J., Liu, G.H. and Chen, M. (2011). Effects of potassium supply on limitations of photosynthesis by mesophyll diffusion conductance in *Carya cathayensis*. *Tree Physiology*, *31*, 1142–1151.

Karami, Z., Mirzaei, H., Emam-Djomeh, Z., Sadeghi Mahoonak, A. R. and Khomeiri, M. (2013). Effect of harvest time on antioxidant activity of *Glycyrrhiza glabra* root extract and evaluation of its antibacterial activity. *International Food Research Journal, 20* (5), 2951-2957.

Karavin, N. (2013). Effects of leaf and plant age on specific leaf area in deciduous tree species *Quercus cerris* L. var. cerris. *Bangladesh Journal Botany, 42* (2), 301-306.

Karimi, A., Majlesi, M. and Rafieian-Kopaei, M. (2015). Herbal versus synthetic drugs: Beliefs and facts. *Journal of Nephropharmacology, 4*(1), 27-30.

Kazemipoor, M., Radzi, C. W., Cordell, G. A. and Yaze, I. (2012). Safety, efficacy and metabolism of traditional medicinal plants in the management of obesity: A Review. *International Journal of Chemical Engineering and Applications, 3*(4), 288-92.

Kebrom, T. H., Brutnell, T. P. (2007). The molecular analysis of the shade avoidance syndrome in the grasses has begun. *Journal of Experimental Botany, 58*, 3079–3089.

Khan, A. A., Sajid, M., Rab, A., Alam, S. and Bari, A. (2014). Effect of potassium sources on the growth, yield and fruit quality of tomato cultivars. *Sarhad Journal of Agriculture, 30* (4), 442.

Khaulah, A. G. and Izham, A. (2014, November). *Nitrogen fertilization on Sabah snake grass in relation to its growth performance*. Paper presented at the International Agriculture Congress Pullman Putrajaya Lakeside, Putrajaya, Malaysia.

Khetsa, Z. P. (2013). *The effect of potassium and water quality on the yield and oil quality of rose geranium (Pelargonium graveolens L.).* (Degree, Central University of Technology, Free State, 2013).

Kim, D. O., Jeong, S. W. and Lee, C. Y. (2003). Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. *Food chemistry, 81* (3), 321-326.

Ko, J-H., Han, K-H., Park, S. and Yang, J. (2004). Plant body weight-induced secondary growth in *Arabidopsis* and its transcription phenotype revealed by whole-transcriptome profiling. *Plant Physiology, 135*, 1069-1083.

Kumar, S. and Kumar, A. (2013). Spatial and harvesting influence on growth, yield, quality, and economic potential of Kalmegh (*Andrographis paniculata* Wall Ex. Nees). *Journal of Agriculture and Rural Development in the Tropics and Subtropics, 114* (1), 69-76.

Kunsorn, P., Ruangrungsi, N., Lipipun, V., Khanboon, A. and Rungsihirunrat, K. (2013). The identities and anti-herpes simplex virus activity of *Clinacanthus nutans* and *Clinacanthus siamensis*. *Asian Pacific Journal of Tropical Biomedicine,* 3 (4), 284-290.

Kyozuka. J. (2007). Control of shoot and root meristem function by cytokinin. *Current Opinion in Plant Biology, 10* (5), 442-446. Doi.org/10.1016/j.pbi.2007.08.010.

Langer, K., Ache, P., Geiger, D., Stinzing, A., Arend, M., Wind, C., Regan, S., Fromm, J. and Hedrich, R. (2002). Poplar potassium transporters capable of controlling K+ homeostasis and K+-dependent xylogenesis. *Plant Journal, London, 37,* 9997-1009.

Liaqat, A., Beatrix, W. A., Anna, K. R., Birgitta, S., Tim, N. and Marie, E.O. (2012). Effects of nutrition strategy on the levels of nutrients and bioactive compounds in blackberries. *European Food Research and Technology, 234*, 33–44.

Liesche, J. (2015). How regulation of phloem transport could link potassium fertilization to increased growth. *Tree Physiology, 36* (1), 1-5. Doi: 10.1093/treephys/tpv120.

Lin, C-Y. and Yeh, D-M. (2008). Potassium nutrition affects leaf growth, anatomy, and macroelements of *Guzmania*. *HortScience, 43* (1), 146-148.

