Faculty of Resource Science and Technology

Systematic study of the genus *Paracostus* C. D. Specht (Costaceae) from Northern West of Sarawak: Leaf Morphological and Anatomical Aspects

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Bachelor of Science with Honours
(Plant Resources Science and Management)
2017

UNIVERSITI MALAYSIA SARAWAK

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Masters	
PhD	

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Systematic study of the genus *Paracostus* C. D. Specht (Costaceae) from Northern West of Sarawak: Leaf Morphological and Anatomical Aspects

Nabilah Syakirah Binti Mohd Ali (49837)

This report submitted in partial fulfillment of the requirement for the degree of

Bachelor of Science with Honours

(Plant Resource Science and Management)

Plant Resource Science and Management Programme

Faculty Resource Science and Technology

Universiti Malaysia Sarawak

2017

APPROVAL

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June, 2017

ACKNOWLEDGEMENTS

Bismillahirrahmanirrahim, first and foremost all the praises to Allah S.W.T., peace and blessings be upon the Prophet of mercy, Muhammad and His companions. Alhamdulillah with Allah s.w.t permission, I manage to complete my final year project paper. Thus through this acknowledgements I would like to express my gratitude to people involved and help me during this project.

A special thanks to my supervisor, Dr. Qammil Muzzammil Abdullah @ Meekiong Kalu, for given me the opportunity to conduct this project and all the advice, patient, encouragement, help and guidance in order for me to complete this project.

Thanks also to the Post Graduate student, Aimi Syazana and Nur Syauqina Syasya, my bestfriend Nur Ismaniza, my lab mate Nur Azieya, Gloria Rinya, Nur Amanina, Muslihah and Nurul Izzati and many more that help and guide me during the entire lab and field work.

To the most important person in my life, my father Mohd Ali Bin Jamaluddin, my mother, Siti Zaharah binti Wahab, my siblings Muhammad Abbas, NurHilal and Aqilah thank you for all your endless love, advice and support all this time. Not to forget Muhammad Luqman who always help and give advice and moral supports to me.

Thanks to all the support and help that I have gain throughout this project that become an inspiration for me to complete this Final Year Project.

Thank you all

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GPS	Global Position System
HUMS	Herbarium of Universiti Malaysia Sarawak
SAR	Herbarium of Sarawak Forest Department

Systematic study of the genus *Paracostus* C. D. Specht (Costaceae) from Northern West of Sarawak: Leaf Morphological and Anatomical aspects

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ABSTRACT

Genus *Paracostus C.* D. Specht & W. J. Stevenson is from the family of Costaceae and commonly known as Spiral Ginger. Previously treated as *Costus,* this genus is restricted to Africa and Borneo. There are about five described species and estimated 7-8 species are distributed in Sarawak. Among this species, they shared several characteristics and only can be distinguish based on the floral character. Thus *P. paradoxus, P. eburneus, P. bullatus* and one undescribed species of *Paracostus* were selected for this study to examine the differences between the species via leaf morphological and anatomical aspects. Morphological characteristics were determined based on observations of the fresh sample. As for the anatomical study, the leaves were observed based on the Light microscope compound. The types of stomata on the adaxial and abaxial were differ within the species. As for the *P. bullatus,* the adaxial; staurocyctic, abaxial; anomocyctic, cyclocyctic and staurocyctic, *P. eburneus,* the adaxial and abaxial are same; cyclocyctic, parahexacytic-monopolar and staurocyctic, *P. paradoxus* stomata only can be observed on the abaxial layers which are anomocyctic, cyclocyctic and staurocyctic and *Paracostus sp*. both abaxial and adaxial are same which are; anomocyctic and staurocyctic. As for the petiole, the differences can be seen through the arrangement of the vascular bundle and total average number of vascular bundle. Both *P. eburneus, P. bullatus* have semi U-shape with trichrome present while *P. paradoxus* and *Paracostus* sp. have slightly V-shape with trichrome present on *Paracostus* sp. but absent for *P. paradoxus*. Total number of vascular bundle of *P. eburneus* is 23, *P. bullatus* is 20, *P. paradoxus* is 35 and *Paracostus* sp. is 20. Identification of the *Paracostus* species can be determined by the morphological and anatomical aspect.

