CHAPTER I

GENERAL INTRODUCTION

1.1 Introduction

The grass family, Poaceae are mostly herbs comprising one of the largest flowering plants families, with approximately 10,000 species, including in 660 to 700 genera (Clayton & Renvoize, 1986; Watson & Dallwitz, 1999). The figures are only after Compositae, Orchidaceae Leguminosae and Rubiaceae in terms of number of species. Grasses can thrive in various habitats and that they have wider geographic range than the other plant families, and can dominate various vegetation types which cover about 30% of the earth's land surface. They are well represented throughout the world and can be found in abundance throughout tropical regions, especially Asia.

This family is the most ecologically and economically important of all plant families. Cereal crops or grains are mostly grasses cultivated for their edible grains called a caryopsis. Cereal grains are grown in greater amount and provide more energy worldwide than any other type of crop; they are therefore staple crops. They are also a rich source of carbohydrate. As food, cereals have two important advantages over roots and most food crops other than nuts. Firstly, they are relatively concentrated foods being low in water and high in reverse carbohydrates, mainly starch, and also oils. Secondly, these characteristics make them able to be stored for relatively long periods and make them more transportable than the other bulky foods such as roots. Maize, rice, wheat, oats, sorghum are among the important cereals.

Sugar cane is the source of sugar in all tropical and subtropical countries of the world. Uses of sugar cane also include the production of alcoholic drink, molasses, and ethanol for fuel. Bamboos are a special, distinctive group of grasses because most of them are woody and often very large; their culms may grow up to 40 m high in some species. Even today, bamboo is still widely used in building and scaffolding, and for utilitarian as well as artistic objects. Up to 20th century in Japan, China, Korea and much of the rest of eastern Asia, bamboo was used for virtually everything from building to cooking ware, from musical instruments to paper-making. Many grasses are definitely elegant and graceful adding structure and form to a garden such as, *Miscanthus*, *Molina*, *Pennisetum*, *Stipa*, *Festuca* (Russelle, 2001; Grounds, 1989).

Applications of Grasses for medicinal properties are locally specific. The British Pharmacopoeia is stated that the rhizome of *Agropyrum repens* contains triticin, dextrose, mucilage, mannitol and inositol. It is a demulcent diuretic and is used internally in the treatment of catarrhal diseases of the genitor-urinary tract, in the form of the lipid extract or decoction. A number of species belong to the genus *Cymbopogon*, produce aromatic oils which accumulate in the tissue and are obtained by stream distillation. *C. schoenanthus* is used in an infusion as a stomachic and the essential oil is said to be useful in rheumatism. *C. nardus*, the citronella grass, is used in an infusion as a stomachic and carminative. *C. citratus* is said to be a good laxative and of use as an anthelmintic. The oil is to be an excellent embrocation for chronic rheumatism, sprains and neuralgia. The stem and roots of *Saccharum*, particularly *S. officinarum*, enter into ayurvedic prescriptions as diuretic, cooling and aphrodisiac. Various parts of plant have figured in cures for snake-bite. The smoke of burning *Panicum antidotale* is used for fumigating wounds and as a disinfectant in smallpox. *Hackelochloa granularis* is prescribed internally with a little sweet oil, in cases of enlarged spleen and liver (Bor, 1960).

The sedges, Cyperaceae is a plant family that used to confuse many people with the grasses. Both are similar in having small flowers borne in bracteate clusters, in the lack of or the extreme modification of perianth segments, in being wind-pollinated, and in the dry, indehiscent, single-seeded fruit. The most apparent morphological differences between the grasses and the sedges are shown in Table 1.1.

From Table 1.1 sedges have three rows of leaves, sheaths with united edges (in contrast to the overlapping sheaths of grasses). Most stems of sedges are triangular and solid, and most leaves are entirely basal. Sedges are commonly in wet places, whereas grasses occur in a wide range of habitats. The families Poaceae and Cyperaceae have been placed in the same order (Glumiflorae, Graminales, or Poales) by many authors. These two families have also been considered close to the Liliaceae and Juncaceae (Clark & Pohl, 1996; Gould & Shaw, 1983).

Table 1.1 Morphological differences between grasses (Poaceae) and sedges (Cyperaceae) (adapted from Duistermaat, 2005; Gould & Shaw, 1983).