Liu, Y., Wang, Q., Zhang, Y., Cui, J., Chen, G. and Xie, B. (2014). Synergistic and antagonistic effects of salinity and ph on germination in switchgrass (*Panicum virgatum* L.). *PLoS ONE, 9* (1), e85282. Doi.org/10.1371/journal.pone.0085282.

Lopo de Sa, A. F., Valeri, S. V., Pessoa da Cruz, M. C., Barbosa, J. C., Rezende, G. M. and Teixeira, M. P. (2014). Effects of potassium application and soil moisture on the growth of *Corymbia citriodora* plants. *CERNE, 20* (4). Doi: org/10.1590/01047760201420041422.

Lough, T. J. and Lucas, W. J. (2006). Integrative plant biology: Role of phloem long-distance macromolecular trafficking. *Annual Reviews Plant Biology, 57*, 203-32.

Lu, L., He, C-e., Jin, Y., Zhang, X. and Wei, J. (2013). Effects of the applications of phosphorus and potassium fertilizers at different growth stages on the root growth and bioactive compounds of *Salvia miltiorrhiza* Bunge. *Australian Journal of Crop Science, 7* (10), 1533-1543.

Lubbe, A., Choi, Y. H., Vreeburg, P. and Verpoorte, R. (2011). Effects of fertilizers on galanthamine and metabolites profiles in *Narcissus* Bulbs by 1H-NMR. *Journal of Agricultural and Food Chemistry, 59*, 3155–3161.

Maggio, A., Zhu, J. K., Hasegawa, P. M. and Bressan, R. A. (2006). Osmogenetics: Aristotle to *Arabidopsis*. *Plant Cell, 18*, 1542-1557.

Mai, C. W., Yap, K. S. I., Kho, M. T., Ismail, N. H., Yusoff, K., Shaari, K., Chin, S. Y. and Lim, E. S. H. (2016). Mechanisms underlying the anti-inflammatory effects of *Clinacanthus nutans* Lindau extracts: inhibition of cytokine production and toll-like receptor-4 activation. *Frontiers in Pharmacology, 7*, 1–11.

Malvi, U. R. (2011). Interaction of micronutrients with major nutrients with special reference to potassium. *Karnataka Journal of Agricultural Sciences, 24* (1), 106-109.

Marasha, N., Mariga, I. K., Ngezimana, W. and Mudau, F. N. (2013). Effect of pruning on carbohydrate dynamics of herbal and medicinal plant species: Prospects leading to research on the influence of pruning on productivity and biochemical composition of Bush tea (*Athrixia phylicoides* D.C.). *African Journal of Agricultural Research, 8* (27), 3528-3533. Doi: 10.5897/AJAR2013.7134.

Marston, A. and Hostettman, K. (2009). Natural product analysis over the last decades. *Planta Medica, 75* (7), 672-682. DOI: 10.1055/s-0029-1185379.

Mathe, A. and Mathe, I. (2008). Quality assurance of cultivated and gathered medicinal plants. *Acta Hort*, 765, 67-76.

Matsumoto, S. N., Araujo, G. D. S. and Viana, A. E. S. (2013). Growth of sweet basil depending on nitrogen and potassium doses. *Horticultura Brasileira*, *31* (3). Doi.org/10.1590/S0102-05362013000300024.

Maudu, M., Mudau, F. N. and Mariga, I. K. (2010). The effect of pruning on growth and chemical composition of cultivated Bush tea (*Athrixia phylicoides* D.C). *Journal of Medicinal Plants Research, 4* (22), 2353-2358. Doi: 10.5897/JMPR10.486.

Mccarthy, M. C. and Enquist, B. J. (2007). Consistency between an allometric approach and optimal partitioning theory in global patterns of plant biomass allocation. *Functional Ecology*, *21*, 713-720. Doi: 10.1111/j.1365-2435.2007. 01276. x.

Mcsteen, P. and Leyser, O. (2005). Shoot branching. *Annual Review of Plant Biology, 56*, 353-374. Doi.org/10.1146/annurev.arplant.56.032604.144122.

Mequanent, Y. and Ayele, N. (2014). The effect of harvesting age on maturity indices of quality parameters of sugarcane varieties at Metahara sugar estate in cool season. *The Journal of agriculture and Natural Resources Sciences, 1* (4), 232-237.