Key words: Costaceae, Northern West of Sarawak, *Paracostus*, Petiole, Stomata

ABSTRAK

Genus Paracostus C. D. Specht adalah dari keluarga Costaceae dan dikenali sebagai Spiral Ginger. Sebelum ini genus Paracostus digelar sebagai Costus dan terdapat di sekitar Africa dan Borneo.Terdapat lima spesies Paracostus yang direkodkan dan diangarkan 7-8 spesies berada di Sarawak. Diantara spesies ini, mereka mempunyai persamaan dalam beberapa ciri dan hanya boleh di bezakan berdasarkan watak bunga. Oleh itu P. paradoxus, P. eburneus, P. bullatus dan satu spesis baru daripada Paracostus telah dipilih untuk menkaji perbezaan antara spesies melalui aspek morfologi dan anatomi. Ciri morfologi ditentukan berdasarkan pemerhatian sampel segar. Bagi kajian anatomi, sample didiperhatikan di bawah kompaun mikroskop cahaya. Jenis stomata pada adaxial dan abaxial adalah berbeza dalam setiap spesies. Stomata bagi P.bullatus di adaxial adalah staurocytic, abaxial; anomocyctic, cyclocyctic dan staurocyctic manakala P. eburneus, mempunyai jenis stomata yang sama di adaxial dan abaxial; cyclocyctic, parahexacytic-monopolar dan staurocyctic, P. paradoxus stomata hanya boleh diperhatikan pada lapisan abaxial sahaja iaitu anomocyctic, cyclocyctic dan staurocyctic dan Paracostus sp. kedua-dua abaxial dan adaxial adalah sama iaitu; anomocyctic dan staurocyctic. Bagi batang daun, perbezaan dapat dilihat melalui susunan berkas vaskular dan jumlah purata bilangan berkas vaskular. Kedua-dua P.eburneus, P. bullatus mempunyai separa U bentuk dan ada trichrome manakala P.paradoxus dan Paracostus sp. mempunyai bentuk V tanpa trichrome untuk P.paradoxus . Jumlah vaskular P. eburneus ialah 23, P. bullatus ialah 20, P.paradoxus adalah 35 dan Paracostus sp. adalah 20. pengenalpastian spesies Paracostus boleh ditentukan dengan aspek morfologi dan anatomi.

Kata kunci: *Batang Daun, Costaceae, Paracostus, Stomata, Utara Barat Sarawak,*

CHAPTER 1

INTRODUCTION

Borneo is an island that consists of three countries which are Malaysia, Indonesia (Kalimantan) and Brunei. Mackinnon (1997) stated that Borneo is the third largest island in the world after New Guinea which represents one of the most biologically diverse collection planets of ecosystems. Besides Borneo also become the centre of distribution and species diversity of the Anacardiaceae, Burseraceae, Celastraceae, Clusiaceae, Euphorbiaceae, Fagaceae, Myrtaceae, Rhizophoraceae (Stevens, 1980) and genus *Rafflesia* (Rafflesiaceae) with four to five of the 14 species were recorded all occur in Sabah and Sarawak (Nais,1992). Due to the wide number variety of plant species in Borneo forests, it also makes Borneo known as the centre of biodiversity in Tropical Asia (Hazebroek & Morshidi, 2001).

Tropical forests in Borneo are considered as one of the twelve mega biodiversity centres in the world (Tan & Eryani, 2009). Soepadmo, Julia and Yahud (2006) stated that the island of Borneo which in Sabah and Sarawak area is conservatively estimated to harbour about 12,000 to 15,000 species of flowering plant which about 3,500 to 5,000 are tree species. Borneo is divided into nine eco region such as the sub montane forest and island’s lowland (Mackinnon, 1997). While Noor Ain (2012) state that Borneo consist of four main types of forest which are the lowland rainforest, montane forest, inland swamp forest and mangrove forest and there are 64 families with 224 genera and 1201 species within the quarter of the Borneo tree flora.