Characters	Grasses (Poaceae)	Sedges (Cyperaceae)
Culm	rounded to flattened, hollow	triangular (at least just below the inflorescence) or rounded to flattened, solid
Leaves	2-rank	3-rank
Sheath margins	mostly open or overlapping	mostly closed or fused
Ligule	generally present and short to long, sometimes absent	absent or present
Flower	each generally subtended by two bracts	each always subtended by only one bract (and a number of perianth-bristles or scales can be present as well)
Florets	arranged in two ranks	spirally arranged or in two ranks
Fruit	caryopsis	usually an achene, never a caryopsis

1.2 General morphology of grass (adapted from Clark & Pohl, 1996; Duistermaat, 2005; Gould & Shaw, 1983; Kucera, 1998; Wycherley & Yosof, 1974).

Habit

Grasses are herbaceous (with the exception of woody bamboos), which means that the stems are typically green and relatively soft, although fibrous, but not woody. Grasses plants may be annual or perennial vary in their duration and growth forms. The annuals grasses die after seed set and usually complete their life cycle in one year. The shoots are all alike and all produce inflorescences. However, some grasses are biennials, because their life cycle is usually about two years. The perennials produce flowering shoots accompanied by vegetative shoots; these persist for a few to many years and have an indefinite life span. Perennial grasses are loosely or densely tufted or form large spreading plants by their rhizomes or stolons.

The grass-plant consists of a root and shoot systems. The root system is fairly uniform throughout the grasses and in individual plants. The roots which emerge from

the seeds on germination are few and short-lived, but having extensive system of fibrous. Adventitious roots develops later from nodes of the stems, especially those at or below the surface of the soil. The shoot system consisting of stem, leaves and inflorescence is much diversified (Fig. 1.1).

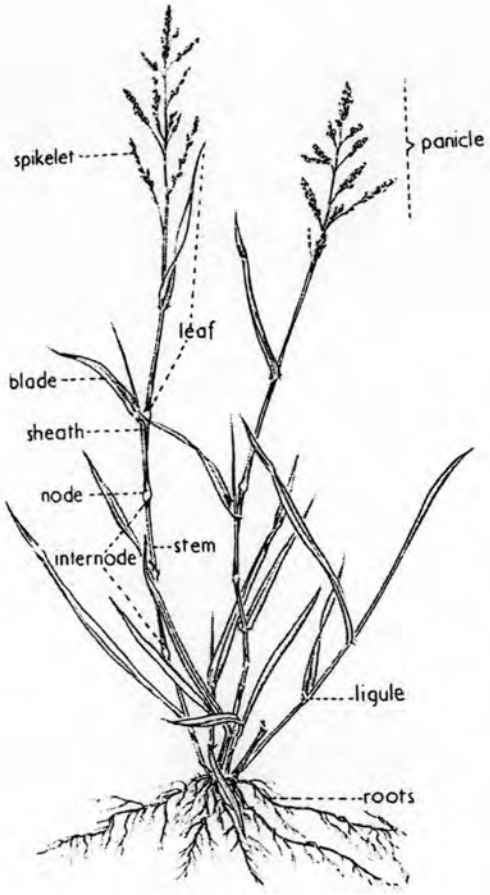

Figure 1.1 Morphological parts of typical grass (after Wycherley & Yosof, 1974).

1.2.1 Vegetative parts

Stem

The aerial stems of a grass is called a culm. It is consists of solid joints or nodes separated by short or long segments, the internodes. The nodes bear the leaves and, if present, roots and branches. The internodes are generally hollow, but are solid in a few grasses. At the base of the culm, they can be very short (about as long as the nodes) resulting in a concentration of leaves, which cover all the nodes. In the upper part of the culm the internodes are elongated. The typical culm grows vertically: erect, or ascending from a geniculate base. Some culms, however, grow horizontally.

Horizontal culms that lie on the soil surface are called stolons. They are generally green and the nodes bearing roots or not and bear well-developed leaves. Culms growing horizontally beneath the soil surface are called rhizome. Rhizomes are generally whitish with rooting nodes and reduced, scale-like leaves.

Leaves

Grasses leaves always arise from the node, arranging in two rows along the culm, but this is often obscured due to the twisting of the sheath or the culm in side the sheath. Each leaf consists of two main parts: the lower portion is the sheath which is wrapped around the stem and the upper portion, the blade, which is hinged to the top of the sheath.

Leaf-sheath

The sheath is a tube around the culm with (slightly) overlapping margins. The sheath may be shorter or longer than the internode. The midrib may be raised or winged, and (minute) transverse veins may be also present. The throat or the base of the blade may have ear-shaped or triangular appendages, referred to as auricles. Auricles can be persistent or deciduous, glabrous or hairy.

The Ligule

At the junction of the sheath with the blade, the sheath may be extended on its inner side to form a very characteristic membranous structure called the ligule; the part outside the junction is called the collar (Fig. 1.2). The ligule, a characteristic feature of the grass family, is usually fairly constant in each species and very often serves as an important means of distinguishing between specimens of different species in their vegetative phase because of they are displays various structural modifications.

