UNIVERSITI PUTRA MALAYSIA

BIOLOGY OF Limnocharis flava (L.) BUCHENAU AND neptunia oleracea LOUR. AND THEIR STATUS AS VEGETABLE CROPS IN SARAWAK, MALAYSIA

NOORASMAH SAUPI

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By

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Abstract of thesis presented to Senate of the Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

BIOLOGY OF *Limnocharis flava* (L.) BUCHENAU AND *Neptunia oleracea* LOUR. AND THEIR STATUS AS VEGETABLE CROPS IN SARAWAK, MALAYSIA

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Chairman : Assoc. Prof. Dr. Muta Harah Zakaria @ Ya, PhD
Faculty : Agriculture and Food Sciences

The invasion and fast growth of aquatic macrophytes, *Limnocharis flava* (L.) Buchenau and *Neptunia oleracea* Lour. caused problems in rice fields and drainage systems. However, they are also offered for sale in native markets and being consumed as leafy vegetables among local urban peoples mainly in central region of Sarawak, Malaysia. These aquatic weeds are harvested from the wild, and there has been no attempt to cultivate them. Hence, this research evaluates their distribution and determine their ecological and morphological characteristics, i.e., habitats and plant adaptations to environments. These information were used for observational and detailed studies on developmental stages, crop and yield patterns, and the availability of these vegetables in native markets and further evaluates their nutritive status.

Limnocharis flava were recorded growing in various habitats of 32 locations, i.e., township and residential ditches, oil palm plantation irrigation and roadside drainage systems. Based on Principal Component Analysis (PCA) of the various environmental parameters, three distinct environments formed the growing sites of *L. flava*, i.e., group A – areas with pH 5.01 – 5.50 and high water temperature, 33.01 – 34.00°C, group B – areas with low water temperature, 27.01 – 28.00°C that flow from roadside drainage system and group C – areas with slow moving water in wide drainage system, 2.0 – 2.5 m with water depth of 1.0 – 1.5 m. Plants grew densely in ditch which had comparatively high concentration of dissolved PO_4^{3-}, NH_3^- and NO_2^- and total N and C, available P, K, Na, Mg and Mn in substrate, e.g., at Public Library Mukah and possessed relatively longer petiole and sheath length, and also bigger blade, floral structures, fruit and seed. There are three types of plant life forms, i.e., submerged, emergent and semi aquatic or marginally. The submerged life form was observed from seed germination to the juvenile plant stage and rarely occurred in the adult mature plant. The submerged juvenile plants' leaves lacked stomata on both surfaces. The plant propagated through seed and plantlet. The plant developed from seed to reproductive plant within 20 to 28 days that involved seven developmental stages, i.e., swollen seed, germinating seed, seedling, juvenile plant with plumular leaves, juvenile plant with petiolate leaves, mature vegetative and reproductive plants. New plantlet emerges in the

middle of the umbel inflorescence of the reproductive plant which then grew into new vegetative and reproductive plants.

For *N. oleracea,* the plants showed two life forms as adaption to the environments, i.e., terrestrial (at Kg Medong and Kg Kekan) and floating (at Kg Penipah). However, the terrestrial life form is less common. The terrestrial plant had woodier stem than the floating plant. The stems were enveloped by thick white aerhenchyma tissues formed when stem is in contact with water within 6 to 8 days. It grew densely in the ditch which had comparatively high concentration of dissolved NO_2^-, NO_3^- and NH_3^- and total N and available Na in substrate, e.g., at Kg Penipah. The plant propagated through seed and stem cutting. Six developmental stages were observed during development from seed to reproductive plant which took 24 to 26 days, i.e., swollen seed, germinating seed, seedling, juvenile plant, mature vegetative and reproductive plants. Auxiliary buds were also observed at the stem of *N. oleracea* which then developed into new vegetative and reproductive plants.

Limnocharis flava and *N. oleracea* can be propagated in created environment, e.g., in tank. NO_3^- or a combination of nutrient (NO_2^-, NO_3^- and NH_3^-) responsible in the increased in number of leaf and inflorescence, blade length and width, and petiole diameter of *L. flava* propagated from seed and plantlet. As for propagation of *N. oleracea,* only NO_3^- was responsible in the increased in length of plant grown from seed and stem cutting. Seven harvesting activities at two weeks interval performed after five weeks of transplanting showed there were no differences in the yield of *L. flava* shoots. For *N. oleracea* propagation from seed and stem cutting, allowed eight harvesting activities at one week interval after five weeks transplanting also showed there were no differences in the yield of shoots.

In the evaluation of plant availability in native markets, *L. flava* were available in the months of January to April, June to July and October in Sibu central market and in February to March in Bintulu tamu. As for *N. oleracea,* it was available only in April and October in Sibu central market. The periodic availability of these plants in native markets was attributed to the preference of other high profitable commodities, e.g., *Durio zibethinus* and endemic fruit, *Canarium odontophyllum*. Tender shoots comprising leaves and inflorescences were consumed raw or blanched or stir-fried. The proximate composition and mineral content analysis revealed that, both *L. flava* and *N. oleracea* possessed high moisture content of 83.75 – 94.59%. *Limnocharis flava* was also high in crude fat content (0.12 – 0.39%), while *N. oleracea* was identified as having high in protein content (3.01 – 3.23%). The tank culture is the favorable method for continuously production instead of gathering the plants from the wild. However, it is necessary to evaluate the annual production of these species at bigger-scale experiments. Other analyses on vitamins, anti-oxidants, anti-nutritional and toxicological are important to evaluate other usefulness of the plant properties.

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

BIOLOGI *Limnocharis flava* (L.) BUCHENAU DAN *Neptunia oleracea* LOUR. DAN STATUS MEREKA SEBAGAI TANAMAN SAYURAN DI SARAWAK, MALAYSIA

Oleh

NOORASMAH BINTI SAUPI

Pengerusi : Prof. Madya Dr. Muta Harah Zakaria @ Ya
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Penaklukan dan pertumbuhan pantas dua makrofit akuatik, *Limnocharis flava* (L.) Buchenau dan *Neptunia oleracea* Lour. menyebabkan masalah di sawah padi dan sistem perparitan. Walau bagaimanapun, ia juga dijual di pasar tempatan (tamu Sarawak) dan dimakan sebagai sayuran berdaun di kalangan penduduk bandar terutamanya di kawasan tengah Sarawak, Malaysia. Rumpai akuatik ini dituai dari kawasan alamiah, dan belum ada lagi percubaan untuk menanam mereka. Oleh itu, kajian ini menilai taburan dan menentukan ciri-ciri ekologi dan morfologi iaitu habitat dan adaptasi tumbuhan kepada persekitaran. Maklumat ini digunakan untuk pemerhatian dan kajian terperinci pada peringkat perkembangan, corak penanaman dan hasilan, dan keterdapatan sayur-sayuran ini di pasar tamu dan seterusnya menilai status khasiatnya.

Limnocharis flava direkodkan tumbuh di pelbagai habitat di 32 lokasi iaitu parit perbandaran dan perumahan, sistem saliran ladang kelapa sawit dan perparitan sisi jalan. Berdasarkan kepada Analisis Komponen Utama (PCA) pelbagai parameter persekitaran, tiga persekitaran berbeza membentuk tempat pertumbuhan *L. flava* iaitu kumpulan A – kawasan dengan pH 5.01 – 5.50 dan suhu air yang tinggi, 33.01 – 34.00°C, kumpulan B – kawasan dengan suhu air yang rendah 27.01 – 28.00°C yang mengalir dari sistem perparitan sisi jalan dan kumpulan C – kawasan dengan air yang mengalir perlahan dalam sistem perparitan yang lebar, 2.0 – 2.5 m dengan kedalaman 1.0 – 1.5 m. Tumbuhan tumbuh dengan padat dalam parit yang mempunyai secara perbandingannya kepekatan tinggi PO_4^{3-}, NH_3^- and NO_2^- terlarut dan jumlah N dan C, P, K, Na, Mg dan Mn tersedia dalam substrat contohnya di Perpustakaan Awam Mukah dan tumbuhan mempunyai tangkai daun dan upih daun yang panjang, dan juga helai daun, struktur bunga, buah dan biji yang lebih besar. Terdapat tiga jenis bentuk kehidupan iaitu tenggelam, termuncul dan separa akuatik atau marginal. Bentuk kehidupan tenggelam telah diperhatikan daripada peringkat percambahan biji ke tumbuhan juvenile dan jarang berlaku dalam tumbuhan dewasa yang matang. Daun tumbuhan juvenil tidak mempunyai stomata di kedua-dua permukaan. Tumbuhan dibiak melalui biji dan plantlet tumbuhan. Tumbuhan berkembang daripada biji kepada tumbuhan reproduktif dalam tempoh 20 hingga 28 hari yang melibatkan tujuh peringkat perkembangan iaitu

biji membengkak, biji bercambah, anak benih, tumbuhan juvenil dengan daun plumular, tumbuhan juvenil dengan daun bertangkai, tumbuhan vegetatif matang dan tumbuhan reproduktif. Plantlet baharu muncul di tengah jambak bunga umbel tumbuhan reproduktif yang kemudian berkembang menjadi tumbuhan vegetatif.

Bagi *N. oleracea,* tumbuhan menunjukkan dua bentuk kehidupan sebagai adaptasi kepada persekitaran iaitu daratan (di Kg Medong dan Kg Kekan) dan terapung (di Kg Penipah). Walau bagaimanapun, bentuk kehidupan daratan adalah jarang ditemui. Tumbuhan daratan mempunyai batang lebih berkayu berbanding dengan tumbuhan terapung. Batang tumbuhan kedua-dua bentuk kehidupan diselaputi oleh tisu arenkima putih tebal yang terbentuk apabila tersentuh dengan air dalam jangkamasa 6 hingga 8 hari. Ia tumbuh dengan padat dalam parit yang mempunyai secara perbandingannya kepekatan NO_2^-, NO_3^- dan NH_3^- terlarut yang tinggi dan jumlah N dan Na tersedia dalam substrat contohnya di Kg Penipah. Tumbuhan membiak melalui biji dan keratan batang. Enam peringkat perkembangan diperhatikan semasa tumbesaran daripada biji kepada tumbuhan reproduktif yang mengambil masa 24 hingga 26 hari iaitu biji membengkak, biji bercambah, anak benih, tumbuhan juvenil, tumbuhan vegetatif matang dan tumbuhan reproduktif. Tunas sisi juga diperhatikan pada batang *N. oleracea* yang kemudiannya berkembang menjadi tumbuhan vegetatif baharu.

Limnocharis flava dan *N. oleracea* dapat dibiak dalam persekitaran yang diolah contohnya dalam tangki. NO_3^-, atau kombinasi nutrien (NO_2^-, NO_3^- dan NH_3^-) bertanggunjawab dalam peningkatan bagi bilangan daun dan jambak bunga, panjang dan lebar helai daun, dan diameter tangkai daun *L. flava* yang ditanam daripada biji dan plantlet. Untuk penanaman *N. oleracea,* hanya NO_3^- bertindak dalam peningkatan panjang tumbuhan yang tumbuh daripada biji dan keratan batang. Tujuh aktiviti penuaian selang dua minggu dilakukan selepas lima minggu pemindahan tanaman menunjukkan tidak terdapat perbezaan dalam hasilan pucuk *L. flava*. Untuk penanaman *N. oleracea* dari biji dan keratan batang, lapan aktiviti penuaian selang dua minggu dilakukan selepas lima minggu pemindahan tanaman telah juga menunjukkan tidak terdapat perbezaan dalam hasilan pucuk.