Mijin, S. (2014). *Growth and nutritional quality of Cosmos caudatus Kunth as affected by rates of organic and inorganic fertilizers and post-harvest cooling*. (Master of science, Universiti Putra Malaysia, 2014).

Millford, G. F. and Johnston, A. E. (2002). Potassium and nitrogen interactions in crop production. Proc. No: 615, International Fertilizer Society, York, UK.

Miranda, M., Vega-Galvez, A., Lopez, J., Parada, G., Sanders, M., Aranda, M., Uribe, E. and Scala, K. D. (2010). Impact of air-drying temperature on nutritional properties, total phenolic content and antioxidant capacity of quinoa seeds (*Chenopodium quinoa* Willd.). *Industrial Crops and Products, 32*, 258-263. Doi:10.1016/j.indcrop.2010.04.019.

Mohidin, H., Hanafi, M. M., Rafii, Y. M., Abdullah, S. N. A., Idris, A. S., Man, S., Idris, J. and Sahebi, M. (2015). Determination of optimum levels of nitrogen, phosphorus and potassium of oil palm seedlings in solution culture. *Bragantia Campinas, 74* (3). Doi.org/10.1590/1678-4499.0408.

Moriuchi, K. S. and Winn, A. A. (2005). Relationships among growth, development and plastic response to environment quality in a perennial plant. *New Physiologist, 166*, 149-158. Doi: 10.1111/j.1469-8137.2005. 01346. x.

Mosihuzzaman, M. and Choudhary, M. I. (2008). Protocols on safety, efficacy, standardization and documentation of herbal medicine. *Pure and Applied Chemistry, 80* (10), 2195-2230. Doi:10.1351/pac200880102195.

Motsara, M. R. and Roy, R. N. (2008). *Guide to Laboratory Establishment for Plant Nutrient Analysis*. Food and Agriculture Organization of the United Nations.

Mudau, F. N., Sounday, P. and Du Toit, E. S. (2007). Effects of nitrogen, phosphorus, and potassium nutrition on total polyphenol content of Bush tea (*Athrixia phylicoides* L.) leaves in shaded nursery environment. *Horticultural Science,* 42 (2), 334-338.

Muller, D. and Leyser, O. (2011). Auxin, cytokinin and the control of shoot branching. *Annals of Botany, 107*, 1203-1212. Doi: 10.1093/aob/mcr069.

Munnu, S., Rakshapal, S., Rajendra, P. P., Neha, G., Nisha, P., Singh H. P. and Verma, R. K. (2016). Effect of N and K doses on biomass and diterpenoid lactones production of Kalmegh (*Andrographi spaniculata* Nees.) in a semi-arid tropical climate. *International Journal of Phytomedicines and Related Industries, 8* (3), 229-232. Doi: 10.5958/0975-6892.2016.00024.1.

Mustapa, A. N., Martin, A., Mato, R. B. and Cocero, M. J. (2015). Extraction of phytocompounds from the medicinal plant *Clinacanthus nutans* Lindau by Microwave-assisted extraction and supercritical carbon dioxide extraction. *Industrial Crops and Products, 74*, 83-94.

Nagarathna, T. K., Shadakshari, Y. G., Jagadish, K. S. and Sanjay, M. T. (2010). Interactions of auxin and cytokinins in regulating axillary bud formation in sunflower (*Helianthus annuus* L.). *Helia, 33* (52), 85-94. Doi: 10.2298/HEL1052085N.

Nasiri, A. (2016*). Effects of light intensity and agronomical practices on growth, yield and quality of Sabah snake grass (Clinacanthus nutans (Burm.f.) Lindau).* (Ph. D, Universiti Putra Malaysia, 2016).

Nasri, H. (2013). Cisplatin therapy and the problem of gender-related nephrotoxicity. *Journal of Nephropharmacol, 2*(2), 13-4.

Niklas, K. J., Cobb, E. D. and Marler, T. (2006) A comparison between the record-height-to-stem diameter allometries of *Pachycaulis* and *Leptocaulis* species. *Annals of Botany*.

Noor, M. A., Fjaz, S., Nawaz, A. and Nawaz, M. M. (2016). The effects of cutting interval on agro-qualitative traits of different millet (*Pennisetum americanum* L.) cultivars. *Journal of the Saudi Society of Agricultural Sciences*. Doi: org/10.1016/j.jssas.2016.07.002.

