Sains Malaysiana 40(12)(2011): 1407–1412

Biological and Ethnobotanical Characteristics of Nipa Palm (*Nypa fructicans* Wurmb.): A Review

(Ciri-Ciri Biologi dan Etnobotani Nipah (*Nypa fruticans* Wurmb.) – Suatu Tinjauan)

KOJI TSUJI, MOHD. NOR FAIZAL GHAZALLI, ZULHAIRIL ARIFFIN,
MOHD. SHUKOR NORDIN, MAYA IZAR KHAIDIZAR, MOHAMMAD EHSAN DULLOO & LEOCADIO S. SEBASTIAN*

ABSTRACT

*Nipa (*Nypa fruticans*) is one of the most widely distributed and useful palm in the mangrove forests in the South, Southeast Asia and Oceania. Its distribution area is known to be larger in ancient time than at present, as evidenced by its fossils found in North America, South America, Egypt and Europe. Nipa has a wide diversity of use. Traditionally it is used as roof materials, cigarette wrapper, medicine and its sap is fermented to alcohol. Recently, research on nipa has focused on its potential use as a biofuel crop because it has several advantages compared with other biofuel-alcohol crops. For example it has high alcohol content, no competition with other crop for agricultural land and no bagasse disposal problem. In spite of such usefulness, scientific reports on biology of nipa are limited. Information on genetic diversity, cytogenetics and chemical composition are lacking for nipa plant. On the other hand, morphological characters of nipa have been described in many reports. This paper attempted to provide a general review of the nipa plant based on available literatures.*

Keywords: Biological characteristics; economic aspect; geographical distribution; Nypa fruticans*; traditional utilization*

ABSTRAK

Nipah merupakan sejenis spesies palma yang tumbuh subur di kawasan hutan bakau di Selatan, Asia Tenggara dan Oceania. Pada suatu ketika, spesies nipah telah ditemui di kawasan taburan yang luas, dan ini dibuktikan dengan penemuan fosilnya di Amerika Utara, Amerika Selatan, Mesir dan Eropah. Nipah mempunyai pelbagai kegunaan dalam amalan masyarakat tradisi seperti penggunaan daunnya sebagai atap rumah, pembalut rokok dan perubatan tradisi serta bahan api biologi yang terhasil daripada penapaian niranya. Penyelidikan spesies nipah kini lebih tertumpu kepada potensinya sebagai tanaman bahan api biologi kerana pelbagai kelebihan seperti kandungan alkohol dalam niranya yang tinggi, kurangnya persaingan penggunaan tanah pertanian dengan tanaman lain dan tiada sisa hampas untuk dilupuskan. Di sebalik pelbagai kebaikan dan potensi spesies ini, laporan saintifik mengenainya masih kurang diterbitkan. Maklumat mengenai kepelbagaian, sitogenetik dan komposisi kimia nipah juga masih kurang dilaporkan. Namun demikian, terdapat banyak laporan yang menerangkan maklumat morfologi nipah. Kertas ini memaparkan tinjauan dan pandangan umum mengenai spesies nipah berdasarkan daripada laporan lain.

Kata kunci: Aspek ekonomi; ciri biologi; kegunaan tradisi; Nypa fruticans*; taburan geografi*

INTRODUCTION

One of the most common, widely distributed, and useful palms in the mangrove forests of Southeast Asia is nipa (*Nypa fruticans* Wurmb.). Nipa is utilized for various traditional purposes in this region and is known by different vernacular names such as “chak” and “at-ta” in Thailand, “dua la” and “dua muoc” in Vietnam, “dani” in Myanmar and “atap palm” in Singapore (Baja-Lapis et al. 2004). Nipa is also a useful source of biofuel because it produces a high amount of sap that can be converted to alcohol. It can produce more ethanol than sugar cane (6,480-10,224 L/hectare/year vs 3,350-6,700 L/hectare/year) (Hamilton & Murphy 1988). In addition, nipa is useful agriculturally and ecologically because its habitat does not compete with food crops and its growth is sustainable. Recently, Malaysian scientists realized the usefulness of nipa again and strategies for effective management of nipa were proposed (Latiff 2008).