Dalam penilaian keterdapatan tumbuhan di pasar tamu, *L. flava* terdapat pada bulan Januari hingga April, Jun hingga Julai dan Oktober di pasar sentral Sibu dan Februari hingga Mac di tamu Bintulu. Bagi *N. oleracea,* ia terdapat hanya dalam bulan April dan Oktober di pasar sentral Sibu. Keterdapatan berkala tumbuhan ini di pasar tamu adalah disebabkan oleh keutamaan diberi kepada komoditi yang memberi keuntungan tinggi, contohnya *Durio zibethinus* dan buah endemik, *Canarium odontophyllum*. Pucuk lembut yang mengandungi daun dan jambak bunga dimakan secara mentah atau dicelur atau digoreng kering. Analisis komposisi proksimat dan kandungan mineral menunjukkan bahawa kedua-dua *L. flava* dan *N. oleracea* mempunyai kandungan kelembapan yang tinggi iaitu 83.75 – 94.59%. *Limnocharis flava* juga tinggi dalam kandungan lemak (0.12 – 0.39%), manakala *N. oleracea* dikenalpasti mempunyai kandungan protein yang tinggi (3.01 – 3.23%). Kaedah penanaman menggunakan tangki adalah sesuai untuk pengeluaran kedua-dua spesies secara berterusan menggantikan kaedah pemungutan tumbuhan dari kawasan alamiah. Walau bagaimanapun, adalah perlu juga untuk menilai pengeluaran tahunan spesies ini dalam eksperimen berskala yang besar. Analisis lain terhadap kandungan vitamin, anti-oksida, anti-nutrisi dan toksikologi adalah penting untuk menilai kandungan khasiat tumbuhan.

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I certify that a Thesis Examination Committee has met on 21 February 2014 to conduct the final examination of Noorasmah Binti Saupi on her thesis entitled "Biology of *Limnocharis flava* (L.) Buchenau and *Neptunia oleracea* Lour. and their status as vegetable crops in Sarawak, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor Philosophy of Science in Agronomy.

Members of the Thesis Examination Committee were as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

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LIST OF ABBREVIATIONS AND SYMBOLS

e.g.	for example
i.e.	that is
No.	number
Jln	Jalan
Kg	Kampung
Bt	Batu
Sg	Sungai
Tg	Tanjung
LAKU	Lembaga Air Kawasan Utara
SJK	Sekolah Jenis Kebangsaan
SMK	Sekolah Menengah Kebangsaan
SPAD	Sarawak Plantation Agriculture Sdn. Bhd.
UPMKB	Universiti Putra Malaysia Campus Bintulu Sarawak

CHAPTER 1

GENERAL INTRODUCTION

Aquatic macrophytes are considered as those large plants which grow in excessive amounts in a continuous supply of water or at least present in soils which are covered with water during a major part of the growing season and interfered with the intended usage of particular area (Weldon *et al.,* 1973; Edwards, 1980). They are divided into four categories based on their life form, namely floating, submerged, emergent and marginal (Edwards, 1980; Mashhor, 1988; Said *et al.*, 1991; Muta Harah *et al.,* 2005; Closs *et al.*, 2006; Singh, 2008).

The high density and population of aquatic macrophytes and their ability for vegetative growth in drainage systems, ponds, reservoirs and paddy fields can cause problems to the humans in terms of in agriculture, health, hydroelectricity dams, reduced water quality and recreational purposes (Table 1.1). For that reason, many researchers considered aquatic macrophytes as invasive or unwanted and refer to them as "aquatic weeds" (Weldon *et al.,* 1973; Edwards, 1980; Said *et al.,* 1991; Mashhor, 1994). One of the best controls of weeds is by utilizing them (Mashhor, 1988). Various reports have been documented on their uses mainly in waste treatment management, agriculture, foods and paper pulps (Table 1.2). As for example, in West Malaysia, 56 species had been used as medicinal plant, 32 species for feed plants, 27 species for vegetables, 16 species for aquarium and 14 species for green manure (Said *et al.,* 1991).

The major pathways involving aquatic macrophytes for food production in South East Asia is shown in Figure 1.1. Basically, aquatic macrophytes provided three types of foods to human being, the foliage for green vegetables, grain or seeds for protein, starch and oil and swollen fleshy roots for starch (National Academy of Sciences, 1976).

Previous studies on the uses of aquatic macrophytes in Sarawak showed that 31 species are edibles, 11 species are use for medicinal, 12 species for fodder, 19 species for ornamental, 2 species for food wrapper, 3 species for paper and mat and 2 species for bio-filter (Muta Harah *et al.,* 2005). Twenty three of freshwater macrophytes are reported utilized for food (Suzalina Akma, 2008; Dayangku Alifah, 2009). Local peoples consumed them either as raw or cooked vegetables. However, most of these aquatic macrophytes in Sarawak are harvested from the wild, and there has been no cultivation for these edible species on a commercial scale (Muta Harah *et al.,* 2005; Suzalina Akma, 2008; Mohd Syahrul, 2009; Dayangku Alifah, 2009). From observations in Sarawak, at least in several places, e.g., Sibu and Bintulu, the common aquatic macrophytes, *Limnocharis flava* (L.) Buchenau and *Neptunia oleracea* Lour. are consumed locally as leafy vegetables. Peoples gathered these plants from several places e.g., irrigation and drainage systems for own consumption and also offered for sale in native markets.

Table 1.1: A summary compiled on problems caused by noxious growth of aquatic macrophytes.

Location	Problems caused by aquatic weeds	References
	Agriculture	
South East Asia	Competition with main crop, *Oryza sativa.*	Pancho and Soerjani (1978)
Thailand	Competition with main crop, *O. sativa.*	Edwards (1980)
Kalasin Province	Blocking the irrigation system.	Cruz-Garcia and Price (2011)
Pa Mong Dam	A large of floating mat plants provides habitats for rats, clog the pumps and block the gateway.	Chomchalow and Pongpangan (1976)
India		
Kumarakom	Competition with main crop, *O. sativa.*	Abhilash *et al.* (2008)
Kerala	Blocking the irrigation system.	Nayar and Sworupanandan (1978)
Kerala	Heavy reduction on the growth of cultivated plants by *Salvinia* sp.	Varshney and Singh (1976)
Andaman Island	Blocking the irrigation system.	Karthigeyan *et al.* (2004)
Indonesia	Competition with main crop, *O. sativa,* clog the pumps and block the gateway.	Koesterman *et al.* (1987)
West Malaysia	Competition with main crop, *O. sativa.*	Haynes and Les (2004); Samy *et al.* (2005)
Muda, Kedah	Competition with main crop, *O. sativa.*	Mashhor (1988); Begum *et al.* (2005); Mohd Adly *et al.* (2009)
Seberang Prai, Penang	Competition with main crop, *O. sativa.*	Abdul Shukor *et al.* (2009)
Kg Sg Bakau, Perlis	Competition with main crop, *O. sativa.*	Ain Nihla *et al.* (2011)
East Malaysia		
Kota Samarahan, Sarawak	Competition with main crop, *O. sativa.*	Baki (1993)
	Aquaculture	
India	Hindrance to fisheries.	Varshney and Singh (1976)
Indonesia		
Irian Jaya	Hindrance to fisheries.	Sukarwo (1991)
Thailand	Reduce the population of fish.	Chomchalow and Pongpangan (1976)

Continued Table 1.1

	Health	
Namibia		
Olushandja Dam	Floating mats of *Ludwigia stolonifera* provide a home for bilharzia-carrying snails.	Burke (2000)
Thailand	*Eichhornia crassipes* provides ideal conditions for growth and multiplication of mollusks.	Chomchalow and Pongpangan (1976)
India	Provide condusive habitat for vectors of malaria.	Varshney and Singh (1976)
Kerala	*Salvinia* generate foul gases which affect the health.	George (1976)
West Malaysia		
Titiwangsa Lake, Perdana Lake and Jaya Lake	Harbored disease vectors.	Mohd Fauzi (1991)
	Residential, irrigation and water reservoirs	
Australia		
Northern Australia	Blocking man made drainage systems.	Waterhouse (2003); DPI (2009)
India	Chocking the flowing waters.	Varshney and Singh (1976)
Rajasthan and Madhya	Submerged weeds reduced the water flow by about 50-70% in Right Main Canal Rajashtan.	Mehta and Sharma (1976)
Sri Lanka	Reduce the flow of water in drainage systems.	Dassanayake (1976)
West Malaysia	Water loss due to *E. crassipes* transpiration.	Mashhor (1994)
East Malaysia		
Miri and Bintulu, Sarawak	Blocking man-made drainage systems.	Suzalina Akma (2008)
	Hydroelectric power	
Thailand		
Pa Mong Dam	Reducing of power generation.	Chomchalow and Pongpangan (1976)
Sri Lanka	Reducing of power generation.	Dassanayake (1976)
Burkina-Paso		
Sahelian lakes	Reducing of power generation.	Müller (2005)
Nigeria	Reducing of power generation.	Abulude (2005)
Indonesia		
Kalimantan	Loss of water through evapotranspiration of *Polygonium barbatum.*	Djasmani (1991)
West Malaysia	*Eichhornia crassipess, Pistia* spp. and *Salvinia* sp. blocking water outlets.	Mohd Fauzi (1991)

Continued Table 1.1

	Recreation and navigation	
Netherland	Dense stands of aquatic vegetation often cause nuisance for boating, swimming and by obstruction of water flow.	van Nes *et al.* (2002)
Thailand		
Nam Pong and Lam Pao	*Hydrilla verticillata* entangling the boat engine.	Chomchalow and Pongpangan (1976)
Pa Mong Dam	The dense mats of *E. crassipess* covering the lake.	Chomchalow and Pongpangan (1976)
India		
Kerala	Larges masses of *Salvinia* brought by large rivers to cochin port area causing hindrance to ships.	George (1976)
West Malaysia		
Titiwangsa Lake, Perdana Lake and Jaya Lake	Destroy the aesthetic values of lakes.	Mohd Fauzi (1991)

Table 1.2: A summary compiled on the uses of some aquatic weeds.