Nurzynska-Wierdak, R., Rozek, E., Dzida, K. and Borowski, B. (2012). Growth response to nitrogen and potassium fertilization of common basil *(Ocimum basilicum* L.) plants. *Acta Scientiarum Polonorum Hortorum Cultus, 11* (2), 275-288.

Oerke, E.C. and Dehne, H.W. (2004). Safeguarding production-losses in major crops and the role of crop protection. *Crop Protection, 23*, 275–285.

Olasoji, J. O., Aluko, A. O., Adeniyan, S. O., Olosunde, A. A. and Okoh, J. O. (2012). Effect of time of harvest on physiological maturity and kenaf (*Hibiscus canabinus*) seed quality. *African Journal of Plant Science, 6* (10), 282-289. Doi: 10.5897/AJPS12.083.

Oliveira, M. D., Cipolatti, E. P., Furlong, E. B. and Soares, L. D. S. (2012). Phenolic compounds and antioxidant activity in fermented rice (*Oryza sativa*) bran. *Ciência Tecnologia de Alimentos, Campinas, 32* (3), 531-537.

Ongaro, V. and Leyser, O. (2008) Hormonal control of shoot branching. *Journal of Experimental Botany, 59*, 67–74.

Onyeonagu, C. C. and Asiegbu, J. E. (2013). Harvest frequency effect on plant height, grass tiller production, plant cover and percentage dry matter production of some forage grasses and legumes in the derived Savannah, Nigeria. *African Journal of agricultural Research, 8* (7), 608-618. Doi: 10.5897/ajar11.2461.

Osakabe, Y., Arinaga, N., Umezawa, T., Katsura, S., Nagamachi, K., Tanaka, H., Ohiraki, H., Yamada, K., Seo,S-U., Abo, M., Yoshimura, E., Shinozaki, K. and Yamanaguchi-Shinozaki, K. (2013). Osmotic stress responses and plant growth controlled by potassium transporters in *Arabidopsis*. *Plant Cell, 25* (2), 609-624. Doi: 10.1105/tpc.112.105700.

Othman, C. N. and Farooqui, M. (2015). Traditional and complementary medicine. *Procedia-Social and Behavioral Sciences, 170*, 262-271. Doi: 10.1016/j.sbspro.2015.01.036.

P'ng, X. W., Akowuah, G. A. and Chin, J. H. (2012). Acute oral toxicity study of *Clinacanthus nutans* in mice. *International journal of pharmaceutical sciences and research, Vol. 3 (11),* 4202 – 4205.

Pal, P. and Ghosh, P. (2010). Effect of different sources and levels of potassium on growth, flowering and yield of African marigold (*Tagetes erecta* Linn) CV. 'Siracole'. *Indian Journal of Natural Products and Resources, 1* (3), 371-375.

Pandey, S. K. and Singh, H. (2011). A simple, cost-effective method for leaf area estimation. *Journal of Botany*, 6 pages. Doi: 10.1155/2011/658240.

Pannangpetch, P., Laupattarakasem, P., Kukongviriyapan, V., Kukongviriyapan, U., Kongyingyoes, B. and Aromdee, C. (2007). Anti-oxidant activity and protective effect against oxidative haemolysis of *Clinacanthus nutans* (Burm.f) Lindau. *Songklanakarin Journal of Science and Technology, 29* (1), 1-9.

Pettigrew, M. (2008). Potassium influences on yield and quality production for maize, wheat, soybean and cotton. *Physiological Plant, 133*, 670–681.

Poorter, H., Niklas, K. J., Reich, P. B., Oleksyn, J., Poot, P. and Mommer, L. (2012). Biomass allocation to leaves, stems and roots: meta-analyses of interspecific variation and environmental control. *New Phytologist, 193*, 30-50. Doi: 10.1111/j.1469-8137.2011.03952.x.

Prajapati, K. and Modi, H. A (2012). The importance of potassium in plant growth-a review. *Indian Journal of Plant Science, 1*(02-03), 177-186.

Pregitzer, K. S. and King, J. S. (2005). Effects of soil temperature on nutrient uptake. In BassiriRad, H. (Ed.). *Nutrient acquisition by plants* (pp 277-310). Retrieved from Springer Link. Springer-Verlag Berlin Heidelberg: Germany.