In spite of such usefulness, there is in general a lack of scientific reports on nipa compared with other useful tropical palms such as coconut and oil palm. Many years has already passed since publication of useful scientific reviews on nipa (Hamilton & Murphy 1988; Päiväke 1996). In this review, we described the biological characters, geographic distribution, traditional utilization, economic aspects and the advantages of nipa as a crop by citing recent reports in addition to Hamilton and Murphy (1988) and Päiväke (1996).

BIOLOGICAL CHARACTERS

TAXONOMIC INFORMATION

Nipa (*Nypa fruticans*) belongs to the family Palmae (Burkill 1935; Corner 1966; Gee 2001; Jian et al. 2010; Uhl & Dransfeld 1987) or Arecaceae (Gee 2001; Hamilton & Murphy 1988). The genus *Nypa* has been placed in its own subfamily, the Nypoideae (Moore 1973; Uhl & Dransfeld 1987; Whitmore 1973) and is the sole species in genus *Nypa* (Jian et al. 2010).

Studies on phylogenetic relationship among species indicated the species genetically related to nipa include *Calamus caesius* (Palmae) and *Mauritia flexuosa* (Palmae) based on sequences on *atp*B, *ndh*F, *rbc*L, *trn*Q-*rps*16, *trn*D-*trn*T (Hahn 2002); *Aegialitis annulata* (Plumbaginaceae) based on sequences on 18S rDNA, *mat*R, *rbc*L (Shi et al. 2005); and *Orontium aquaticum* (Araceae) and *Tofieldia glutinosa* (Tofieldiaceae) based on sequences on *mat*K, *trn*T-F, *rbc*L (Müller et al. 2006).

CYTOGENETIC INFORMATION

Chromosome number of nipa is not yet clear (Päiväke, 1996). Corner (1966) reported that nipa has a diploid chromosome number of 16 (n=8) while Moore (1973) reported 34 chromosomes (n=17). Further cytogenetic study on nipa is needed to explain the variation in reported chromosome numbers.

HABITAT

Nipa is sometimes called "the mangrove palm" because it thrives well in the mangrove environment, favoring brackish water environments such as estuaries or shallow lagoons (Baja-Lapis et al. 2004; Corner 1966; Tomlinson 1986; Whitmore 1973). Nipa also colonizes the upper tidal reaches of rivers (Whitmore 1973), semi-liquid mud of estuaries (Baja-Lapis et al. 2004; Burkill 1935; Corner 1966) and along coastlines (Tomlinson 1986).

MORPHOLOGICAL CHARACTERS

The morphology of nipa has been described by many authors: Arnold (1952), Baja-Lapis et al. (2004), Collinson (1993), Corner (1966), Moore (1973), Päiväke (1996), Tomlinson (1986), Whitmore (1973). Baja-Lapis et al. (2004) described the morphological characters of nipa as follows. Nipa grows in clusters, often forming large colonies and without visible stems above the ground. The underground stem called rhizome lies horizontally underneath the ground and reaches to about half a meter long. At the end of the growing rhizome, a new plant rises adding to the cluster in the colony. The leaves called fronds are large feather-like in appearance, sometimes reaching more than 7 meters long with the mature fronds usually leaning away from the centre of the growing plant. The leaflets progressively become shorter towards the stalk and the top of the frond. The arrangement of the flowers in the floral axis (inflorescence) has erect and stout stalk with a large orange colored sheath (called spathe), which is olive green at the top. The stalk ends with a cluster of female flowers which are enclosed by gold colored leaf-like structure (called bracts), and the sides with club-shaped unstalked spikes of male flowers. Both male and female flowers are yellow, the males in thick spikes and the females with large head. The cluster of fruits is more or less the size of a human head with about 20-30 cm in diameter, supported by a thick stalk, dark brown colour when fresh. The individual one-seeded woody fruit breaks when ripe. The seeds which usually germinate naturally while floating on the water in the swamps establish themselves in the mud flats and along muddy banks.

Two reports mentioned morphological diversity of nipa in Malaysia. The Malaysians recognized two varieties, which they call 'nipah gala' and 'nipah padi', differing in the position of the leaflets (Burkill 1935; Päiväke 1996). This information is partially supported by our ethnobotanical data collected in 2009. A villager in Perak, Malaysia recognized three types of nipa called 'padi', 'sawa' and 'tikus'. Based on tilt of leaflet, Corner (1966) reported two kinds of nipa in Malaysia. These reports suggest that the nipa populations in Malaysia may consist of more than two morphological types.