Limestone is a sedimentary of rock which composes of mineral calcite and aragonite. Limestone formation is found throughout Borneo and includes extensive areas in the Peninsular and the limestone hills of Sarawak (Noor Ain, 2012). The complexities of limestone have been influence by the topography, soil light intensity and moist of the rock face (Jumaat & Zahiruddin, 2005) In Sarawak, limestone area is located in Bau, Serian which in the Kuching division. Bandarin (2001), state that limestone area consists of high level of radiation which is endemism to plant and animal species. Jumaat and Zahiruddin (2005) state that at least 600 species of plant have been recorded from the limestone forest which mostly were rare and endemic species such as *Nepenthes northiana* which restricted in Bau limestone.

Zingiberales is one of the monocotyledon plants that allocate or widely distribute in the tropical region. Most members of Zingiberales are native to the tropical Asia and consist of the major economic importance (*Zingiber officinale* and *Musa acuminata*) and ornamental value (genus *Heliconia).* This order consists of eight families with approximately 92 genera and 2,111 species. Tomlinson (1962) stated that this order can be distinguish from other orders based on the morphological and anatomical character of the species. Costaceae is spiral ginger family (Maas, 1979). It can be distinguish from other family based on their morphology which are branches aerial shoot and monistichous or spiral phyllotaxy. Costaceae consist of seven genera which one of them is genus *Paracostus. Paracostus* has restricted distribution which occurs in Borneo and Africa.

1.1 Problem Statement

Paracostus is one of the Costaceae genus that can be clearly distinguished based on the inflorescence characteristic and have flowering season. Therefore, the identification of the *Paracostus* species in the field without the flower is difficult due the similarity of the leaf morphology and might lead to misidentification of species. There are a lot of studies on the *Paracostus* morphology but lack on the *Paracostus* anatomy. Thus further studies on the *Paracostus* anatomy should be conducted as a proof to support the identification of the *Paracostus* species based on other morphological characteristics.

1.2 Objectives

The purposes of this study are as below:

I. To compare leaf morphological characteristic of *Paracostus* species from Northern West of Sarawak.

II. To differentiate the anatomical characteristic of *Paracostus* species from Northern West of Sarawak.

III. To produce the identification key between the selected species of the *Paracostus* in the Northern West of Sarawak.

IV. To map the sampling site of the selected species of the *Paracostus* in Northern West part of Sarawak

CHAPTER 2

LITERATURE REVIEW

2.1 Order of Zingiberales

Zingiberales order are a group of large monocotyledon plant which can be found in tropical and subtropical area which have the herbaceous, spices and ornamental economically important value (Kress *et al*., 2001). Tomlinson (1962) state that taxonomist was recognized the order as a natural entity because of the comparable in its homogeneity to grasses, palms or orchids. Zingiberales is a well characterizes and sharply defined which the families were well marked and sharply defined as one the Zingiberales (Cronquist, 1981).

Zingiberales order is inserted within eumonocots, which are Arecales, Commelinales and Poales (Kress, Prince & Williams, 2002). This order comprises of five sub-classes (Alismatidae, Arecidae, Comnelinidae, Liliadae and Zingiberidae) and eight families which are the Musaceae (banana), Strelitziaceae (bird of paradise), Heliconiaceae (heliconias), Lowiaceae (Orchidantha), Zingiberaceae (ginger), Costaceae (spiral ginger), Cannaceae (Queensland arrowroot) and Marantaceae (Arrowroot). This eight families shared similar characteristics; rhizomatous herb; young leaf roll and present midrib, present of ligule, involucral bract, stamen and filament formed staminoid structure and zigomorphic flower (Kress, 1990; Larsen et al., 1999).

The order Zingiberales has long been regarded in the taxonomic literature as a natural monophyletic group within the monocotyledon. Dahlgren and Clifford (1982) stated that two informal group of Zingiberales are form because they share the morphological and anatomical character : the” banana group” which consist of Musaceae, Strelitziaceae, Heliconiaceae and Lowiaceae also known as paraphyletic basal group order and the other group are “ginger group” which consist of Zingiberaceae, Costaceae, Cannaceae and Marantaceae. As stated in Kirchoff (1988) the flower of the ginger group is highly modified compare to those of banana group. Larsen *et al.* (1999) divided the Zingiberales order into two informal group based on the functional stamen which Musaceae, Strelitziaceae, Heliconiaceae, Lowiaceae have similarity of five functional stamen while Zingiberaceae, Costaceae, Cannaceae and Marantaceae have similarity of one functional stamen.