Ravichandran, R. (2004). The impact of pruning and time from pruning on quality and aroma constituents of black tea. *Food Chemistry, 84*,7-11.

Raya, K. B., Ahmad, S. H., Farhana, S. F., Mohammad, M., Tajidin, N. E. and Parvez, A. (2015). Changes in phytochemical contents in different parts of *Clinacanthus nutans* (Burm. f.) Lindau due to storage duration. *Bragantia Campinas, 74* (4), 445-452. Doi.org/10.1590/1678-4499.0469.

Rizwan, K., Zubair, M., Rasool, N., Riaz, M., Zia-Ul-Haq, M. and de Feo, V. (2012). Phytochemical and biological studies of *Agave attenuata*. *International Journal of Molecular Sciences, 13*(5), 6440–6451. Doi.org/10.3390/ijms13056440.

Rowe, N., Isnard, S. and Speck, T. (2004). Diversity of mechanical architecture in climbing plants: An evolutionary perspective. *Journal of Plant Growth, 23*, 108-128.

Rubio, V., Bustos, R., Irigoyen, M. l., Cardona-Lópex, X., Rojas-Triana, M. and Paz-Ares, J. (2008). Plant hormones and nutrient signaling. *Plant Molecular Biology, 69*, 361-373.

Sakdarat, S., Shuyprom, A., Dechatiwongse Na Ayudhya, A., Karagianis, G. and G. Waterman, P. (2008). Chemical composition investigation of the *Clinacanthus nutans* Lindau leaves. *Thai Journal of phytopharmacy, 13 (2)*

Sakdarat, S., Shyuprom, A., Pientong, C., Ekalaksananan, T. and Thongchai, S. (2009). Bioactiive constituents for the leaves of *Clinacanthus nutans* Lindau. *Bioorganic and Medicinal Chemistry, 17*. Doi: 10.1016/j.bmc.2009.01.059.

Samat, N. M. A. A (2013). *Planting distance towards performances of Sabah snake grass (Clinacanthus nutans (Burm.f.) Lindau)*. (Universiti Putra Malaysia, 2013).

Sanchez, P., Nehlin, L. and Greb, T. (2012). From thin to thick: Major transitions during stem development. *Trends in Plant Science, 17* (2). Doi: 10.1016/j.tplants.2011.11.004.

Sarega, N., Imam, M. U., Ooi, D., Chan, K. W., Md Esa, N., Zawawi, N. and Ismail, M. (2016). phenolic rich extract from *Clinacanthus nutans* attenuates hyperlipidemia-associated oxidative stress in rats. *Oxidative Medicine and Cellular Longevity*, 1–16.

Saxena, M., Saxena, J., Nema, R., Singh, D. and Gupta, A. (2013). Phytochemistry of medicinal plant. *Journal of Pharmacognosy and Phytochemistry*, 1 (6).

Schijlen, E. G. W. M., Ric de Vos, C. H., Tunen, A. J. V. and Bovy, A. G. (2004). Modification of flavonoid biosynthesis in crop plants. *Phytochemistry*, 65, 2631-2648. Doi: 10.1016/j.phytochem.2004.07.028.

Schippman, U., Leaman, D. J. and Cunningham, A. B. (2002). A comparison of cultivation and wild collection of medicinal and aromatic plants under sustainability aspects. In Bogers, R. J., Craker, L. E., and Lange, D. (Eds.), *Medicinal and Aromatic Plants*, (75-95). Springer: Netherlands.

Schultz, H. R. (1992). An empirical model for the simulation of leaf appearance and leaf area development of primary shoots of several grapevines (V. *vinifera* L.). *Science Horticulture*, *52*, 179-200.

Shabala, S., Babourina, O. and Newman, I. (2000). Ion-specific mechanisms of osmoregulation in bean mesophyll cell. *Journal of Experimental Botany, 51*, 1243–1253.

Shani, E., Yanai, O. and Ori, N. (2006). The role of hormones in shoot apical meristem function. *Current opinion in plant biology, 9* (5), 484-489.

Sharma, N. K., Singh, R. J. and Kumar, K. (2012). Dry matter accumulation and nutrient uptake by wheat (*Triticum aestivum* L.) under poplar (*Populus deltoides*) based agroforestry system. *ISRN Agronomy*, Articles ID 359673, 7 pages. Doi:10.5402/2012/359673.