Leaf-blades

The leaf-blade is similar to the other monocotyledonous plants, typically linear or lanceolate, arises on the top of the sheath. It is generally flat and elongated or inrolled with more or less prominent longitudinal veins. Transverse veins are sometimes present as well.

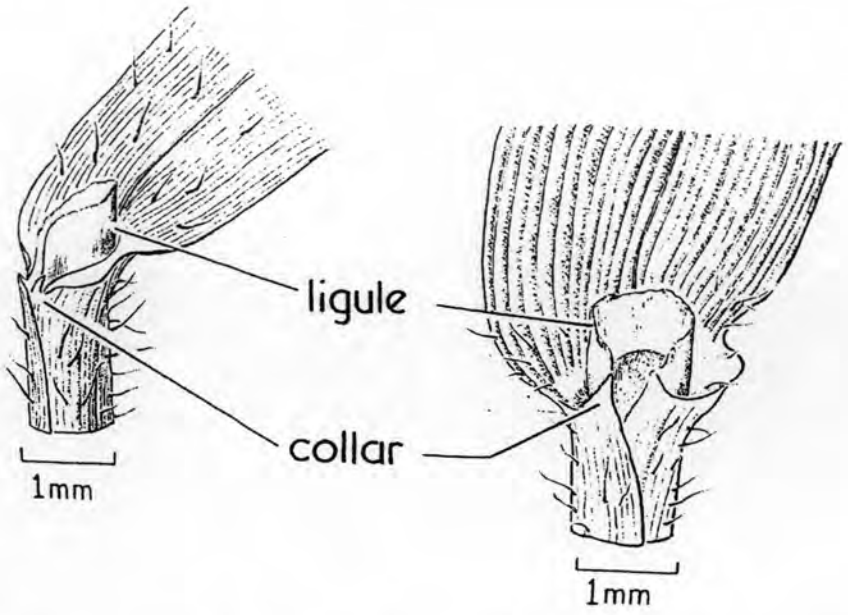

Figure 1.2 Part of leaf-blade and sheath illustrating the collar and the ligule (after Wycherley & Yosof, 1974).

1.2.2 Reproductive part

Inflorescences

The erect flowering stem or culm of a grass is terminated by an inflorescence. The inflorescence consists of distinct units called spikelets borne on the main axis or rachis. A few species have an inflorescence consisting of one spikelet only. However, the majority of grasses have inflorescences consisting of many spikelets, which display great variety in modifications of basic spikelet structure and in the different possible arrangements of the spikelets.

Spikelet

The spikelet is the basic unit of the inflorescence. It consists of one to several florets, each of which encloses the true flower, the whole subtended by two empty bracts called glumes. The lower (or first) and upper (or second) glumes. The glumes, rachilla, and the one to many florets together form a spikelet (Fig. 1.3). Above the empty glumes are one or more floral glumes. A floral glume are called "lemma" and "palea". The lemma is usually the larger and is on the side away from the rachilla. The spikelets of certain grasses or groups bear awns, which are mostly solitary projections of the mid-vein of either glumes or lemmas or both. Awns vary in length,

thickness, and form (straight, geniculate, twisted, etc.) and are a useful character in identification.

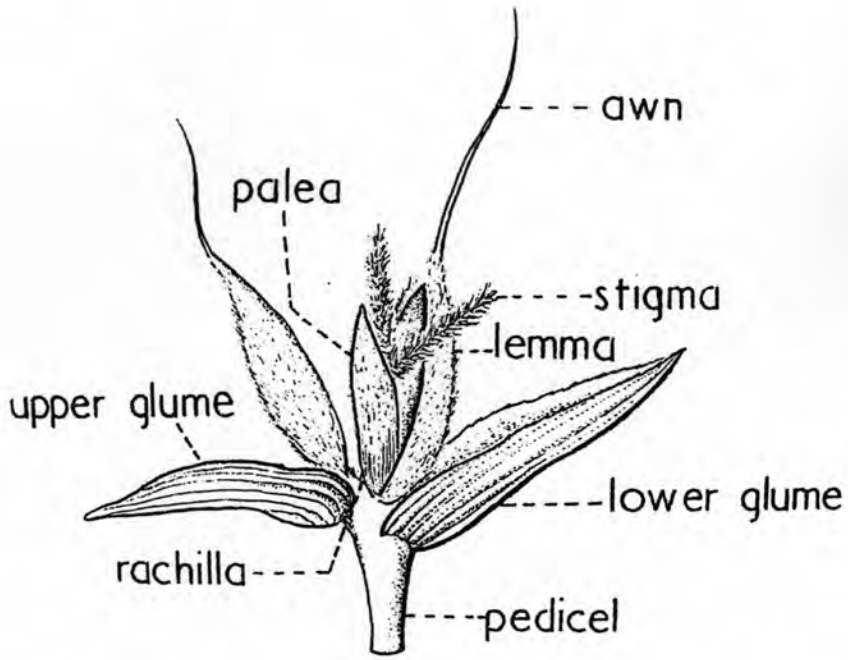

Figure 1.3 A spikelet (after Wycherley & Yosof, 1974).