Location	Uses of aquatic weeds	References
	Waste water treatments	
Denmark	*Phragmites australis* has been used in wastewater treatment.	Brix and Schierup (1989)
West Malaysia		
Kg Sg Bakau, Perlis	*Limnocharis flava* have been identified suitable for use in constructed wetland to treat landfill leachate.	Ain Nihla *et al.* (2011)
India	Combination of *Eichhornia crassipes-Lemna minor* and *E. crassipes-Pistia stratiotes* were found the best possible for removal N and P from dairy industry.	Upadhay (2004)
Thailand		
Prachinburi Province	*Neptunia oleracea* was used to treat the effluent from shrimp effluent tank.	Suppadit *et al.* (2005)
Colombia		
Ayapel, Betanci and Lorica wetlands, Córdoba	*Eichhornia crassipes, Ludwigia helminthorriza,* and *Polygonum punctatum* could be proposed as Cu and Zn phytoremediators.	Núñez *et al.* (2011)
Namibia		
Olushandja Dam	Sedges and reedbeds naturally filtering domestic pollutants in Olushandja dam.	Burke (2000)
	Agriculture	
Australia		
Griffith, New South Wales	*Azolla pinnata* has been used as fertilizer, supplying a substantial amount of organic N for the crop mainly rice, and also to improve soil structure.	Cary and Bowmer (1991)
South East Asia	*A. pinnata, Salvinia* sp., *Pistia stratiotes, Lemna minor*, *Hydrilla verticullata, L. flava, Typha angustifolia* and *Sagittaria latifolia* can be used as a live stock fodder.	Edwards (1980)
	Foods	
America		
Northern America	*Alisma subcordatum, Commelina communis, Nastartium officinale, Nelumbo lutea, Nuphar luteum, Nymphae odorata, Portulaca oleracea, S. latifolia* and *T. angustifolia* are edibles.	Duke (2001)
India		
Gorakhpur	*Veronica anagallis-aquatica, E. crassipes, Ipomoea reptans, Polygonum hydropiper, Allmania nodiflora* and *Cassia sophora* have been reported as potential source of leaf proteins.	Pandey and Srivastava (1991)
South East Asia	*Trapa bispinosa, N. oleracea, L. flava, Monochoria vaginalis, Ipomoea aquatica, Colocasia esculenta* have been reported as foods.	Edwards (1980)

Continued Table 1.2

West Malaysia	*Limnocharis flava, M. vaginalis* and *I. aquatica* are recorded as leafy vegetables.	Samy *et al.* (2005)
	Paper and pulp	
Indonesia		
Krawang	*Eichhornia crassipes* that had long fiber and low lignin have been reported a potential source of pulps.	Joedodibroto *et al.* (1983)
India		
Yamuna Nagar	*Salvinia molesta* with high holocellulose and low amount of lignin has been indentified for pulp and paper production.	Bhardwaj (2005)

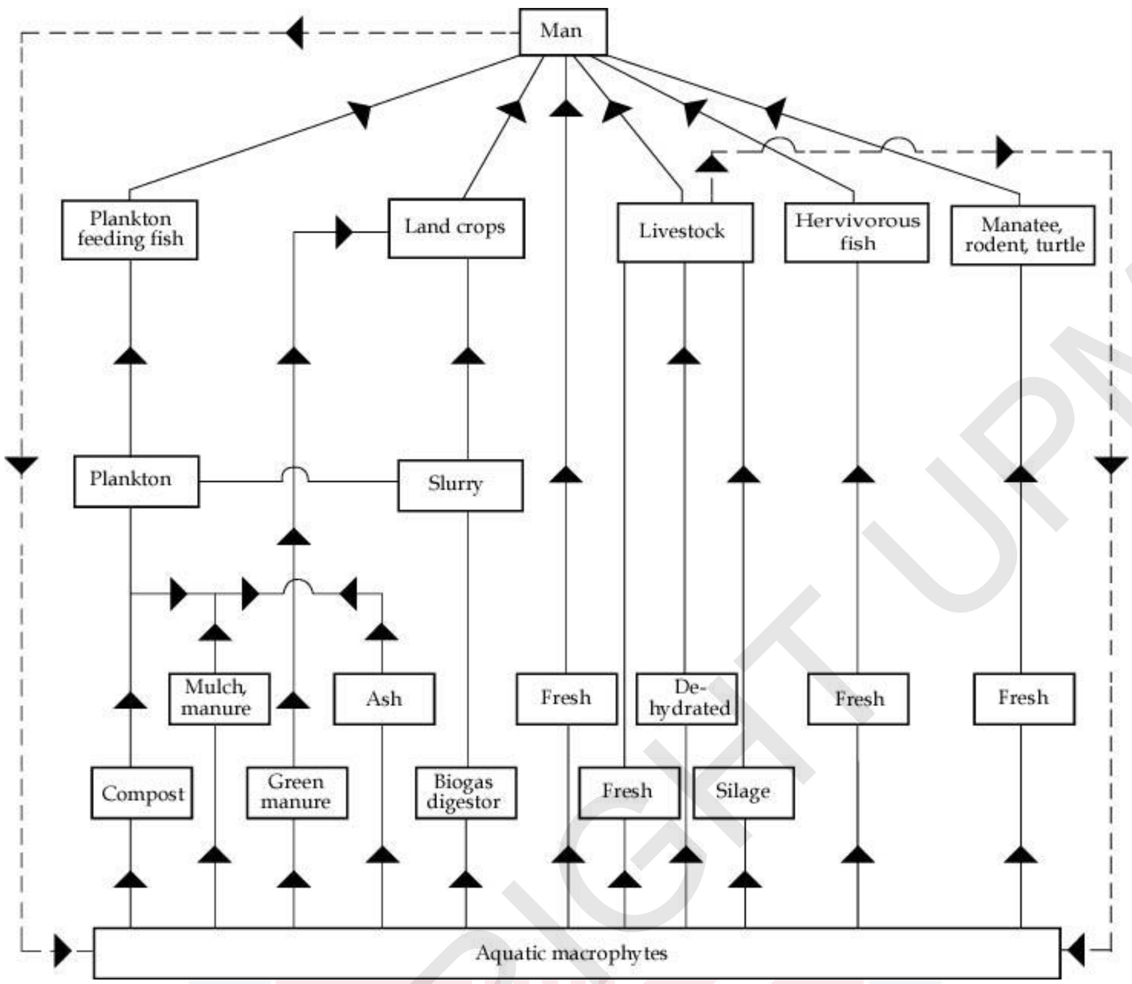

Figure 1.1: The major pathways involving aquatic macrophytes in food productions in South East Asia (Source: Edwards, 1980).

Limnocharis flava is synonym to *Alisma flava, L. emarginata* Kunth and *L. plumieri* Richard (van den Bergh, 1994). It is belonging to Butomaceae or Limnocharitaceae (Kaul, 1978; van den Bergh, 1994). *Limnocharis flava* is known locally by various names as paku rawan, keladi itik, jinjir (West Malaysia) and emparuk (Sarawak) (Voon *et al.,* 1990; van den Bergh, 1994; Rukayah, 2002; Samy *et al.,* 2005; Mohd Syahrul, 2009; Dayangku Alifah, 2009). It was introduced into tropical Asia before 1870 and become thoroughly naturalized throughout Malaysia (Edwards, 1980; Karim *et al.,* 2004) and becomes serious tropical weeds invading irrigated rice fields, channels, wetland areas of Southeast Asian countries (Cook *et al.,* 1974; Waterhouse, 2003; Begum *et al.,* 2005; Abhilash *et al.,* 2008). This species can multiply by bulbils developed on the inflorescence stalk and through seed dispersal (Nayar and Sworupanandan, 1978; Waterhouse, 2003). A single fruit produces about 1000 seeds and a single plant may produce as many as 1 million seeds per year (Kotawala, 1976; Abhilash *et al.,* 2008). Several reports concerning on the description and propagation of *L. flava* are published i.e., vegetative and reproductive morphology (van Steenis, 1958; Kaul, 1967; 1976; Henderson, 1974; Kostermans *et al.,* 1987; Keng, 1983; Jones, 1993; van den Bergh, 1994; Lim *et al.,* 1998; Karthigeyan *et al.*, 2004), habitat (Begum *et al.*, 2005; Abhilash *et al.*, 2008; Abdul Shukor *et al.,* 2009) and plant development and propagation (Wilder, 1974; Kaul, 1978; Nayar and Sworupanandan, 1978; Song *et al.,* 2000; Brooks *et al.,* 2008).

In Java, Indonesia, young plants are much-esteemed vegetable although not appreciated elsewhere (Kostermans *et al.,* 1987). A young shoot comprising leaves and petioles and flower cluster or unopened inflorescence are collected, consumed either raw or grilled or cooked for a short time before being eaten (Cook *et al.,* 1974; Edwards, 1980; Kostermans *et al.,* 1987; Voon *et al.,* 1990; van den Bergh, 1994; Rukayah, 2002; Haynes and Les, 2004; Muta Harah *et al.*, 2005; Samy *et al.*, 2005). It is commonly cultivated in fertile soil in West Java and Thailand and harvested after 2 – 3 months before being marketed as secondary crop (van den Bergh, 1994; Haynes and Les, 2004). Each bunch contained 20 sprouts and 1000 bunches can be harvested in an area of 1 ha (van den Bergh, 1994). This lesser known vegetable is also commonly sold in native markets in Sarawak, East Malaysia at RM 1.00 to 2.00 per bunch (Muta Harah *et al.*, 2005; Mohd Syahrul 2009; Dayangku Alifah, 2009).

Other aquatic macrophytes commonly consumed as green leafy vegetable is water mimosa, *N. oleracea.* It is synonym to *N. prostrata* (Lamk) Baillon and *N. natans* (L.f) Druce. It is known by various names as keman air, keman gajah, kangkung puteri in West Malaysia and daun tangki in Sarawak (Rukayah, 2002; Halimatul Saadiah, 2003). A plant has bipinnate leaves and stems made buoyant by their spongy white covering. The young shoot comprising of leaves, spongy stems and young seedpods can be eaten raw and cooked as green vegetables (National Academy of Sciences, 1976; Edwards, 1980; Paisooksantivatana, 1994; Rukayah, 2002; Halimatul Saadiah, 2003; Muta Harah *et al*., 2005; Samy *et al*., 2005; Mohd Syahrul, 2009, Dayangku Alifah, 2009; Jain *et al.,* 2011). Subjects pertaining to *N. oleracea* include its description and morphology (Windler, 1966; Ridley, 1967; Shah and James, 1968; Holtum, 1969; Henderson, 1974; Pancho and Soerjani, 1978; Paisooksantivatana, 1994; Kamarudin and Latiff, 2002; Holtum and Ivan, 2002), distribution and ecology (Windler, 1966; Ridley, 1967) and propagations (Paisooksantivatana, 1994).

It can be found floating or prostrate near the edge of water reservoir, water channel and ditches with stagnant to slow moving water of pH 5.4 – 6.0 (Cook *et al.,* 1974; Paisooksantivatana, 1994). In Thailand, it is commonly used as a vegetable and cultivated in inundated fields or in canals (National Academy of Sciences, 1976; Edwards, 1980; Paisooksantivatana, 1994). *Neptunia oleracea* can be harvested after 3 – 4 weeks after planting and 250 shoots are gathered into bunch then traded in local market. About 30,000 – 50,000 shoots can be harvested for each harvest in one hectare area (Paisooksantivatana, 1994). In Sarawak *N. oleracea* is sold in Sibu central market and Tamu Nyelong Sarikei depending on the availability at RM 1.00 – 2.00 per bunch (Muta Harah *et al*., 2005).

Generally in Malaysia, most of the studies of wild or indigenous fruits and vegetables are recorded in West Malaysia e.g., research on wild fruit plants (Chung *et al.,* 2004), salad and vegetables (Rukayah, 2002), and herbs (Samy *et al.,* 2005). In Sarawak, reports pertaining on utilization and marketable of indigenous fruits and vegetables were documented by Voon *et al.* (1990) and Mohd Syahrul (2009). Several studies were focusing on aquatic macrophytes distribution and utilization (Muta Harah *et al.,* 2005; Suzalina Akma, 2008) and marketable species (Dayangku Alifah, 2009). Those studies reported on the occurrences of *L. flava* and *N. oleracea* in Sarawak native markets with data observation on their availability throughout the year.