GENETIC DIVERSITY

There are only a few reports on genetic diversity of nipa populations. Jian et al. (2010) analyzed the samples collected from China, Thailand and Vietnam by using SSR and ISSR markers. Low genetic diversity was detected among these samples. Setoguchi et al. (1999) analyzed the samples collected from Funaura and Iriomote island in Japan by using RAPD marker. They concluded that the populations examined consist of clones derived from a single individual by vegetative propagation because of their low genetic diversity.

CHEMICAL COMPOUNDS

There is very little report on the chemical constitution in nipa plant. Tannin was reported by Burkill (1935) and Fong (1992). Tannin is located mainly in the leaves to the extent of 10%, though the quality of it is not good (Burkill 1935). A survey of useful chemical compounds in nipa plant is needed.

In the floral scent, 25 chemical compounds were detected by Azuma et al. (2002). These chemical compounds consist of fatty acid derivatives, terpenoids, carotenoid derivatives, benzenoids and unknown compounds.

PESTS AND DISEASES

One species of *Plesispa*, named *P. nipae* Maulik have been reported to cause damage to nipa (Corbett 1932; Sivapragasam & Hong 2007). In addition, rats in Papua New Guinea (Päiväke 1996) and monkeys and pigs in northern Borneo (Päiväke 1996; Wood 1925) may damage young seedlings.

Geographic Distribution

GEOGRAPHICAL DISTRIBUTION AT PRESENT TIME

Nipa is widely distributed. The distribution ranges from Sri Lanka, the Ganges Delta, Myanmar, and to the Malay Peninsula, through Indonesia, Papua New Guinea and the Solomon Islands, and up north in the Philippines and down south in northern Queensland (Tomlinson 1986; Baja-Lapis et al. 2004; Corner 1966; Gee 2001; Päiväke 1996; Saenger et al. 1983; Whitmore 1973) Local information about nipa is plentiful in these regions, e.g. in Australia (Bunt et al. 1982; Covacevich 1981), Indonesia (Johannes 1979; Samingan 1980), Papua New Guinea (Pajimans & Rollet 1977; Percival & Womersley 1975), Philippines (Agaloos & Nepomuceno 1977; Gonzales, 1979), Thailand (Aksornkoae 1976; Changprai 1984), Malaysia (Burkill 1935; Fong 1984; Whitmore 1973), India (Anonymous 1966; Thothathri 1980), Bangladesh (Khan & Karim 1982), Vietnam (Fong 1984; Moore 1973), Sri Lanka (Fong 1984; Moore 1973), Myanmar (Fong 1984; Moore 1973), Carolines (Fong 1984; Moore 1973), Ryukus (Fong 1984; Moore 1973) and Solomons (Fong 1984; Moore 1973).

Nipa was introduced into West Africa in 1906 (Päiväke 1996; Saenger et al. 1983) and since then it has been well established, co-existing with native mangroves in Southeastern Nigeria (Moses 2000; Ukpong 1997).

GEOGRAPHIC DISTRIBUTION IN ANCIENT TIME

Nipa is one of the earliest angiosperms assignable to a modern genus; it is thus also one of the oldest palms and one of the first monocots in the fossil plant record (Muller 1981; Päiväke 1996). The fossils of 100 million years old have been found from the Cretaceous period of Borneo which resembles exactly the living species (Whitmore 1973). Nipa most likely made its first appearance in the New World over 74 million years ago (Gee 2001). The maximum expansion of the biogeographical distribution of nipa in earth's history corresponds with the climatic optimum of the Cenozoic period during the early Eocene era (Gee 2001). Nipa ranged as far north as present-day southern England which was at a paleolatitude of roughly 45°N during the Eocene (Ziegler 1990) and as far south as the southernmost coastlines of what is today Tasmania, the most polar occurrence of this palm at a paleolatitude of about 65°S (Pole & Macphhail 1996).