Shimizu-Sato, S., Tanaka, M. and Mori, H. (2009). Auxin–cytokinin interactions in the control of shoot branching. *Plant molecular biology, 69* (4), 429.

Shuyprom, A. (2004). *Chemical composition investigation of the Clinacanthus nutans (Burm. F.) Lindau leaves*. (Suranaree University of Technology, 2004).

Sinclair, T. R., Gilbert, R. A., Perdomo, R. E., Shine Jr, J. M., Powell, G. and Montes, G. (2004). Sugarcane leaf area development under field conditions in Florida, USA. *Field Crops Research, 88*, 171-178. Doi: 10.1016/j.fcr.2003.12.005.

Singh, M. (2008). Effect of nitrogen and potassium fertilizer on growth, herbage and oil yield of irrigated Palmarosa (*Cymbopogon martinii* [roxb.] wats. var. motia burk) in a semi-arid tropical climate. *Archives of Agronomy and Soil Science, 54* (4), 395-400. Doi.org/10.1080/03650340802158219.

Siti, Z. M., Tahir, A., Farah, I., Ami Fazlin, S. M., Sondi, S., Azman, A. H., Maimunah, A. H., Haniza, M. A., Siti Haslinda, M. D., Zulkarnain, A. K., Zakiah, I. and Wan Zaleha, W. C. (2009). Use of traditional and complementary medicine in Malaysia: A baseline study. *Complementary Therapies in Medicine, 17*(5-6), 292-299. Doi.org/10.1016/j.ctim.2009.04.002

Sitienei, K., Home, P. G., Kamau, D. M. and Wanyoko, J. K. (2013). The influence of fertilizer type and application rates in tea cultivation on nitrogen and potassium efficiencies. *African Journal of Agricultural Research, 8* (28), 3770-3777. Doi: 10.5897/AJAR2013.7695.

Sittiso, S., Ekalaksananan, T., Pientong, C., Sakdarat, S., Charoensri, N. and Kongyingyoes. (2010). Effects of compounds from *Clinacanthus nutans* on dengue virus type 2 infection. *Srinagarind Medicine Journal, 25*.

Solomon, A. and Beemnet, M. (2011). Row spacing and harvesting age affect agronomic characteristics and essential oil yield of Japanese mint (*Mentha arvensis* L.). *Medicinal and Aromatic Plant Science and Biotechnology, 5* (1), 74-76.

Sookmai, W., Ekaalaksananan, T., Pientong, C., Sakdarat, S. and Kongyingyoes, B. (2011). The anti-papillomavirus infectivity of *Clincantus nutans* compounds. *Srinagarind Medicinal Journal, 26*, 240-242.

Sparks, D. L. (2016). *Advances in Agronomy*. Elsevier Inc: Zoe Kruze.

Stalikas, C. D. (2007). Extraction, separation, and detection methods for phenolic acids and flavonoids. *Journal of Separation Science, 30* (18), 3268–3295.

Strik, B.C. (2008). A review of nitrogen nutrition of Rubus. In *Proceedings of the IXth International Rubus and Ribes Symposium*, Pucon, Chile, 403–410.

Sulaiman, I. S. C., Basri, M., Chan, K. W., Ashari, S. E., Masoumi, H. R. F. and Ismail, M. (2015). In vitro antioxidant, cytotoxic and phytochemical studies of *Clinacanthus nutans* Lindau leaf extracts. *African Journal of Pharmacy and Pharmacology, 9* (34), 861-874. Doi: 10.5897/AJPP2015. 4396.

Sultana, B., Anwar, F. and Ashraf, M. (2009). Effect of extraction solvent/technique on the antioxidant activity of selected medicinal plant extracts. *Molecules, 14*, 2167-2180. Doi:10.3390/molecules14062167.

Sultana, J., Siddique, M. A. and Rashid, M. H. A. (2012). Effects of cowdung and potassium on growth and yield of Kohlrabi. *Journal of Bangladesh Agriculture University, 10* (1), 27-32.

Sumida, A., Ito, H. And Isagi, Y. (1997). Trade-off between height growth and stem diameter growth for an evergreen oak, *Quercus glauca*, in a mixed hardwood forest. *Functional Ecology, 11*, 300–309. Doi:10.1046/j.1365-2435.1997.00085.x.