Despite the uses of *L. flava* and *N. oleracea* as food by the local people, the plants have not been given due attention in terms of their propagation modes, availability and nutritional content. For this reason, this present study was conducted to complement those studies mentioned above focusing on the plants' biology, availability in native markets, proximate and minerals compositions, and also their propagation modes. It is hope that the information would be used for advocating their increased utilization as vegetable crops. The objectives of this study are:

(i) to determine the distribution, habitat and environmental conditions of *L. flava* and *N. oleracea* in central region of Sarawak;
(ii) to evaluate the morphological characteristics of *L. flava* and *N. oleracea*;
(iii) to determine the developmental stages, propagation methods and productions of *L. flava* and *N. oleracea*;

(iv) to assess the availability and nutrient contents of *L. flava* and *N. oleracea* in local markets.

The findings are reported in the different chapters. Chapter 3 is on the distribution, types of habitat and environmental conditions. Chapter 4 and Chapter 5 present the vegetative and reproductive morphology of *L. flava* and *N. oleracea* respectively. The propagation and production of these plants is given in Chapter 6. Chapter 7 reported on the availability and nutrient status of both plant species. The summary, general conclusion and recommendation for future research are discussed in Chapter 8.

REFERENCES

Abdul Shukor, J., Muhammad Saiful, A. H., Begum, M., Anuar, A. R. and Azmi, M. (2009). Influence of Flooding, intensity and duration on rice growth and yield. *Pertanika Journal of Tropical Agricultural Science, 32*, (2), 195–208.

Abhilash, P. C., Singh, N., Sylas, V. P., Kumar, A., Mathew, J. C., Satheesh, R. and Thomas, A. P. (2008). Eco-distribution mapping of invasive weed *Limnocharis flava* (L.) Buchenau using geographical information system: Implications for containment and integrated weed management for ecosystem conservation. *Taiwania, 1*, 30-41.

Abulude, F. O. (2005). Nutritional evaluation of aquatic weeds in Nigeria. *Electronic Journal of Environmental, Agriculture and Food Chemistry, 4*(1), 835-840.

Achinewhu, S. G., Ogbonna, C. and Hard, A. D. (1995). Chemical composition of indigenous wild herbs, spices fruits, nuts and leafy vegetables used as food. *Plants Foods for Human Nutrition, 48*, 341-388.

Ain Nihla, K., Roslaili, A. A. and Mohd Faizal, A. J. (2011). Removal of heavy metals from landfill leachate using horizontal and vertical subsurface flow constructed wetland planted with *Limnocharis flava. International Journal of Civil and Engineering, 11*(05), 85-91.

Adepoju, O. T. and Oyewole, E. O. (2008). Nutritional importance and micronutrient potentials of two non-conventional indigenous green leafy vegetables from Nigeria. *Agricultural Journal, 3*(5), 362-368.

Akta Makanan 1983 dan Peraturan-peraturan Makanan (1985). Kuala Lumpur: MDC Publishers Printers Sdn. Bhd.

Alazard, D. (1985). Stem and root nodulation in *Aeschynomene* spp. *Applied and Environmental Microbiology, 50*(3), 732-734.

Alfawaz, M. A. (2006). Chemical composition of hummayd (*Rumex vesicarius*) grown in Saudi Arabia. *Journal of Food Composition and Analysis*, *19*(6-7), 552-555.

Alli Smith, Y. R. (2009). Determination of chemical composition of *Senna siamea* (Cassia leaves). *Pakistan Journal of Nutritional, 8*(2), 119-121.

Alofe, F. V., Odeyemi, O. and Oke, O. L. (1996). Three edible wild mushrooms from Nigeria: Their proximate and mineral composition. *Plant Foods for Human Nutrition, 49*, 63-73.

Amusa, N. A., Adegbite, A., Muhammed, A. S. and Baiyewu R. A. (2003). Yam diseases and its management in Nigeria. *African Journal of Biotechnology, 2*(12), 497-502.

Ashman, M. R. and Puri, G. (2002). *Essential Soil Science: A Clear and Concise Introduction to Soil Science.* UK: Blackwell science Ltd.

AOAC. (1990). *Official Methods of Analysis of Association of Official Analytical Chemist* (15th ed). Arlington, Virginia, USA: Association of Official Analytical Chemists International.

Baki, B. B. (1993). Spatial analysis of weeds in selected rice fields of Samarahan, Sarawak. *Mardi Resource Journal, 21*(2), 121-128.

Barminas, J. T., Charles, M. and Emmanuel, D. (1998). Mineral composition of non-conventional leafy vegetables. *Plant Food for Human Nutrition, 53*, 29-36.

Barko, J. W. and Smart, R. M. (1986). Sediment-related mechanisms of growth limitation in submersed macrophytes. *Ecology, 67*(5), 1328-1340.

Becker, T. and Müller, J. V. (2007). Floristic affinities, life-form spectra and habitat preferences of the vegetation of two semi-aris regions in Sahelian West and Southern Africa. *Basic and Applied Dryland Research, 1,* 33-50.

Begum, M., Abdul Shukor, J., Azmi, M., Rajan, A. and Syed-Omar, S. R. (2005). Weed diversity of rice fields in four districts of Muda Rice Granary Area, North-West Peninsular Malaysia. *Malaysian Applied Biology, 34*(2), 31-41.

Behera, M. D., Chitale, S., Shaw, A. Roy, P. S. and Murthy, M. S. R. (2012). Wetland monitoring, serving as an index of land use change-a study in Samaspur Wetlands, Uttar Pradesh. *Journal of Indian Society of Remote Sensing, 40*(2), 287-297.

Bhardwaj, K. R. (2005). Potential use of an aquatic weed, *Salvinia molesta* in paper industry. *Bulletin of National Institute of Ecology, 15,* 145-151.

Borah, S., Baruah, A. M., Das, A. K. and Borah, J. (2009). Determination of mineral content in commonly consumed leafy vegetables. *Food Analysis and Methods, 2*, 226-230.

Boyd, C. E. (2000). *Water Quality: An Introduction.* USA: Kluwer Academic Publishers.

Bray, J. R. and Curtis, J. T. (1957). An ordination of the upland forest communities of southern Wisconsin. *Ecology and Monography, 27*, 325-349.

Bremner, J. M. (1965). Inorganic forms of nitrogen. *Agronomy, 9,* 1179-1237.

Brix, H. and Schierup, H. H. (1989). The use of aquatic macrophytes in water-pollution control. *AMBIO, 18*(2), 100-107.

Brooks, S. J., Weber, J. M., Setter, S. D. and Akacich, B. A. (2008). Seed production and maturation of *Limnocharis flava* (L.) Buchenau in the field and glasshouse. In van Klinken, R. O., Osten, V. A., Penetta, F. D. and Scanian, J. C. (Eds.), *Proceeding of the 16th Australian Weeds Conference, Queensland Weeds Society, Australia*. (pp 180-182).

Brown, A. L. (1971). *Ecology of Freshwater.* London: Heinemann Educational Books.

Burke, A. (2000). Plant diversity of a man-made wetland – The Olushandja Dam in north central Namibia. *Dinteria, 26*, 25-44.

Burkill, I. H. (1966). *A Dictionary of the Economic Products of the Malay Peninsular Volume II.* Governments of Malaysia and Singapore.

Cary, P. R. and Bowmer, K. H. (1991). Aquatic plants – friend of foe? In *Proceeding of the Symposium on Aquatic Weed Management*. 15-17 May 1990. Bogor Indonesia. (pp 39-45).

Catarino, L., Duarte, M. C. and Diniz, M. A. (2001). Aquatic and wetland plants in Guinea-Bissau: an overview. *Systematic and Geography of Plants, 71*(2), 197-208.

Chefetz, B., Hatcher, P. G., Hadar, Y. and Chen, Y. (1996). Chemical and biological characterization of organic matter during composting of municipal solid waste. *Journal of Environmental Quality, 25,* 776–785.

Chin, H. F. (1999). *Malaysian Vegetables in Colour: A complete guide*. Kuala Lumpur: Tropical Press Sdn. Bhd.

Chomchalow, N. and Pongpangan, S. (1976). Aquatic weeds in Thailand: Occurrence, problems, and existing and proposed control measures. In Varshney, C. K. and Rzoska, J. (Eds.), *Aquatic Weeds in South East Asia: Proceedings of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi*, (pp 43-50).

Chou, Y.J., Elliot, G. N., James, E. K., Lin, K. Y., Chou, J. S., Sheu, S. Y., Sheu, D. S., Sprent, J. I. and Chen, W. M. (2007). *Labrys neptuniae* sp. Nov., isolated from root nodules of the aquatic legume *Neptunia oleracea. International Journal of Systematic and Evolutionary Microbiology, 57,* 577-581.

Chung, R. C. K., Soepadmo, E., Kamarudin, S. and Syahrir, F. (2004). *Wild Fruit Plants of Peninsular Malaysia.* Selangor: Forest Research Institute.

Clark, K. R. and Warwick, R. M. (2001). *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*. (2nd ed). Plymouth, Uk: PRIMER-E. Ltd.

Closs, G., Downes, B. and Boulton, A. (2006). *Freshwater Ecology: A Scientific Introduction.* USA: Blackwell Publishing.

Colmer, T. D. and Pedersen, O. (2008). Underwater photosynthesis and respiration in leaves of submerged wetland plants: gas films improve CO_2 and O_2 exchange. *New Phytologist, 177,* 918–926.

Cook, C. D. K., Gut, B. J., Rix, E. M., Scheneller, J. and Seitz, M. (1974). *Water Plants of the World: A Manual for the Identification of the Genera of Freshwater Macrophytes.* England: Dr. W. Junk b.v. Publisher, The Hague.

Cook, C. D. K. (1996). *Aquatic Plant Book.* SPB Academic Publisher.

Cronk, J. K. and Fennessy, M. S. (2001). *Wetland Plants: Biology and Ecology.* USA: Lewis Publishers.

Cruz-Garcia, G. S. and Price, L. L. (2011). Ethnobotanical investigation of 'wild' plants used by rice farmers in Kalasin, Northeast Thailand. *Journal of Ethnobiology and Ethnomedicine, 7*(33), 1-20.

Dairo, F. A. S. and Adanlawo, I. G. (2007). Nutritional quality of *Crassocephalum crepidioides* and *Senecio biafrae. Pakistan Journal of Nutritional, 6*(1), 35-39.

Dassanayake, M. D. (1976). Noxious aquatic vegetation control in Sri Lanka. In Varshney, C. K. and Rzoska, J. (Eds.), *Aquatic Weeds in South East Asia: Proceedings of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi*, (pp 59-61).

Davis, S. M. (1991). Growth decomposition and nutrient retention of *Cladium jamaicense* Crantz and *Typha domingensis* Pers. in the Florida Everglades. *Aquatic Botany, 40*, 203-224.

Dayangku Alifah, A. S. (2009). *Aquatic Macrophytes Diversity and Utilization by Ethnic Group.* (Unpublished BSc's thesis). Universiti Putra Malaysia, Selangor.

deMan, J. M. (1999). *Principles of Food Chemistry.* (3rd ed). USA: Springer.

Department of Employment, Economic Development and Innovation of State of Queensland, DPI. (2009). *Neptunia oleracea* or *N. plena, Fact sheet Declared Class 1 Pest Plant.* Retrieved from

http://www.dpi.qld.gov.au/documents/Biosecurity_EnvironmentalPests/IPA-Water-Mimosa-Factsheet.pdf

Djasmani, H. (1991). Problem and control of *Polygonium barbatum* in Ir. P.M. Noor Reservoir, South Kalimantan, Indonesia. In *Proceeding, Symposium on Aquatic Management,* 15-17 May, 1990, Bogor, Indonesia. BIOTROP Special Publication 40, (pp63– 68).