According to the fossil records of pollens and fruits, the past distribution area of nipa was wider than that at present. Nipa was found in North America (Corner 1966; Fong 1984; Frederinksen 1980, 1988; Gee 2001; Germeraad et al. 1968; Graham 1995), South America and particularly Brazil (Corner 1966; Fong 1984; Gee 2001; Tralau 1964; Whitmore 1973), Europe (Fong 1984; Tralau 1964) especially in southern England (Whitmore 1973; Ziegler 1990), Egypt (Schrank 1987), West Africa (Fong 1984; Tralau 1964; Whitmore 1973), India (Corner 1966; Fong 1984), Borneo (Corner 1966; Fong 1984; Whitmore 1973), and Tasmania (Pole & Macphhail 1996).

TRADITIONAL UTILIZATION

Nipa has historically provided useful products to indigenous peoples living near or in the coastal and estuarine mangrove forests. (Hamilton & Murphy 1988; Päiväke 1996).

MATURED LEAVES

Matured leaves have been used for roof thatching (Baja-Lapis et al. 2004; Burkill 1935; Fong 1984, 1992; Hamilton & Murphy 1988; Ilias et al. 2002; Päiväke 1996), Robillos 1978), wall-partitioning of dwellings (Baja-Lapis et al. 2004; Burkill 1935; Fong 1984; Hamilton & Murphy 1988; Robillos 1978), roof of boat (Burkill 1935), umbrella (Burkill 1935; Fong 1984; Robinson 1911), sun-hat (Burkill 1935; Fong 1984, 1992; Päiväke 1996; Robinson 1911), rain-coat (Burkill 1935; Fong 1984; Robinson 1911), basket (Baja-Lapis et al. 2004; Burkill 1935; Fong 1984, 1992; Päiväke 1996; Robinson 1911), mat (Baja-Lapis et al. 2004; Burkill 1935; Fong 1992; Päiväke 1996; Robinson 1911), bags (Burkill 1935; Fong 1992; Robinson 1911). Shingle thatch industry is locally a very important source of revenue (Hamilton & Murphy 1988).

YOUNG LEAVES

Young leaves are made into cigarette wrappers (Baja-Lapis et al. 2004; Burkill 1935; Fong 1984, 1992; Päiväke 1996; Robinson 1911). Young leaves also are used to wrap cooked rice (Fong 1992).

PETIOLES

Petioles are used for floats for fishnets (Fong 1984, 1992), arrows (Burkill 1935). They are also chopped and boiled to obtain salt (Browne 1955).

MAIN AXES

Main axes are used for fishing poles (Fong 1984, 1992).

LEAFLET MIDRIBS

Leaflet midribs are used as brooms (Fong 1992), and can be soaked in water and twisted as ropes (Fong 1984).

DRIED PETIOLES AND STALKS

Dried petioles and stalks are used as firewood (Brown 1951; Burkill 1935) and in rare cases, are made into brooms (Burkill 1935).

OUTER LAYERS OF THE LEAF-STALK

Outer layers of the leaf-stalk yield pulps suitable for making good-quality boards of intermediate density (Razzaque 1969).

YOUNG SEEDS

Young seeds are edible (Burkill 1935; Hamilton & Murphy 1988; Whitmore 1973). They are utilized as food in the form of sweetmeat (Fong 1984) and snack (Päiväke 1996). They are also used to flavor a commercial ice cream "attap chi" and local ice confections in Malaysia (Hamilton & Murphy 1988).

MATURED SEEDS

Matured seeds are hard enough to have been thought of as a material for buttons (Burkill 1935; Fong 1984; Päiväke 1996; Whitmore 1973) but that was in the days before the advent of cheap plastics (Whitmore 1973).

BUDS AND PETALS

Buds of the stem are also edible (Burkill 1935). Petals of the flowers are used as aromatic tea (Baja-Lapis et al. 2004).

YOUNG SHOOTS, DECAYED WOODS, ROOTS OR LEAVES

These parts are sometimes used for medicinal purposes. One of the traditional prescriptions for treating herpes is drinking the juice from a young shoot with coconut milk (Burkill 1935). The juice is used against herpes (Päiväke 1996). Though the target disease is not described, decayed woods are also medicinal in Borneo (Burkill 1935). By burning the roots or leaves and lixiviating the ash, salt may be obtained. This ash "garam nipah", is used medicinally in Borneo for tooth-ache and head-ache (Burkill 1935; Päiväke 1996).