Swart, E. A. M. D., Groenwold, R., Kanne, H. J., Stam, P., Marcelis, L. F. M. and Voorrips, R. E. (2004). Non-destructive estimation of leaf area for different plant ages and accessions of *Capsicum annuum* L. *Journal of Horticultural Science and Biotechnology, 79* (5), 764-770.

Taiz, L. and Zeiger, E. (2006). *Plant Physiology*. (4th ed.). Sinauer Associates: Sunderland, M. A.

Tavarini, S. and Angelini, L. G. (2012). *Stevia rebaudiana* Bertoni as a source of bioactive compounds: the effect of harvest time, experimental site and crop age on steviolglycoside content and antioxidant properties. *Journal of the Science of Food and Agriculture, 93*, 2121-2129. Doi: 10.1002/jsfa.6016.

Teshima, K-I., Kaneko, T., Ohtani, K., Kasi, R., Lhieochaiphant, S., Picheansoomthon, C. and Yamasaki, K. (1998). Sulphur-containing glucosides from *Clinacanthus nutans*. *Phytochemistry, 48*, 831-835.

Thawaranantha, D., Balachandra, K., Jongtrakulsiri, S., Chavalittumrong, P., Bhumiswasdi, J. and Jayavasu, C. (1992). In vitro antiviral activity of *Clinacanthus nutans* on varicella zoster virus. *Siriraj Hospital Gaazette, 44*, 285–291.

Thomsen, M. O. (2012). *The Impact of Cultivation Techniques and Induced Stress on Bioactive Compounds in Echinacea Species*. (AARHUS University, 2012).

Tomemori, H., Hamamura, K. and Tanabe, K. (2002). Interactive effects of sodium and potassium on the growth and photosynthesis of spinach and komatsuna. *Plant Production Science, 5*, 281–285.

Troufflard, S., Mullen, W., Larson, T. R., Graham, I. A., Crozier, A., Amtmann, A. and Armengaurd, P. (2010). Potassium deficiency induces the biosynthesis of oxylipins and glucosinolates in *Arabidopsis thaliana*. *BMC Plant Biology, 10*, 172–182.

Tsonev, T., Velikova, V., Yildiz-Aktas, L., Gurel, A. and Edreva, A. (2011). Effect of water deficit and potassium fertilization on photosynthetic activity in cotton plants. *Plant Biosystem, 145*, 841–847.

Tu, S-F., Liu, R., Cheng, Y-B., Hsu, Y-M., Du, Y-C., El-Shazly, M., Wu, Y-C. and Chang, F-R. (2014). Chemical constituents and bioactivities of *Clinacanthus nutans* aerial parts. *Molecules, 19*, 20382–20390.

Tuntiwachwuttikul, P., Pootaeng-on, Y., Pansa, P., Srisanpang, T. and Taylor, W. C. (2003). Sulfur-containing compounds from *Clinacanthus siamensis*. *Chemical and Pharmaceutical Bulletin, 51* (12), 1423-1425.

Vachirayonstien, T., Promkhatkaew, D., Bunjob, M., Chueyprom, A., Chavalittumrong, P. and Sawanpanyalert, P. (2010). Molecular evaluation of extracellular activity of medicinal herb *Clinacanthus nutans* against herpes simplex virus type-2. *Natural Product Research, 24* (3), 236-245.

Wakeel, A. (2013). Potassium-sodium interactions in soil and plant under saline-sodic conditions. *Journal of Plant Nutrition and Soil Science, 176* (3), 344-354. Doi: 10.1002/jpln.201200417.

Wang, M., Carrell, E. J., Ali, Z., Avula, B., Avonto, C., Parcher, J. F. and Khan, I. A. (2014). Comparison of three chromatographic techniques for the detection of mitragynine and other indole and oxindole alkaloids in Mitragyna Speciosa (kratom) plants. *Journal of Separation Science, 37*, 1411-1418.

Wang, M., Zheng, Q., Shen, Q. and Guo, S. (2013). The critical role of potassium in plant stress response. *International Journal of Molecular Sciences, 14*, 7370-7390. Doi: 10.3390/ijms14047370.