Duke, J. A. (2001). *Handbook of Edible Weeds.* USA: Herbal Reference Library.

Dutta, A. C. (1971). *A Class-book of Botany.* (4th ed). New York: Oxford University Press.

Edwards, P. (1980). *Food Potential of Aquatic Macrophytes*. Manila: 1st. International Center for Living Aquatic Resources Management.

Ennos, R. and Sheffield, E. (2000). *Plant Life.* USA: Blackwell Sciences.

EPA. (2009). Industrial waste resource guidelines: Sampling and analysis of waters, wastewaters, soils and wastes. Retrieved from http://epanote2.epa.vic.gov.au .

Escudero N. L., Albarracin S., Fernández S., De Arellano L. M., and Mucciarelli, S. (1999). Nutrient and antinutrient composition of *Amaranthus muricatus*. *Journal of Plants Foods Human Nutrition, 54,* 327-336.

Ezebilo, E. E. (2010). Conservation of a leafy vegetable important for communities in the Nigerian rainforest. *Forest Ecology and Management, 259*, 1660-1665.

Fasakin, K. (2004). Proximate composition of bungu (*Ceratotheca* Endl.) leaves and seeds. *Biokemistri, 16*(2), 88-92.

Fenner, M. (1985). *Seed Ecology.* London: Chapman and Hall.

Fenner, M. and Thompson, K. (2005). *The Ecology of Seeds.* United Kingdom: Cambridge University Press.

Fleck, H. (1981). *Introduction to Nutrition* (4th ed). New York: Macmillan Publishing Co.

Flyman, M. V. and Afloyan, A. J. (2006). A survey of plants used as wild vegetables in four districts of Botswana. *Ecology of Food and Nutrition, 45,* 406-415.

Flyman, M. V. and Afloyan, A. J. (2007). Proximate and mineral composition of the leaves of *Momordica balsamina* L.: underutilized wild vegetable in Bostwana. *International Journal of Food Sciences and Nutrition, 58*(6), 419-423.

Forman, L. and Bridson, D. (1989). *The Herbarium Handbook.* Great Britain: Royal Botanic Gardens Kew.

Forno, I. W., Fichera, J. and Prior, S. (2000). Assessing the risk to *Neptunia oleracea* Lour. by moth, *Neustrota gunniella* (Busk), a biological control agent for *Mimosa pigra* L. In Spencer, N. R. (Ed.), *Proceeding of the X International Symposium on Biological Control of Weeds.* Montana State University, Bozeman, Montana, USA (pp 449-457).

George, K. (1976). Studies on the chemical control of some important aquatic weeds of Kerala *Salvinia, Ludwigia* and *Cyperus*. In Varshney, C. K. and Rzoska, J. (Eds.), *Aquatic Weeds in South East Asia: Proceedings of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi*, (pp. 255-262).

Glew, R. S., VanderJagt, D. J., Bosse, R., Huang, Y. S., Chuang, L. T. and Glew, R. H. (2005). The nutrient content of three edible plants of the Republic of Nigeria. *Journal of Food Composition and Analysis*, *18,* 15-27.

Grivetti, L. E. and Ogle, B. M. (2000). Value of traditional foods in meeting macro and micronutrient needs: the wild plant connection. *Nutritional Research and Review, 13*(1), 31-46.

Gordon, E. (1998). Seed characteristics of plant species from riverine wetlands in Venezuela. *Aquatic Botany, 60*, 417-431.

Grubben, G. J. H., Siemonsma, J. S. and Kasem, P. (1994). Introduction. In Siemonsma, J.S. and Kasem, P. (Eds.), *Plant Resources of South-East Asia 8: Vegetables* (pp 1 – 54). Bogor Indonesia: PROSEA.

Greuilich, S., Barrat-Segretian, M. and Bornette, G. (2001). Basal rosette or floating leaf canopy – an example of plasticity in a rare aquatic macrophyte. *Hydrobiologia, 448*, 53-59.

Guil-Guerrero, J. L., Gimenez-Gimenez, A., Rodriguez-Garcia, I. and Torija-Isasa, M. E. (1998). Nutritional composition of *Sonchus* species (*S. asper* L, *S. oleraceus* L *and S. tenerrimus* L). *Journal Science of Food and Agriculture, 76*, 628-632.

Gupta, P. K. (2004). *Soil, Plant, Water and Fertilizer Analysis.* India: India Agrobios.

Halimatul Saadiah, A. S. (2003). *Sayur-sayuran Semenanjung Malaysia* (1st ed). Kuala Lumpur: Dewan Bahasa dan Pustaka.

Hassan, L. G. and Umar, K. J. (2006). Nutritional value of balsam apple (*Momordica balsamina* L.) leaves. *Pakistan Journal of Nutrition, 5*(6), 522-529.

Haynes, R. R. and Les, D. H. (2004). Alismatales (water plaintains). In *Nature Encyclopedia of Life Sciences* (pp 1-4).

Haynes, R. R. and Holm-Nielsen, L. B. (1992). The Limnocharitae. *Flora Neotropica, 56*, 1-32.

Hazra, P. and Som, M. G. (2005). *Vegetable Science*. India: Kalyani Publisher.

Henderson, M. R. (1974). *Malayan Wild Flowers: Monocotyledon Part II.* Kuala Lumpur: The Malayan Nature Society.

Holtum, R. E. and Ivan, E. (2002). *Gardening in the Tropics.* Singapore: Times Edition.

Holtum, R. E. (1969). *Plant Life in Malaya.* Kuala Lumpur: Longman Group Limited.

Ibrikci, H., Knewtson, S. J. B. and Grusak, M. A. (2003). Chickpea leaves as a vegetable green for humans: evaluation of mineral. *Journal of the Science of Food and Agriculture, 83*, 945-950.

Imsande, J. and Touraine, B. (1994). N demand and regulation of nitrate uptake. *Plant Physiology, 105,* 3-7.

Insel, P., Turner, R. E. and Ross, D. (2002). *Nutrition.* (1st ed). USA: Jones and Bartlett.

Institute of Medicine. (1997). *Dietary Reference Intakes: Calcium, Phosphorous, Magnesium, Vitamin D and Fluoride.* Washington DC, USA: National Academy Press.

Institute of Medicine. (2001). *Dietary Reference Intakes: Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc.* Washington DC, USA: National Academy Press.

Institute of Medicine. (2005a). *Dietary Reference Intakes: Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Acid Amino.* Washington DC, USA: National Academy Press.

Institute of Medicine. (2005b). *Dietary Reference Intakes: Water, Potassium, Sodium, Chloride and Sulphate*. Washington DC, USA: National Academy Press.

Ivan, P. (1988). *Plants and Flowers of Malaysia.* Singapore: Times Edition.

Jain, A., Sundriyal, M., Roshnibala, S., Kotoky, R., Kanjilal, P. B., Singh, H. B. and Sundriyal, R. C. (2011). Dieatary use and conservation concern of edible wetland plants at Indo-Burma hotspot: a case study from Northeast India. *Journal of Ethhnobiology and Ethnomedicine, 7*(29), 1-17.

Janicke, H. (2009). Potential of underutilized crops for the tropics. In Discovering opportunities, expanding the economic horizon: *Proceedings of National Conference on New Crops and Bio-Resources 2009.* Tan, S. L. (Ed.). Malaysian Agricultural Reserach and Devlopment Institute, Negeri Sembilan (pp 3-9).

Joedodibroto, R., Widyanto, L. S. and Soerjani, M. (1983). Potential uses of some aquatic weeds as paper pulp. *Journal of Aquatic Management, 21*, 29-32.

John, C. M., Sylas, V. P., Paul, J. and Unni, K. S. (2009). Floating islands in a tropical wetland of Peninsular India. *Wetlands Ecology Management, 17*, 641-653.

Jones, D. T. (1993). *Flora of Malaysia: Illustrated.* Kuala Lumpur: Oxford University Press.

Kadam, S. S. and Salunkhe, D. K. (1998). Vegetables in human nutrition. In Salunkhe, D. K. and Kadam, S. S. (Eds.), *Handbook of Vegetable Science and Technology: Production, Composition, Storage and Processing.* (pp 695-703). New York: Marcel Dekker Inc.

Kamarudin, M. S. and Latiff, A. (2002). *Tumbuhan Ubatan Malaysia.* UKM: Pusat Pengurusan Penyelidikan UKM.

Karim, S. M. R., Azmi, B. M. and Ismail, B. S. (2004). Weed problems and their management in rice fields of Malaysia: An overview. *Weed Biology Management, 4*, 177-186.

Karthigeyan, K. Sumathi, R., Jayathi, J., Diwakar, P. G. and Lakra, G. J. (2004). *Limnocharis flava* (L.) Buchenau – A little known and troublesome weed in Andaman Island. *Current Science, 87*(2), 140-141.

Kaul, B. R. (1967). Ontogeny and anatomy of the flower of *Limnocharis flava* (Butomaceae). *American Journal of Botany, 54*(10), 1223-1230.

Kaul, B. R. (1976). Conduplicate and specialized carpels in the Alismatales. *American Journal of Botany, 63*(2), 175-182.

Kaul, V., Zutshi, D. P. and Vass, K. K. (1976). Aquatic weeds in Kashmir. In Varshney, C. K. and Rzoska, J. (Eds.), *Aquatic Weeds in South East Asia: Proceedings of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi*, (pp 79-83).

Kaul, B. R. (1978). Morphology of germination and establishment of aquatic seedlings in Alismataceae and Hydrocharitaceae. *Aquatic Botany, 5*, 139-147.

Keeley, B. E., Osmond, C. B. and Raven, J. A. (1984). Stylites, a vascular land plant without stomata absorbs CO_2 via its roots. *Nature, 310*, 694 – 695.

Keng, H. (1983). *Orders and Families of Malayan Seed Plants.* (3rd ed). Singapore: Singapore University Press.

Kershaw, K. A. (1973). *Quantitative and Dynamic Plant Ecology.* (2nd ed). London: The English Language Book Society and Edward Arnold (Publishers) Ltd.

Khairul Adha, A. R., Siti Khadijah, D., Siti Shapor, S., Aziz, A. Yuzine, E. and Ena Rena, I. (2009). Freshwater fish diversity and composition in Batang Kerang Floodplain, Balai Ringin, Sarawak. *Pertanika Journal of Tropical Agricultural Science, 32*(1), 7-16.

Kotawala, J. (1976). Noxious water vegetation in Sri Lanka: the extent and impact of existing infestations. In Varshney, C. K. and Rzoska, J. (Eds.), *Aquatic Weeds in South East Asia: Proceedings of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi*, (pp 51-58).

Kostermans, A. J. G. H., Wirjahardja, S. and Dekker, R. J. (1987). The weeds: Description, ecology and control. In Soerjani, M., Kostermans, A. J. G. H. and Tjitrosoepomo, G. (Eds.) *Weeds of Rice in Indonesia.* Jakarta: Balai Pustaka (pp 28-564).

Köhler, J. (2006). Detergent phosphates: An EU policy assessment. *Journal of Business Chemistry, 3*(2), 15-30.

Kreibich, H., Kern, J., de Camargo, P. B., Moreira, M. Z., Victória, R. L. and Werner, D. (2006). Estimation of symbiotic N_2 fixation in Amazon floodplain forest. *Oecologia, 147*, 359-368.