SAP

Nipa yields abundant sap from the cut stalks of fully developed inflorescences or young inflorescences after the floral or fruit heads have been removed (Fong 1992; Hamilton & Murphy 1988; Päiväke 1996). Prior to the cutting, the stalk of the inflorescence is beaten repeatedly for days (Fong 1984). Beating the young inflorescence induces higher sap yield (Whitmore 1973). Kicking the base of the stalk is also traditional practice to induce higher sap yield (Cole 1922; Hamilton & Murphy 1988) and the yield is influenced by frequency of treatment (Päiväke 1985).

The sap has been utilized as a material of treacle (Päiväke 1996), amorphous (Päiväke 1996) and for producing vinegar (Baja-Lapis et al. 2004; Burkill 1935; Hamilton & Murphy 1988; Päiväke 1996), alcohol that is used as biofuel (Hamilton & Murphy 1988; Päiväke 1996) and distilled or fermented beverage called "tuba" or "soom" in the Philippines, "arak" or "tuak" in Indonesia, "toddy" in Malaysia, India, Bangladesh (Hamilton & Murphy 1988; Päiväke 1996). The sap is also used to feed pigs especially during lean time in Indonesia (Baja-Lapis et al. 2004).

ECONOMIC ASPECT AND ADVANTAGES

FUEL-ALCOHOL PRODUCTION

Nipa is able to produce higher yields alcohol compared with other crops: nipa by traditional management 6,480-10,224 L/hectare/year, sugarcane 3,3506,700 L/hectare/year, cassava 3,240-8,640 L/hectare/year, sweet potato 6,750-18,000 L/hectare/year, coconut sap 5,000 L/hectare/year (Hamilton & Murphy 1988). The amount of alcohol is expected to increase up to 18,165 L by modern management (Halos 1981), making nipa an attractive potential source of biofiel.

Before the World War II, Malaysia dealt with the manufacture of alcohol out of nipa, which was used as fuel for vehicles (Baja-Lapis et al. 2004). The plantation in Malaysia, the only real commercial plantation in the world before World War II, produced close to 15,600 L/hectare/year (Dennett 1927). Making industrial alcohol from nipa was also an important industry in the Philippines in the early decades of 20 century (Whitmore 1973). However, the industry was short-lived due to political problems and competitive price of gasoline prevailed during that period (Fong 1984; Whitmore 1973).

The utilization and study on alcohol form nipa continued modestly until the middle of 20th century. Two factories produced alcohol from nipa in Sarawak, Malaysia (Chai & Lai 1984) up to the 1980's. During the same time, similar studies were carried out in the Philippines (Halos 1981) and in Papua New Guinea (Newcombe et al. 1980). At present time, considering the focus on biofuel as future energy source, it is expected that the utilization and study of alcohol from nipa become a focus once again.

OTHER ADVANTAGES

In addition to growing nipa for its alcohol, there are other advantages of growing nipa. First, continuous productivity of nipa means no displaced labour, which is one of major problem in sugarcane ecosystem (Hamilton & Murphy 1988). Second, production of nipa is not interrupted by replanting and rotation (Hamilton &Murphy 1988). Third, there is no bagasse disposal problem (Hamilton &Murphy 1988). Fourth, nipa does not compete with other crops for agricultural land except where total reclamation is undertaken on mangrove land (Hamilton &Murphy 1988). Fifth, capability of nipa shoot biomass as a potential adsorbent for removing and recovering heavy metal ions such as Pb^{2+} and Cu^{2+} from aqueous solution was also reported (Wan Ngah & Hanafiah 2008; Wankasi et al. 2006).

ACKNOWLEDGMENT

This study was accomplished during the Japan-CGIAR fellowship program of Dr. Koji Tsuji. We are most grateful for the financial support provided by the fellowship program and to the two host institutions, Bioversity

International and Malaysian Agricultural Research and Development Institute (MARDI).

REFERENCES

Agaloos, L.C. & Nepomuceon, P.M. 1977. Ecology of Calauit Island. *Sylvatrop* 2: 163-178.

Aksornkoae, S. 1976. Structure of mangrove forest at Amphoe Khlung Changwat Chantaburi, Thailand. *Forest Res. Bull.* 38, Faculty of Forestry, Kasetsart University (Bangkok).