Tomlinson (1962) state that this order can be distinguished from other orders based on the morphology which the rhizomatous herb, leaves with open, sometimes ligulate sheath, lamina entire with lateral vein diverging from a common midrib and one-half of blade completely rolled around the other during development. Zingiberales specialized character; petiolate laminar leave with pinnate venation, presence of septal nectaries, oxalate raphides, five to six functional stamens, well developed starchy endosperm and UV-fluorescent content of cell wall characters can be used to differentiate Zingiberales from others (Dahlgren, Clifford & Yeo, 2012).

Zingiberales differ from other closely related monocots due to their specializes apomorphies or derived traits which are the isomorphic root hair cells, presence of intracellular silica bodies, epigynous owers, pollen grains without distinctive apertures but with a reduced exine layer and an elaborated intine layer, nuclear endosperm development, and arillate seeds (Kress, 1990). Zingiberales undergo evolution which causes several significant changes in term of floral morphology which involve the perianth and androecial whorls which also lead to the evolution of pollination syndrome (Rudall & Bateman, 2004).

Figure 1: The picture of the Zingiberales order. (Source from: Smithsonian National Museum of Natural History, 2016)

2.2 Costaceae

Costaceae or spiral ginger family is a pantropical monocotyledon that consists of four genera with 150 of species and easy to recognize within the order Zingiberales (Noor Ain, 2012). It is distinguished from other families such as bananas (Musaceae) and ginger (Zingiberaceae) by its well-develop and sometimes branched aerial shoots that have a characteristic spiral monistichous (one-sided) phyllotaxy (Kirchoff & Rutishauser 1990) and the absence of aromatic oils (Specht, Stevenson & Desalle., 2001). Costaceae have been classified under the Zingiber group due to the floral structure of the single fertile stamen with others five infertile stamens fuse and form the large petaloid labellum or staminodial labellum.

Costaceae is well represented in the New World, the ancestral distribution of the Costaceae occupy the area from Africa, America, Melanesia, and Southeast Asia (Kress & Specht,2006). The most basal lineages of Costaceae appear to have their roots in South America (Chamaecostus, Dimercostus and Monocostus clade), Africa (Costus and Paracostus clade) and Southeast Asia (Cheilicostus and Tapeinochilos clade) (Specht, 2006).

Schumann (1904) divided the genus *Costus* into five subgenera; *Costus, Chamaecostus, Cheilocosttus, Paracostus and Cadalvena* with four genera within the Costaceae family; *Costus, Dimercostus, Monocostus and Tapeinochilos* (Larsen *et al.,* 1999). Latest study conducted by Specht *et al*. (2001) using molecular phylogenetic analysis stated that *Dimercostus, Monocostus,* and *Tapeinochilos* are all monophyletic lineage while *Costus* is polyphyletic lineage and they propose the reclassification of genus *Costus* and new phylogeny into four new genera that consist of *Costus*, *Chamaecostus*, *Cheilocostus and Paracostus.* They stated that all the *Costus* species from Asia (except for *P. paradoxus*) were transferred to the genus *Cheilocostus* while the Bornean *P. paradoxus* and the African species, *C. englerianus* were placed under the sub-genus *Paracostus*.

The classification of the genera within the costaceae family were based upon the general characteristic of overall floral morphology (Meekiong *et al*., 2006). Most of the androecium of the Costaceae has also been replaced by petaloid structures, and the single fertile stamen is often attached to an enlarged petaloid "filament" (Kress & Specht, 2006).

Recently, genus *Cheilocostus* name was changed to *Hellenia* name by Govaerts (2013) because the name *Hellenia* had been used earlier by Retzius in 1791 as a replacement name for *Bankse. Cheilocostus* name started to be used when Specht and Stevenson proposed three new phylogeny under the Costaceae by using molecular analysis in 2006. The genus *Hellenia,* had been supported by Dutta in 2010. She stated that the name was validated by Miquel where he merely mentioned it as synonymy under *Costus*. Dutta (2010) was however correct in recognising as a valid name for this genus.