Lacuol, P. and Freedman, B. (2006). Environmental influences on aquatic plants in freshwater ecosystems. *Environmental Reviews, 14*(2), 89-136

Lim, W. H., Kho, B. L., Tay, T. H. and Low, W. L. (1998). *Plants of Putrajaya Wetlands.* Putrajaya, Malaysia: Perbadanan Putrajaya and Putrajaya Holdings Sdn. Bhd.

Lomoljo, R. M., Ismail, A. and Yap, C. K. (2009). Nitrate, ammonia and phosphate concentration in surface water of Kuala Gula Bird Sanctuary, West Coast of Peninsular, Malaysia. *Pertanika Journal of Tropical Agricultural Science, 32*(1), 1-5.

Lyimo, M., Temu, R. P. C and Mugula, J. K. (2003). Identification and nutrient composition of indigenous vegetables of Tanzania. *Plant Foods for Human Nutrition, 58*, 85-92.

Maisuthisakul, P., Pasuk, S. and Ritthiruangdej, P. (2008). Relationship between antioxidant properties and chemical composition of some Thai plants. *Journal of Food Composition and Analysis, 21,* 229-240.

Mashhor, M. (1988). Aquatic weeds in rice waterways. In *Proceeding of the National Seminar and Workshop on Rice Weed Management.* Penang, (pp 69-78).

Mashhor, M. (1994). *Biologi Rumpai.* Pulau Pinang: Penerbit Universiti Sains Malaysia.

Mehta, I. and Sharma, R. K. (1976). Weeds on the flow capacity Chambal irrigation system in Kota, Rajashtan. In Varshney, C. K. and Rzoska, J. (Eds.), *Aquatic Weeds in South East Asia: Proceedings of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi*, (pp 85-90).

Metcalfe, C. R. (1931). The “aerenchyma”of the *Sesbania* and *Neptunia. Bulletin of Miscellaneous Information (Royal Garden Kew), 3,* 151-154.

Mohd. Fauzi, R. (1991). The status of aquatic weeds in Malaysia. In *Proceeding of the Symposium on Aquatic Weed Management*. 15-17 May 1990. Bogor Indonesia, (pp 39-45).

Mohd Adly, A., Amir Shah, R. M. S. and Mashhor, M. (2009). Distribution of weedy species from different rice management practices plots in Muda rice agrosystem. In Shahrul Anuar, M. S., Amir Shah, R. M. S. and Che Salmah, M. R. (Eds.), *Rice Agrosystem: Biodiversity and its Environment with Special Reference to Muda Agricultural Development Authority (MADA), Penerbit Universiti Sains Malaysia,* (pp 109-118).

Mohd Shahwahid, H. O. (1990). *A Preliminary Economic Valuation of Wetland Plant Species in Peninsular Malaysia.* WWF Project 3927: WWF Malaysia, Institute for Advance Studies University of Malaya and Asian Bureau.

Mohd Syahrul, A. M. S. (2009). *Marketable Wild Plants at Selected Sarawak Native Markets.* (Unpublished BSc's thesis). Universiti Putra Malaysia, Serdang.

Mohd Shukri, M. A., Salma, I., Mirfat, A. H. S., and Mohd Shukor, N. (2009). Rare and underutilized fruits and ulam species: new sources for high antioxidant and potential heal benefits. In Discovering opportunities, expanding the economic horizon: *Proceedings of National Conference on New Crops and Bio-Resources 2009.* Tan, S. L. (Ed.). Malaysian Agricultural Reserach and Devlopment Institute, Negeri Sembilan. (pp 73-86).

Muhd Arif, S. S. (2009). *Marketable Wild Fruits at Selected Sarawak Native Markets.* (Unpublished BSc's thesis). Universiti Putra Malaysia, Serdang.

Müller, J. V. (2005). Ephemeral vegetation at shorelines of Sahelian seasonal lakes. *Systematic and Geography of Plants, 75*(2), 239-257.

Murphy, J. and Ridley, J. P. (1967). A modified single solution method for determination of phosphate in natural waters. *Analytica Chemica Acta, 27,* 31-36.

Muta Harah, Z. (2001). *Biology and Ecology of Halophila beccarii Aschers. in Peninsular Malaysia.* (Unpublished PhD's thesis). Universiti Putra Malaysia, Serdang.

Muta Harah, Z., Japar Sidik, B., Raesah, A. Maini, C. and Suzalina, A. (2005). Aquatic macrophytes in natural and man made water bodies. *Bio-Science Research Bulletin, 21*(1), 27-36.

Nabors, M. W. (2004). *Introduction to Botany.* USA: Pearson Benjamin Cummings.

Nather Khan, I. S. A. (1990). *Socio-economic Value of Aquatic Plants (Freshwater Macrophytes) of Peninsular Malaysia.* Kuala Lumpur: AWB/WWFM. Publication. No. 67C.

National Academy of Sciences. (1976). *Making Aquatic Weeds Useful: Some Perspectives for Developing Countries*. Washington DC.

Nayar, B. K. and Sworupanandan, K. (1978). Morphology of the fruit and mechanism of seed dispersal of the freshwater weed *Limnocharis flava*. In *Proceedings of Indian Academy of Science*, *87*(2), 49-53.

Núñez, S. E. R., Negrete, J. L. M., Rios, J. E. A., Hadad, H. R. and Maine, M. A. (2011). Hg, Cu, Pb, Cd, and Zn accumulation in macrophytes growing in tropical wetlands. *Water, Air and Soil Pollution, 216*, 361-373.

Odhav, B., Beekrum, S., Akula, U. and Baijnath, H. (2007). Preliminary of nutritional value of traditional leafy vegetables in Kwazulu-Natal, South Africa. *Journal of Food Composition and Analysis, 20,* 430-435.

Ong, H. C. (2008). *Vegetables: for Health and Healing*. Malaysia: Utusan Publication and distributors.

Ogle, B. M., Tuyet, H. T., Duyet, H. N. and Dung, N. N. X. (2003). Food, feed or medicine: the multiple functions of edible wild plants in Vietnam. *Economic Botany, 57*(1), 103-117.

Orech, F. O., Aargard-Hansen, J. and Friis, H. (2007). Ethnoecology of traditional leafy vegetables of the Luo people of Bondo district, western Kenya. *International Journal of Food Sciences and Nutrition, 58*(7), 522-530.

Paisooksantivatana, Y. (1994). *Neptunia oleraceae* Loureiro. In Siemonsma, S. and Kasem, P. (Eds.), *Plant Resources of South-East Asia 8: Vegetables,* (pp 217–218). Bogor Indonesia: PROSEA.

Palada, M. C. and Crossman, S. M. A. (1999). Evaluation of tropical leaf vegetables in the Virgin Islands. In Janick, J. (Ed.), *Perspectives on New Crops and New Uses.* Alexandria, VA: ASHS Press.

Pancho, J. V. and Soerjani, M. (1978). *Aquatic Weeds of Southeast Asia: A Systematic Account of Common Southeast Asia Aquatic Weeds.* Philippines: National Publishing Cooperative Incorporate.

Pandey V. N and Srivastava, A. K. (1991). Yield and nutritional quality of leaf protein concentrate from *Eleocharis dulcis* (Burm. f) Hensch. *Aquatic Botany, 41,* 369-374.

Parvathi, S. and Kumar, V. J. F. (2002). Studies on chemical composition and utilization of the wild edible vegetable athalakai (*Momordica tuberosa*) *Plants Food for Human Nutrition, 57,* 215-222.

Pemberton, R. W. and Lee, N. S. (1996). Wild food plants in South Korea: market presence, new crops and exports to United States. *Economic Botany, 50*(1), 57-70.

Peter, N. G., Chua, K. S. and Joseph, K. (1991). *A Guide of Freshwater Life in Singapore.* Singapore: Science Centre.

Peirce, J. J., Weiner, R. F. and Vesilind, P. A. (1998). *Environmental Pollution and Control* (4th ed). U.S.A: Butterworth-Heinemann.

Priestly, J. H. and Scott, L. I. (1957). *An Introduction to Botany with Special Reference to the Structure of the Flowering Plant*. United Kingdom: Longmans, Green and Co.

Prusty, B. A. K., Azeez, P. A. and Jagdeesh, E. P. (2007). Alkali and transisiton metals in macrophytes of a wetland system. *Bulletin of Environment, Contamination and Toxicology, 78*, 405-410.

Raigón M., Prohens J., Munóz-Falón, J. E., and Nuez, F. (2008). Comparison of eggplant landraces and commercial varieties for fruit content, phenolics, minerals, dry matter and protein. *Journal of Food Composition and Analysis, 21,* 370-376.

Ramachandran, V., Ramaprabhu, T. and Singh, S. B. (1976). A survey of aquatic weed infestations in Andhra Pradesh. In Varshney, C. K. and Rzoska, J. (Eds.), *Aquatic Weeds in South East Asia: Proceedings of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi*, (pp 91-98).

Redzic, S. J. (2006). Wild edible plants and their traditional use in the human nutrition in Bosnia-Herzegovina. *Ecology of Food and Nutrition, 45,* 189-232.

Rivas, R., Willems, A., Subba-Rao, N. S., Mateos, P. F., Dazzo, F. B., Kroppenstedt, R. M., Martínez-Molina, E., Gillis, M. and Velázquez, E. (2003). Description of *Devosia neptuniae* sp. nov. that nodulates and fixes nitrogen in symbiosis with *Neptunia natans*, an aquatic legume from India. *Systematic and Applied Microbiology, 26*(1), 47–53.

Ridley, H. N. (1967). *The Flora of the Malay Peninsular Vol I.: Polypetale.* Netherland: A. Asher and Co.

Robinson, B. L. (1898). Revision of the North American of *Neptunia. Proceeding of the American Academy of Arts and Science, 33*(17), 332-334.

Rukayah, A. (2002). *Ulam dan Sayuran Tempatan Semenanjung Malaysia (*2nd ed). Kuala Lumpur: Dewan Bahasa dan Pustaka.

Said, I. M., Nather Khan, I. S. A. and Yahya, N. A. (1991). The socio-economic value of aquatic plants with reference to Peninsular Malaysia. In *Proceeding, Symposium on Aquatic Weed Management*. 15-17 May 1990. Bogor Indonesia, (pp 177-193).

Saito, Y. and Atobe, S. (1970). Phytosociological study of intertidal marine algae, I. Usujuri Benten-Jima, Hokkaido. *Bulletin of the Faculty of Fisheries, Hokkaido University, 21,* 37-69.

Samy, J., Sugumaran, M. and Kate, L. L. W. (2005). *Herbs of Malaysia: An Introduction to the Medicinal, Culinary, Aromatic and Cosmetic Use of Herbs* (1st ed). Malaysia: Times Edition.

Saupi, N., Zakaria, M. and Bujang, J. S. (2009). Analytic chemical composition and mineral content of yellow velvetleaf (*Limnocharis flava* L. Buchenau)'s Edible parts. *Journal of Applied Sciences, 9*(16), 2969-2974.

Schollenberger, C. J. and Simon, R. H. (1945). Determination of exchange capacity and exchangeable bases in soil-ammonium acetate method. *Soil Science, 59*(1), 13-24.

Sculthorpe, C. D. (1967). *The Biology of Aquatic Vascular Plants.* London: Edward Arnold.

Shah, J. J. and James, M. R. (1968). Sieve tube elements in the stem of *Neptunia oleracea* Lour. *Australian Journal of Botany, 16*, 433-444.