Anon. 1966. *Nypa* Wurmb. In *The Wealth of India: Raw Materials*, vol. 7. pp. 73-74. (New Delhi). Publications and Information Directorate.

Arnold, C.A. 1952. Tertiary plants from North America 1: A *Nypa* fruit from the Eocene of Texas. *The Palaeobotanist* 1: 73-74.

Azuma, H., Toyota, M., Asakawa, Y., Takaso, T. & Tobe, H. 2002. Floral scent chemistry of mangrove plants. *J. Plant. Res.* 115: 47-53.

Baja-Lapis, A.C., David, M.E., Reyes, C.G. & Audije, B.S. 2004. *ASEAN's 100 Most Precious Plants*. The European Commision (Philippines).

Brown, W.H. 1951. Useful plants of the Philippines. *Techn. Bull.*, vol I. Dept. Agric. and Nat. Resources 10. (Manila).

Browne, F.G. 1955. *Forest trees of Sarawak and Brunei*. Kuching. Gov. Printing Office.

Bunt, J.S., Williams, W.T. & Clay, H.J. 1982. River water salinity and distribution of mangrove species along several rivers in North Queenslands, Australia. *Austral. J. Bot.* 30: 401-412.

Burkill, I.H. 1935. *Nipa*. In *A Dictionary of the Economic Products of the Malay Peninsula*, vol. II. pp. 1557-1561. (London). Crown Agents for the Colonies.

Chai, P.K. & Lai, K.K. 1984. Management and utilization of the mangrove forests of Sarawak. In *Proc. Asian Symposium on Mangrove Environment: Research and Management*, edited by Soepadmo, E. pp. 785-795. August 1980, Univ. Malaya, Kuala Lumpur.

Changperai, C. 1984. Mangrove soil and their utilization in Thailand. In *Proc. Asian Symposium on Mangrove Environment: Research and Management*, edited by Soepadmo, E. pp. 521-533. August 1980, Univ. Malaya, Kuala Lumpur.

Cole, H.I. 1922. Manufacture of industrial alcohol and alcohol motor fuel in the Philippine Islands. *Philipp. J. Sci.* 21: 17-46.

Collinson, M.E. 1993. Taphonomy and fruiting biology of recent and fossil *Nypa*. *Spec. Papers Palaeontol.* 49: 165-180.

Corbett, G.H. 1932. *Insects of coconut in Malaya*, General series No. 10. Department of Agriculture. Straits Settlements and Federated Malay States

Corner, E.J.H. 1966. *The Natural History of Palms*. London: Weidenfeld and Nicholson.

Covacevich, J. 1981. Distribution of the *Nypa* palm in Australia (*Nypa fruticans*). *Principes* 25: 184-188.

Dennett, J.H. 1927. Final observations on the nipah palm as a source of alcohol. *Malayan Agric. J.* 15: 420-432.

Fong, F.W. 1984. Nipa swamps-a neglected mangrove resource. In: *Proc. Asian Symposium on Mangrove Environment: Research and Management*, edited by Soepadmo, E. pp. 663-671. August 1980, Univ. Malaya, Kuala Lumpur.

Fong, F.W. 1992. Perspective for sustainable resource utilization and management of nipa vegetation. *Economic Botany* 46: 45-54.

Frederinksen, N.O. 1980. Sporomorphs from the Jackson Group (upper Eocene) and adjacent strata of Mississippi and western Alabama. *U.S. Geol. Surv. Prof. Paper* 1084: 1-75 + 16 pls.

Frederinksen, N.O. 1988. Sporomorph biostratigraphy, floral changes, and paleoclimatology, Eocene and earliest Oligocene of the eastern Gulf Coast. *U.S. Geol. Surv. Prof. Paper* 1448: 1-64 + 16 pls.

Gee, C.T. 2001. The mangrove palm *Nypa* in the geologic past of the New World. *Wetlands Ecology and Management* 9: 181-194.

Germeraad, J.H., Hopping, C.A. & Muller, J. 1968. Palynology of Tertiary sediments from tropical areas. *Rev. Palaeobot. Palynol.* 6: 189-348.

Gonzales, L.L. 1979. Nipa and its innumerable uses. *Canopy* 7: 9.

Graham, A. 1995. Diversification of Gulf/Caribbean mangrove communities through Cenozoic time. *Biotropica* 27: 20-27.