Specht and Stevenson (2006) state that subgenus *Costus* consist of two separate sections which are *Costus* sect. *ornithophilus* and *Costus* sect. *costus.* which are classified based on the character of the labellum and reflected two distinct floral forms associated with pollination syndrome. *Costus* sect. *Ornithophilus* have a tubular labellum and adapt to bird pollination for an example *Costus mallortieanus,* while *Costus* sect. *Costus* have broad labellum and adapt to pollination by bees mostly found in *Dimercostus* sp.

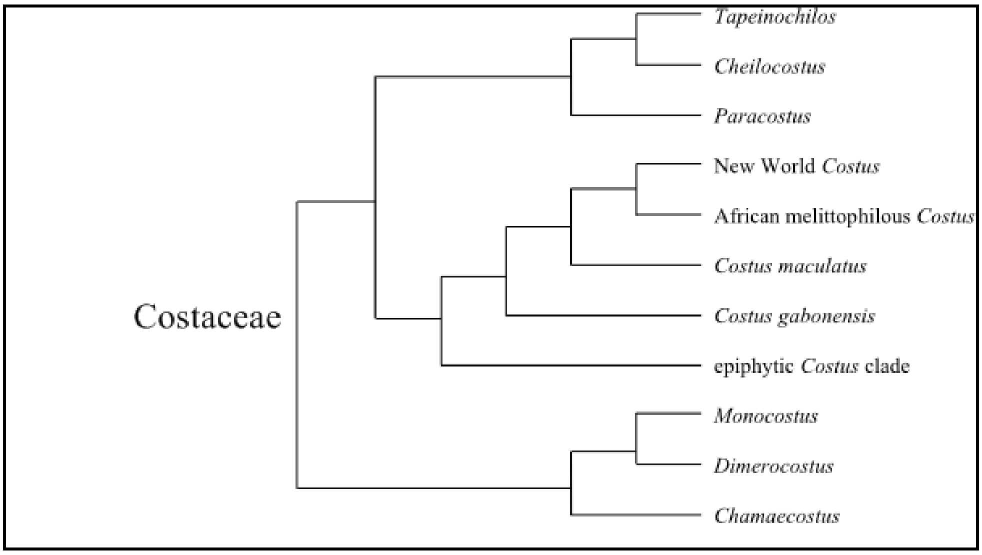

Figure 2: Cladogram of *Costaceae* based on morphology and DNA sequence. (Adopted from: Specht, 2006)

2.3 *Paracostus* C. Specht

Paracostus is a long rhizome creeping plant with spiral monistichous or phyllotaxy character. Based on Specht (2006) *Paracostus* is a prostrate rhizomatous herbs or climbing herbs -genera that are segregated from the genus *Costus*. All the species of Costaceae in Asia have been classified under the genus *Hellenia* or the old name known as genus *Cheilocostus* and all the species of Costaceae that distribute from the area of Borneo and Africa including *P. paradoxus* and *P. englerianus* have been classified under the genus *Paracostus* .*Paracostus* can be easily identify based on their morphology character of spiral monistichous leaves, inflorescence and height which less than 1.5m

Paracostus is a flowering season plant. Their inflorescence character can be used to identify the species. Meekiong *et al.* (2006) stated that, *Paracostus* can be differentiated from other genus based on its unique inflorescence characters which emerges from the node of the rhizome or from the upper part below the first leaf. The inflorescence characters also can be used to distinguish from the genus *Hellenia*. The flowers of *Paracostus* were supported by inconspicuous bract, inflorescence with few flowers while the *Hellenia* were supported by conspicuous bract and consist of condensed flower (Poulsen & Specht, 2010). *Paracostus* inflorescence emerges from the axis of the leaf and appears terminal due to secondary displacement along with lack of continued apical growth of the shoot meristem (Specht, 2006). Noor Ain, (2012) recorded the flowering season of *P. paradoxus* were on February, August and November and as for *P. muluensis* were recorded flowering from November to April.

Paracostus is one of the genera that are more success in producing sucker and form large size of clump, rarely grow from the seed but produce small fruits. Meekiong *et al*. (2006) state that *Paracostus* seeds were dispersed through the rainfall mechanism. Latest studied by Norazima *et al.* (2012) *Paracostus* consist of six species in Sarawak *P. bullatus*, *P. eburneus*, *P. muluensis*, *P. paradoxus*, *P. sardinianus* and undescribed species which some of these species shared similar morphology characters and solely distinguished by the floral morphology. Meekiong *et al.* (2006) stated that most of the herbarium specimens of *P. muluensis* was misidentified as the *P. paradoxus* because of lacked information on the flower morphology. Field observation suggested that these two species can be easily recognized by the floral characteristics.