Shardendu, J. and Ambasht, R. S. (1991). Relationship of nutrients in water with biomass and nutrient accumulation of submerged macrophytes of a tropical wetland. *New Phytologist, 117*(3), 493-500.

Sharip, Z., Schooler, S. S., Hipsey, M. R. and Hobbs, R. J. (2011). Eutrophication, agriculture and water level control shift aquatic plant communities from floating-leaved to submerged macrophytes in Lake Chini, Malaysia. *Biological Invasion.* DOI 10.1007/s10530-011-0137-1

Sharma, K. P., Khan, T. I. and Bhardwaj, N. (1984). Temperature-regulated seed germination in *Neptunia oleracea* Lour. and its ecological significance. *Aquatic Botany, 20*, 185-188.

Sheela, K., Nath, K. G., Vijaylakshmi, D., Yankanchi, G. M. and Patil, R. B. (2004). Proximate composition of underutilized green leafy vegetables in southern Karnataka. *Journal of Human Ecology, 15*(3), 227-229.

Shin, E. C., Craft, B. D., Pegg, R. B., Phillips, R. D. and Eitenmiller, R. R. (2010). Chemometric approach to fatty acid profiles in Runner-type peanut cultivars by principal component analysis (PCA). *Food Chemistry, 119,* 1262-1270.

Singh, S. K. (2008). *Plant Ecology.* Delhi: Campus Books International.

Singhal, R. S. and Kulkarni, P. R. (1998). Leafy vegetables. In Salunkhe, D. K. and Kadam, S. S. (Eds.), *Handbook of Vegetable Science and Technology: Production, Composition, Storage and Processing.* (pp 533-588). New York: Marcel Dekker Inc.

Soepadmo, E. (1986). Aquatic flowering plants. *Nature Malaysiana, 11*(3), 16-25.

Song, Z. P., Guo, Y. H. and Huang, S. Q. (2000). Studies on the breeding system of *Limnocharis flava* (Butomaceae). *Acta Phytotaxonomica Sinica, 38*(1), 53-59.

Sripen, S., Duangswadi, M. Nasuthon, S. and Tanaprayothsak, W. (1991). Growth potential of aquatic plants in relation to the nutrients in the Makssan reservoir, Bangkok, Thailand. In *Proceeding, Symposium on Aquatic Weed Management.* 15-17 May 1990. Bogor, Indonesia (pp 87-100).

Stern, K. R. (2006). *Introductory Plant Biology.* (10th ed). New York: McGraw-Hill Higher Education.

Subba-Rao, N. S., Mateos, P. F. Baker, D., Pankratz, H. S., Plama, J., Dazzo, F. B. and Sprent, J. I. (1995). The unique root-nodule symbiosis between *Rhizobium* and the aquatic legume, *Neptunia natans.* (L.f.) Druce. *Planta, 196,* 311-320.

Sukarwo, P. (1991). Analysis of vegetation of aquatic weeds in Sentani lake, Irian Jaya. In *Proceeding of the Symposium on Aquatic Weed Management*. 15-17 May 1990. Bogor Indonesia. (pp 79-86).

Sundriyal, M. and Sundriyal, R. C. (2001). Wild edible plants of the Sikkim Himalaya: Nutritive values of selected species. *Economic Botany, 55*(3), 377-390.

Suppadit, T., Phoochinda, W. and Bunsitichai, P. (2005). Treatment of effluent from shrimp farm by using water mimosa (*Neptunia oleracea* Lour.) *Journal of ISSAAS, 11*(2), 1-9.

Suzalina Akma, A. (2008). *Biological and Ecological Aspects of Freshwater Macrophytes in the Coastal Areas of Bintulu and Miri, Sarawak, Malaysia.* (Unpublished MSc's thesis). Universiti Putra Malaysia, Serdang.

Tardio, J., Pardo-de-Santayana, M. and Morales, R. (2006). Edible plants in Spain. *Botanical Journal the Linnean Society*, *152*, 27-71.

Taylor, K. G. and Robbins, R. C. (1968). The amino acid composition of water hyacinth (*Eichhornia crassipes*) and its value as a protein supplement. *Hyacinth Control Journal, 7*, 24–25.

Tolanur, S. (2006). *Practical Soil Science and Agricultural Chemistry.* India: International Book Distributing Co.

Umar, K. J., Hassan, L. G., Dangoggo, S. M. and Ladan, M. J. (2007). Nutritional composition of water spinach (*Ipomoea aquatica* Forrsk.) leaves. *Journal of Applied Sciences, 7*(6), 803-809.

Upadhay, A. R. (2004). *Aquatic Plants for the Waste Water Treatment.* Delhi: Daya Publishing House.

Varshney, C. K. and Singh, K. P. (1976). A survey of aquatic weed problem in India. In Varshney, C. K. and Rzoska, J. (Eds.), *Aquatic Weeds in South East Asia: Proceedings of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi*, (pp 31-41).

van Balgooy, M. M. J. (2001). *Malesian Seed Plant: Portraits of Tree Families. Volume 3.* Rijksherbarium/Hortus Botanicus.

van den Bergh, M. H. (1994). *Limnocharis flava* (L.)Buchenau. In Siemonsma, S. and Kasem, P. (Eds.), *Plant Resources of South-East Asia 8: Vegetables* (pp 192–194). Bogor Indonesia: PROSEA.

van Nes, E. H., Scheffer, M., van den Berg, M. S., and Coops, H. (2002). Aquatic macrophytes restore, eradicate or is there comparise? *Aquatic Botany, 72,* 387-403.

van Steenis, C. G. G. J. (1958). Butomaceae. In van Steenis, C. G. G. J. (Ed.), *Flora Malesiana: Series I Spermatophyte Volume 5.* (pp 188-120). Bogor, Indonesia and Leyden, Netherlands: P. Noordhoff Ltd.

Voon, B. H., Sim, T. H. and Sabariah, P. (1990). *Sayur-sayuran dan Buah-buahan Hutan di Sarawak.* Sarawak: Department of Agriculture Sarawak.

Voon, B. H. and Kueh, H. S. (1999). The nutritional value of indigenous fruits and vegetables in Sarawak. *Asia Pacific Journal of Clinical Nutrition, 8*(1), 24-31.

Waterhouse, B. M. (2003). Know your enemy: recent records of potentially serious weeds in Northern Australia, Papua New Guinea and Papua (Indonesia). *Telopea, 10*(1), 477-485.

Weldon, L. W., Blackburn, R. D. and Harrison, D. S. (1973). *Common Aquatic Weeds.* New York: New York Dover.

White, R. E. (2009). *Principles and Practice of Soil Science: The Soil as a Natural Resource.* (4th ed). USA: Blackwell Publishing.

Wilder, G. J. (1974). Symmetry and development of *Butomus umbellatus* (Butomaceae) and *Limnocharis flava* (Limnocharitaceae). *American Journal of Botany, 61*(4), 379-394.

Windler, D. R. (1966). A revision of the genus *Neptunia* (Leguminosae). *Australian Journal of Botany, 14*, 379-420.

Wittig, R. (2005). The syntaxanomy of the aquatic vegetation in Burkina Faso. In Wittig, R. and Guinko, S. (Eds.), *Studies on the Aquatic Vegetation of Burkina Faso Vol 9.* (pp 3-10). Solingan: Verlag Natur and Wissenscaft.

Yesodharan, K. and Sujana, K. A. (2007). Wild edible plant traditionally used by the tribes in the Parambikulam Wildlife Sanctuary, Kerala, India. *Natural Product Radiance, 69*(1), 74-80.

Yildrim, E., Dursun, A. and Turan, M. (2001). Determination of the nutrition contents of the wild plants used as vegetables in Upper Corus Valley. *Turkey Journal of Botany, 25*, 367-371.

BIODATA OF STUDENT

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CANDIDATE OF Ph.D OF AGRONOMY

Noorasmah Binti Saupi was born at Kampung Jemoreng, Matu in 1981. She obtained Sijil Pelajaran Malaysia (SPM) from Sekolah Menengah Sains Miri in 1998. In 1999 she graduated with Sijil Matrikulasi and subsequently in 2003, Bachelor of Science (Hons.) in Plant Resource Science and Management from Universiti Malaysia Sarawak. In 2007, she obtained Master of Science in Plant Ecology from Universiti Malaysia Sarawak and the M.Sc. Thesis entitled "Ecology of *Cryptocoryne cordata* var. *zonata* in Sarawak, Malaysia". From July 2008 until present day she is doing her post-graduate study.

Previous academic and other relevant appointments:

Year	**Appointments**
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LIST OF PUBLICATIONS

Journal:

1. **Saupi, N.,** Zakaria, M and Bujang, J.S. 2009. Analytic chemical composition and mineral content of yellow velvetleaf (*Limnocharis flava* L. Buchenau)'s Edible parts. *Journal of Applied Sciences.* 9 (16): 2969-2974.
2. **Noorasmah Saupi**, Muta Harah Zakaria, Japar Sidik Bujang and Aziz Arshad. 2014. Proximate composition and mineral contents of *Neptunia oleracea* Lourerio, an aquatic plant from Malaysia. Emirates Journal of Food and Agriculture. Accepted.

Poster presented:

1. **Noorasmah Saupi**, Muta Harah Zakaria, Japar Sidik Bujang and Aziz Arshad. 2010. Proximate composition of *Neptunia oleracea* Loureiro edible parts. *International Conference on Food Research (ICFR2010): Sustainable and Quality Food for All*. 22-24th November 2010. JW Marriott Putrajaya, Malaysia.

LIST OF CORRECTION

NAME	**:**	NOORASMAH BINTI SAUPI
MATRIC NO.	**:**	GS22324
PROGRAM	**:**	PhD
APPROVED FIELD OF STUDY	**:**	AGRONOMY
FACULTY	**:**	AGRICULTURE AND FOOD SCIENCES (UPMKB)
SUPERVISOR	**:**	PROF. MADYA DR. MUTA HARAH ZAKARIA
SUGGESTED THESIS TITLE	**:**	BIOLOGY OF *Limnocharis flava* (L.) BUCHENAU AND *Neptunia oleracea* LOURERIO AND THEIR STATUS AS VEGETABLE CROPS IN SARAWAK, MALAYSIA