Hahn, W.J. 2002. A phylogenetic analysis of the Arecoid Line of palms based on plastid DNA sequence data. *Molecular Phylogenetics and Evolution* 23: 189-204.

Halos, S.C. 1981. Nipa for alcogas production. *Canopy* 7: 15.

Hamilton, L.S. & Murphy, D.H. 1988. Use and management of nipa palm (*Nypa fruticans*, Arecaceae) : a review. *Economic Botany* 42: 206-213.

Ilias, G.N.M., Rahman, M.A., Hannan, M.O., Feroz, S.M. & Abdullah, F. 2002. Study on CCB (Chromated Copper Boric Acid) dip preservation of Golpata (*Nypa fruticans*). *Pertanika J. Sci. Technol.* 10: 201-208.

Jian, S., Ban, J., Ren, H. & Yan, H. 2010. Low genetic variation detected within the widespread mangrove species *Nypa fruticans* (Palmae) from Southeast Asia. *Aquatic Botany* 92. 23-27.

Johannes, H. 1979. *Pangan dan bensin dari nipah dan sagu serta bensin dari enceng gondok*. Bull. Fak. Kehutanan. Yogyakarta: Univ. Gadjah Mada, No. 10.

Khan, M.S. & Karim, A. 1982. Bangladesh: utilization of the deltaic zone. In *Man, Land, and Sea,* edited by Soysa, C., L.S. Chai & W.H. Collier. pp. 85-102. Agricultural Development Council (Bangkok).

Latiff, A. 2008. Malaysian nipah: an appraisal of its scientific, economic potential and future. In *Prosiding Seminar Pengurusan dan Pemuliharaan Nipah 2008*. pp. 49-58. February 2008, Hotel Vistana, Pulau Pinang.

Moore, H.E. 1973. The major groups of palms and their distribution. *Gentes Herbarum* 11: 27-141.

Moses, B.S. 2000. A review of artisanal marine and brackishwater fisheries of south-eastern Nigeria. *Fisheries Research* 47: 81-92.

Muller, J. 1981. Fossil pollen records of extract angiosperms. *Bot. Rev.* 47: 1-142.

Müller, K.F., Borsch, T. & Hilu, K.W. 2006. Phylogenetic utility of rapidly evolving DNA at high taxonomical levels : Constructing *mat*K, *trn*T-F and *rbc*L in basal angiosperms. *Molecular Phylogenetics and Evolution* 41: 99-117.

Newcombe, K., Holmes, E.B. & Päiväke, A. 1980. Palm energy. Alcohol fuel from the sago and nipa palms of Papua New Guinea. *Energy Planning Unit Rep. 6*. Dept. of Minerals and Energy (Papua New Guinea).

Pajimans, K. & Rollet, B. 1977. The mangroves of Gally Reach, Papua New Guinea. *Forest Ecol. and Management* 1: 119-140.

Päiväke, A.E.A. 1985. Tapping practices and sap yields of the nipa palm (*Nypa fruticans*) in Papua New Guinea. *Agric. Ecosyst. Environ.* 131: 59-72.

Päiväke, A.E.A. 1996. In *Plant resource of south-east Asia No. 9: Plant yielding non-seed carbohydrates*, edited by Flach M. & Rumawas ed. pp. 133-137. (Prosea Foundation (Indonesia).

Percival, M. & Womersley, J.S. 1975. *Floristics and Ecology of the Mangrove Vegetation of Papua New Guiena*. Bot. Bull. Division of Botany, Dept. of Forests (Papua New Guinea).

Pole, M.S. & Macphail, M.K. 1996. Eocene *Nypa* from Regatta Point, Tasmania. *Rev. Palaeobot. Palynol.* 92: 55-67.

Razzaque, M.A. 1969. Manufacture of insulation-type boards from golpata and rice-stalk. *Forest-Dale News* 2: 50-57.

Robillos, Y.U. 1978. The nipa shingle industry of Batangas. *Forpride Digest* 7: 58-66.

Robinson, C.B. 1911. Philippine hat. *Philipp. J. Sci. Series* C 6: 93-129.