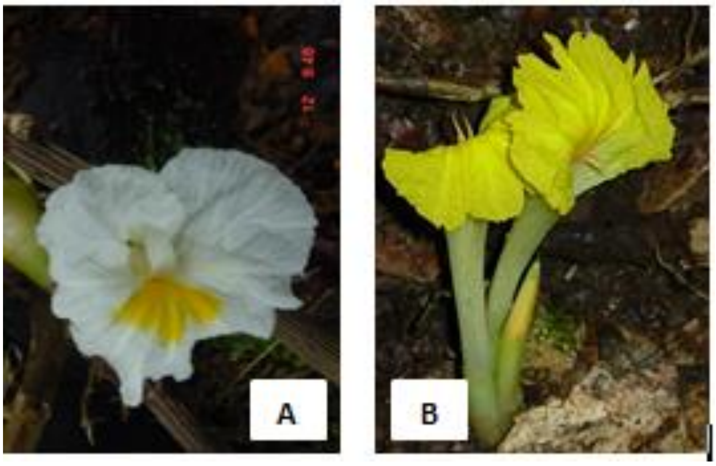

Figure 3: Picture labellum of **A;** *P. muluensis* with fan shaped yellow patch **B;** *P. paradoxus*. (Source: Meekiong Kalu)

2.4 Distribution of *Paracostus*

Besides being distinguished based on morphology genus *Paracostus* also can be identified based on their distribution and ecology. Meekiong *et al.* (2006) stated that genus *Paracostus* are widely distributed in Sarawak and normally being found in shady, wet or damp areas on foot of limestone hills, Mixed Dipterocarp and Kerangas forest. Meanwhile genus *Hellenia* can be found widely distributed in South East Asia, Malaysia (Peninsular) and New Guinea. *Paracostus* can be found in form of solitary clump which in moderate to big population patches, while *Hellenia* commonly found in form of solitary clump in damp and wet place like near small streams or river. For an example *H. speciosus* was found from lowland peat swamp areas to more than 800 m altitude (Noor Ain, 2012).

Paracostus bullatus was recorded from Gunung Poing and *P. eburneus* in Gunung Podam which both of this *Paracostus* species located in the limestone area of Bau, Sarawak. Meanwhile *P. paradoxus* was recorded found grows in semi shady areas, damp and wet place near a small stream in the hill mixed dipterocarp of Matang, Belaga and Sabal, Sarawak. *Paracostus muluensis* was recorded growing in clump formation in the damp and wet place of mixed dipterocarp forest and Kerangas forest of Belaga and Miri, Sarawak and *P. sardinianus* distribute in Lambir area.

2.5 Plant Anatomy

Plant anatomy is the study of the plant cell and tissue culture. According to Radford *et al.* (1974) anatomical properties of plant are being used in taxonomical studies for more than hundred years. It help taxonomist to identify the species by using the internal part of plants and Cronquist (1981) stated that the plant anatomical study can also be used to understand the evolution of groups of species.

Leaf is a part of plant that always being use to conduct the anatomical classification. Kantachok, Chantaranothai and Thammathawon (2007) stated that leaf anatomical data can be used to support the morphological evidence for the plant classification. Singh and Srivastava (2011) mentioned that leaf consists of two types which are dorsiventral leaves (dicotyledon) and isobilateral leaves (monocotyledon). Dorsiventral leaf grows in horizontal direction with distinct upper and lower surface which the upper being more strongly illuminated than the flower. Isobilateral leave hang vertically which both surface of the leaves receive direct and equal amount of sunlight.

Petiole consists of vascular tissue, sclerenchyma, medullary, vascular bundle and trichrome which are distinctive among plants species. Dahlgren (1982) stated that, petiole anatomy can be used as information to differentiate between species. Petiole vascular patterns can be used in taxonomic distinction of certain taxa (Rojo, 1987). According to Dahlgren, Clifford and Yeo (1985) a true petiole only present in certain group of monocotyledon which in other group their leaves are linear and no significant differences between the lamina and petiole.