Wang, Y-T. (2007). Potassium nutrition affects phalaenopsis growth and flowering. *HortScience, 42* (7), 1563-1567.

Wanikiat, P., Panthong, A., Sujayanon, P., Yoosok, C., Rossi, A. G. and Reutrakul, V. (2007). The anti-inflammatory effects and the inhibition of neutrophil responsiveness by *Barleria lupulina* and *Clinacanthus nutans* extracts. *Journal of Ethnopharmacology*, 116 *(2)*, 234-244.

Waraich, E. A., Ahmad, R., Hur, R. G. M., Ehsanullah, Ahmad, A. and Mahmood, N. (2011). Response of foliar application of KNO3 on yield, yield components and lint quality of cotton (*Gossypium hirsutum* L.). *African Journal of Agricultural Research, 6*, 5457-5463.

Winkel-Shirley, B. (2001). Flavonoid biosynthesis: A colorful model for genetics, biochemistry, cell biology, and biotechnology. *Plant Physiology, 126*, 485–493.

Wong, F-C., Yong, A-L., Ting, E. P-S., Khoo, S-C., Ong, H-C. and Chai, T-T. (2014). Antioxidant, metal chelating, anti-glucosidase activities and phytochemical analysis of selected tropical medicinal plants. *Iranian Journal of Pharmaceutical Research, 13* (4), 1409-1415.

World Health Organization (2009). *Monographs on selected medicinal plants*. Available from http://apps.who.int/medicinedocs/en/d/Js16713e/.

World Health Organization (2014). *WHO Traditional Medicine Strategy 2014-2023*. Available from http://www.who.int/medicines/publications/traditional/trm_strategy14_23/en/.

World Health Organization (WHO) (2003). *Guildelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants*. Available from http://apps.who.int/medicinedocs/en/d/Js4928e/.

Xie, J., Tang, L., Wang, Z., Xu, G. and Li, Y. (2012). Distinguishing the biomass allocation variance resulting from ontogenetic drift or acclimation to soil texture. *Plus One, 7* (7). Doi: 10.1371/journal.pone.0041502.

Yilmaz, G., Kandemir, N. and Kinalioglu, K. (2004). Effects of different pruning intervals on fresh shoot yield and some quality properties of tea (*Camellia sinensis* L. Kuntze) in Turkey. *Pakistan Journal of Biological Sciences, 7*, 1208-1212.

Yong, Y. K., Tan, J. J., Teh, S. S., Mah, S. H., Ee, G. C. L., Chiong, H. S. and Ahmad, Z. (2013). *Clinacanthus nutans* extracts are antioxidant with antiproliferative effect on cultured human cancer cell lines. *Evidence-Based Complementary and Alternative Medicine*, Vol. 2013, Article ID 462751, 8 pages. doi.org/10.1155/2013/462751.

Zain, N. A. M. and Ismail, M. R. (2016). Effects of potassium rates and types on growth, leaf gas exchange and biochemical changes in rice (*Oryza sativa*) planted under cyclic water stress. *Agricultural Water Management, 164*, 83-90. Doi: org/10.1016/j.agwat.2015.09.022.

Zakaria, M. and Mohd, M. A. (2010). *Traditional Malay Medicinal Plants*. Malaysia: Institut Terjemahan Negara Malaysia Berhad.

Zelelew, D. Z., Lal, S., Kidane, T. T. and Ghebreslassie, B. M. (2016). Effect of potassium levels on growth and productivity of potato varieties. *American Journal of Plant Sciences, 7*, 1629-1638.

Zhang, H., Song, T., Wang, K., Wang, G., Liao, J., Xu, G. and Zeng, F. (2015). Biogeographical patterns of forest biomass allocation vary by climate, soil and forest characteristics in China. *Environmental Research Letters, 10* (4).

Zhu, Z. B., Liang, Z. S., Han, R. L. and Wang, X. (2009). Impact of fertilization on drought response in the medicinal herb *Bupleurum chinense* DC: Growth and saikosaponin production. *Industrial Crop and Products, 29* (2-3), 629-633.

Zigene, Z. D., Kassahun, B. M. and Ketaw, T. T. (2012). Effects of harvesting age and spacing on leaf yield and essential oil yield of rosemary (*Rosmarinus officinalis* L.). *The African Journal of Plant Science and Biotechnology, 6* (1), 9-12.