Saenger, P., Hegerl, E.J. & Davis, J.D.S. (ed). 1983. Global status of mangrove ecosystems. *Commission on Ecology Papers* No. 3. Int. Union for Cons. Nature and Nat. Resources, Gland (Switzerland).

Samingan, M.T. 1980. Notes on the vegetation of the tidal areas of South Sumatra, Indonesia, with special reference to Karang Agung. In *Proc. Vth Int. Symposium of Tropical Ecology*, edited by Furtado, J. pp. 1107-1112. International Society of Tropical Ecology, Kuala Lumpur.

Schrank, E. 1987. Palaeozoic and Mesozoic palynomorphs from northeastern Africa (Egypt and Sudan) with special reference to Late Cretaceous pollen and dinoflagellates. *Berl. geowissensch. Abh., R. A.* 75: 249-310.

Setoguchi, H., Watanabe, K., Takaso, T., Nakazato, N. & Tobe, H. 1999. Genetic diversity of the natural monument *Nypa fruticans* (Palmae) at Funaura, Iriomote Island. *Acta Geobot. Phytotax.* 50: 201-205.

Shi, S., Huang, Y., Zeng, K., Tan, F., He, H., Huang, J. & Fu, Y. 2005. Molecular phylogenetic analysis of mangroves: independent evolutionary origins of vivipary and salt secretion. *Molecular Phylogenetics and Evolution* 34: 159-166.

Sivapragasam, A & Hong, L.W. 2007. *Plesispa reichi*: a pest of increasing importance in Malaysia. In: *Developing an Asia-Pacific Strategy for Forest Invasive Species: The Coconut Beetle Problem-Bridging Agriculture and Forestry*, edited by Appanah, S., H. C. Sim & K. V. Sankaran. pp. 55-62. FAO Regional office for Asia and the Pacific (Bangkok).

Thothathri, K. 1980. Plant resources and their utilization in the Andaman and Nicabar islands, India. *J. Econ. Taxon. Bot.* 1: 111-114.

Tomlinson, P.B. 1986. *The Botany of Mangroves*. Cambridge: Cambridge University Press.

Tralau, H. 1964. The genus *Nypa* van Wurmb. *Kongl. Svenska Vetenskapsakad. Handl.* IV. 10: 1-29.

Uhl, N.W. & Dransfield, J. 1987. *Genera Palmarum.* (Kansas): Allen Press, Lawrence. Whitmore, T.C. 1973. *Palms of Malaysia* London: Oxford University Press.

Ukpong, I.E. 1997. Mangrove swamp at a saline/fresh water interface near Creek Town, Southeastern Nigeria. *Catena* 29: 61-71.

Wan Ngah, W.S. & Hanafiah, M.A.K.M. 2008. Removal of heavy metal from wastewater by chemically modified plant wastes as adsorbents: A Review. *J. Bioresource Technology* 99: 3948-3948.

Wankasi, D., Horsfall Jr., M. & Spiff, A.I. 2006. Sorption kinetics of $Pb^{2+}$and Cu^{2+} ions from aqueous solution by Nipah palm (*Nypa fruticans* Wurmb) shoot biomass. *Elec. J. Biotechnol.* 9: 587-592.

Wood, D.D. 1925. The production of alcohol for motor fuel from the nipa palm in North Borneo. *Bull. Imp. Inst. Gr. Brit.* 23: 175-181.

Ziegler, P.A. 1990. *Geological Atlas of Western and Central Europe*, 2nd and revised edition. Shell Internationale Petroleum Maatschappij B.V., The Hague, 237 pp. + 56 encls.

Koji Tsuji & Leocadio S. Sebastian*
Bioversity International Regional Office for Asia
The Pacific and Oceania, P.O. Box 236
UPM Post Office, Serdang
43400 Selangor D.E.
Malaysia

Mohd. Nor Faizal Ghazalli, Zulhairil Ariffin, Mohd. Shukor Nordin & Maya Izar Khaidizar
Strategic Resources Research Center
Malaysian Agricultural and Development Institute
P.O. Box 12301, General Post Office
50774 Kuala Lumpur
Malaysia

Mohammad Ehsan Dulloo
Bioversity International Headquarters
Via dei Tre Denari 472/a
00057 Maccarese Rome, Italy

*Corresponding author; email: l.sebastian@cgiar.org

Received: 7 July 2010
Accepted: 11 November 2010