NO.	COMMENTS FROM THE EXAMINATION COMMITTEE	CORRECTIONS MADE	PAGE NO.
1.	**Title:** The title of the thesis should be “Biology of *Limnocharis flava* (L.) Buchenau and their Status as Vegetable Crops in Sarawak”	Biology of *Limnocharis flava* (L.) Buchenau and their Status as Vegetable Crops in Sarawak, Malaysia	
2.	**Abstract:** Abstract is too long and it should be shortened. It should also not have too many speculation	Abstract was shortened.	ii-iii
3.	**List of Abbreviation and Symbols:** Abbreviation for specific terms should be in respective Table/Figure/Plate.	Deleted and specified in Table/Figure/Plate.	
4.	**Chapter 1:** **Grammatical and spelling errors:** a. Aquatic macrophytes are considered as those large plants which grow in excessive amounts in a continuous supply of water or at least present in soils which are covered with water during a major part of the growing season and interfered the intended usage of particular area (Weldon *et al.,* 1973; Edwards, 1980).	a. Aquatic macrophytes are considered as those large plants which grow in excessive amounts in a continuous supply of water or at least present in soils which are covered with water during a major part of the growing season and interfered with the intended usage of particular area (Weldon *et al.,* 1973; Edwards, 1980).	1
	b. The high density and population of aquatic macrophytes and their ability for vegetative growth in drainage systems, ponds, reservoirs and paddy fields can cause problems to the	b. The high density and population of aquatic macrophytes and their ability for vegetative growth in drainage systems, ponds, reservoirs and paddy fields can cause problems to the	1

	human in term of in agriculture sector, human health, hydroelectricity dams, reduced water quality and recreational purposes (Table 1.1).	humans in terms of in agriculture, health, hydroelectricity dams, reduced water quality and recreational purposes (Table 1.1).	
	c. For that reason, many researchers referred aquatic macrophytes as invasive or unwanted to the “aquatic weeds” (Weldon *et al.,* 1973; Edwards, 1980; Said *et al.,* 1991; Mashhor, 1994). One of the best controls of weeds is by utilizing them (Mashhor, 1988).	c. For that reason, many researchers considered aquatic macrophytes as invasive or unwanted and refer to them as “aquatic weeds” (Weldon *et al.,* 1973; Edwards, 1980; Said *et al.,* 1991; Mashhor, 1994).	1
	d. Various reports have been documented on the use of them mainly in waste treatment management, agriculture, foods and paper pulps (Table 1.2).	d. Various reports have been documented on their uses mainly in waste treatment management, agriculture, foods and paper pulps (Table 1.2).	1
	e. A young shoot comprise leaves and petioles and flower cluster or unopened inflorescence are collected, consumed either raw or grilled or cooked for a short time before being eaten (Cook *et al.,* 1974; Edwards, 1980; Kostermans *et al.,* 1987; Voon *et al.,* 1990; van den Bergh, 1994; Rukayah, 2002; Haynes and Les, 2004; Muta Harah *et al.*, 2005; Samy *et al.*, 2005).	e. A young shoot comprising of leaves and petioles and flower cluster or unopened inflorescence are collected, consumed either raw or grilled or cooked for a short time before being eaten (Cook *et al.,* 1974; Edwards, 1980; Kostermans *et al.,* 1987; Voon *et al.,* 1990; van den Bergh, 1994; Rukayah, 2002; Haynes and Les, 2004; Muta Harah *et al.*, 2005; Samy *et al.*, 2005).	8
	f. It is by various names as keman air, keman gajah, kangkung puteri in Peninsular Malaysia and daun tangki in Sarawak (Rukayah, 2002; Halimatul Saadiah, 2003). A plant with bipinate leaves and stems made buoyant by their spongy white covering. The young shoot comprising leaves, spongy stems and young seedpods can be eaten raw and cooked as	f. It is known by various names as keman air, keman gajah, kangkung puteri in Peninsular Malaysia and daun tangki in Sarawak (Rukayah, 2002; Halimatul Saadiah, 2003). A plant has bipinnate leaves and stems made buoyant by their spongy white covering. The young shoot comprising of leaves, spongy stems and young seedpods can be eaten raw	8

	green vegetables (National Academy of Sciences, 1976; Edwards, 1980; Paisooksantivatana, 1994; Rukayah, 2002; Halimatul Saadiah, 2003; Muta Harah *et al*., 2005; Samy *et al*., 2005; Mohd Syahrul, 2009, Dayangku Alifah, 2009; Jain *et al.,* 2011).	and cooked as green vegetables (National Academy of Sciences, 1976; Edwards, 1980; Paisooksantivatana, 1994; Rukayah, 2002; Halimatul Saadiah, 2003; Muta Harah *et al*., 2005; Samy *et al*., 2005; Mohd Syahrul, 2009, Dayangku Alifah, 2009; Jain *et al.,* 2011).	
	g. *Neptunia oleracea* can be harvested after 3 – 4 weeks after planting and 250 shoots are gathered into bunch then traded in local market.	g. *Neptunia oleracea* can be harvested after 3–4 weeks after planting and 250 shoots are gathered into bunch then traded in local market.	9
5.	**Chapter 3:** **3.2 Materials and methods:** Water and soil sample size : "Water from these sites were collected in the bottle and placed into ice chest before being transported to the laboratory to determine the concentration of ortho-phosphate, ammonia, nitrate and nitrite. Soil samples were collected from rooting depth (up to 30 cm) of *L. flava* and *N. oleracea* using plastic auger following the method by Abhilash *et al.* (2008). The samples were then placed in labeled plastic bags for transportation back to the laboratory to determine the concentration of total organic nitrogen and carbon, available macro and micro nutrients."	Five hundred milliliter of water from these sites were collected in the bottle and placed in an ice chest before being transported to the laboratory to determine the concentration of ortho-phosphate, ammonia, nitrate and nitrite. Three replications of water sample were collected from each site. Two kilogram of soil samples were collected from rooting depth (up to 30 cm) of *L. flava* and *N. oleracea* using plastic auger following the method by Abhilash *et al.* (2008). The samples were then placed in labeled plastic bags for transportation back to the laboratory to determine the concentration of total organic nitrogen and carbon, available macro and micro nutrients. Three replications of soil sample were also collected	38

		from each site."	
	3.3 Results and discussion: Symbol of sample number, N.	n	44, 57, 59, 62,
	Use of LSD for mean comparison must be based on LSD value (p≤0.05), and this LSD values must be inserted in each tables for each parameter / variables.	All mean comparison based on LSD values and inserted in each tables.	44, 57, 59, 62
	Alphabetical order a>b>c on water pH of *N. oleracea* habitat in Table 3.7: b, c, a	b>a> c	59
	Grammatical error: most	highest	55
	Each experimental chapter should have a conclusion section.	**3.4 Conclusion**	63
6.	**Chapter 4** **4.3 Results and discussion:** Symbol of sample size, N	n	69, 70
	Use of LSD for mean comparison must be based on LSD value (p≤0.05), and this LSD values must be inserted in each tables for each parameter / variables.	All mean comparison based on LSD values and inserted in each tables.	69, 70
	Each experimental chapter should have a conclusion section.	**4.4 Conclusion**	78, 80

7.	**Chapter 5** **5.3 Results and discussion:** Symbol of sample size, N	n	84, 85
	Use of LSD for mean comparison must be based on LSD value (p≤0.05), and this LSD values must be inserted in each tables for each parameter / variables.	All mean comparison based on LSD values and inserted in each tables.	84, 85
	Each experimental chapter should have a conclusion section.	**5.4 Conclusion**	94
	Number to word: 31 to 58	Thirty one to fifty eight	89
	10	Ten	92
	3 to 4	Three to four	92
	Rephrase: 10 exserted stamens with 4.01 to 6.54 mm long and 0.11 to 0.24 mm width white slender flattened filaments and 0.50 to 1.56 mm long and 0.19 to 0.83 mm width bilocular yellow anther that, lacking a terminal stalked gland (Plate 5.3d).	Ten exserted stamens with 4.01 to 6.54 mm long and 0.11 to 0.24 mm width white slender flattened filaments and 0.50 to 1.56 mm long and 0.19 to 0.83 mm width bilocular yellow anther lacking a terminal stalked gland (Plate 5.3d).	92
8.	**Chapter 6** **6.3 Results and discussion:** Symbol of sample size, N.	n	112, 114, 115, 116, 117, 119,

			121, 122, 125, 126, 128
	The results are sufficiently discussed, but the candidate need to offer some reasons for the results recorded: a. For *N. oleracea* grown from the seed and stem cutting, only NO_3^- is responsible for the increased in plant length with *p* value 0.657 and 0.878 respectively.	a. For *N. oleracea* grown from the seed and stem cutting, only NO_3^- is responsible for the increased in plant length with *p* value 0.657 and 0.878 respectively. The rate of NO_3^- uptake increases during vegetative growth in legume crops (Imsande and Touraine, 1994).	120
	b. The high growth performance on vegetative part was also demonstrated for *N. oleracea* by stem cutting materials. Besides, stem cutting produce high shoot formation and has a tendency to gain more yields. In Thailand, both stem cutting and seed are practiced for cultivation (Paisooksantivatana, 1994). This present study showed the yield is almost ten times higher than in field culture as reported by Paisooksantivatana (1994).	b. The high growth performance on vegetative part was also demonstrated for *N. oleracea* by stem cutting materials. Besides, stem cutting produce high shoot formation and which has a tendency to gain more yields. The plant that frequently cut stimulates development of side shoots (Palada and Crossman, 1999). In Thailand, both stem cutting and seed are practiced for cultivation (Paisooksantivatana, 1994). This present study showed the yield is almost ten times higher than in field culture as reported by Paisooksantivatana (1994) may be attributed to the competition when the plant grow in limited space of tank.	129
	Each experimental chapter should have a conclusion section.	**6.4 Conclusion**	132

9.	**Chapter 7** **6.3 Results and discussion:** Symbol of sample size, N.	n	142, 144, 147, 149, 152, 155, 157
	Use of LSD for mean comparison must be based on LSD value (p≤0.05), and this LSD values must be inserted in each tables for each parameter/variables.	All mean comparison based on LSD values and inserted in each tables.	142,144, 146, 149
	Each experimental chapter should have a conclusion section.	**7.4 Conclusion**	155
10.	**References:** All of the references cited must be correctly taken care as suggested by the examiners. Please refer to their reports:		
	a. Duke (2001) not listed in References	a. Duke, J. A. (2001). *Handbook of edible weeds.* USA: Herbal Reference Library.	168
	b. Shardendu and Ambasht (1991) not listed in References	b. Present but not in sequence after the reference of "Shah, J. J. and James, M. R. (1968). Sieve tube elements in the stem of *Neptunia oleracea* Lour. *Australian Journal of Botany, 16*, 433-444."	177

	c. Reference of Abilash *et al.* (2008) or Abhilash *et al.* (2008)	c. Abhilash *et al.* (2008)	2, 8, 13, 14, 16, 36, 38, 52, 59, 63, 62, 64, 95
	d. Reference of Edwards (1980) or Edward (1980)	d. Edwards (1980)	5, 13, 36, 38
	e. Reference of Koestermans *et al.* (1987) or Kostermans *et al.* (1987)	e. Kostermans *et al.* (1987)	8, 13, 17, 52
	f. Reference of Subba-Rao *et al.* (1995) or Subha-Rao *et al.* (1995)	f. Subba-Rao *et al.* (1995)	17, 87
	g. Reference of Closs *et al.,* 2006 or Closs *et al.*, 2004	g. Closs *et al.*, 2006	1
	h. Reference of Windler (1966) or Windler (1996)	h. Windler (1966)	30
	i. Correction of first author surname of Yi-Ju *et al.* (2007)	i. Chou, Y.J., Elliot, G. N., James, E. K., Lin, K. Y., Chou, J. S., Sheu, S. Y., Sheu, D. S., Sprent, J. I. and Chen, W. M. (2007). *Labrys neptuniae* sp. Nov., isolated from root nodules of the aquatic legume *Neptunia oleracea. International Journal of Systematic and Evolutionary Microbiology, 57,* 577-581.	12, 17, 26, 30, 37, 58, 87
11.	**Spelling of incorrect biological terms:**		
	gymnoecium	gynoecium	77, 78, 92,
	androceium	androecium	92

	hermaphoridite	hermaphrodite	92
	aerhenchyma	aerenchyma	87, 160
	euthropication	eutropication	177
	subratum	substratum	181
	auxiliary	axillary	110, 160
	orthpohosphate	orthophosphate	181
	sysnonym	synonym	80