Floret

The actual floret is between the lemma and palea. There is a variety of possible conditions and arrangements of the florets. The sex organs may be aborted and the floret is then sterile. If only the stamens are present or only the pistil is developed, the floret is referred to as male or female respectively. If both sexes are functional in the same floret the condition is bisexual or perfect or hermaphrodite. The perfect flower consists of stamens and pistil (Fig. 1.4). The most common number of stamen is three, but sometimes there are as many as six (e.g. *Zizania*). The filament of the grass stamen is typically delicate and flexible. The pistil consists of feathery, usually 2-parted stigmas and a 1-seeded ovary, the latter developing as the grain or caryopsis. At the base of the ovary, there are two or rarely three scales, called lodicules. The lodicules vary in sizes, but usually rather small. There are vestigial parts of an ancestral perianth. Their function is believed to push the lemma and palea apart when the sex organs are mature.

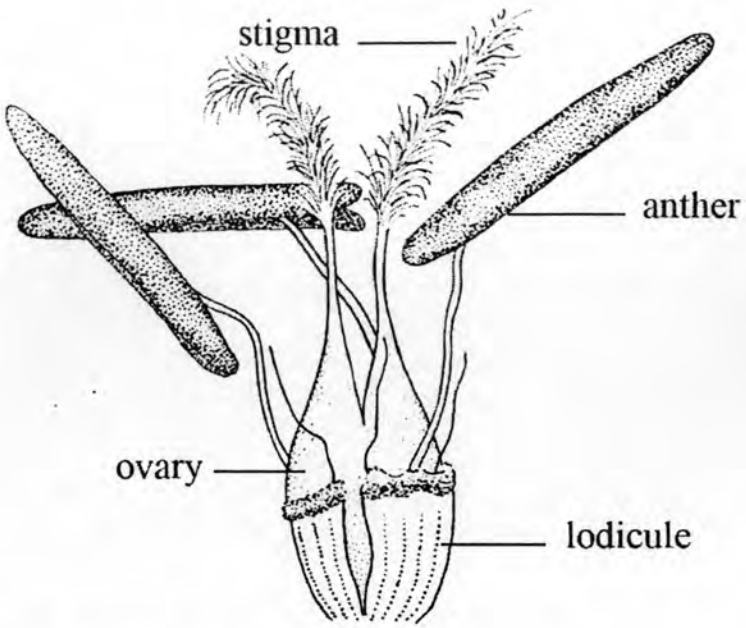

Figure 1.4 The grass floret (after Gould & Shaw, 1983).

Caryopsis

A fertilized ovule develops within the ovary, it is enclosed with ovary wall or pericarp when mature; a single seed-fruit is called a caryopsis.

1.3 Literature reviews

1.3.1 The previous classification systems of grass family

Robert Brown (1810) was the first person who subdivided the grass family into two subfamilies, the Pooideae and Panicoideae based on differences in spikelet morphology. This primary subdivision has been used as a basis by most authors later. Brown's concept was maintained and elaborated on by Bentham (1883), Hackel (1887), Hayek (1925) and Hubbard (1934). These botanists are among those who have made outstanding contributions to the classification of the Gramineae as a whole.

The modern foundation for the classification was established by Avdulov (1931), who introduced the use of cryptic characters, for example chromosome characteristics and linked them to morphological, anatomical features as well as the orientation and size of the first seedling leaf. It is really the turning point in the study of the grass family and launched new vistas in classification to which an increasing number of scientists are contributing (Bor, 1960). Synchronously, Prat (1936) also

used information from anatomy, physiology and geography in addition to morphology and chromosomes. The outstanding feature of classification systems initiated by Avdulov (1931) and Prat (1936) is the apparent necessity for an increased number of sub-families (Pilger, 1954; Tateoka, 1957; Jacques-Félix, 1958; Parodi, 1959; Stebbins & Crampton, 1959 and Prat, 1960). These authors have subdivided the grass family in to 5 to 10 subfamiles.

In 1992, a phenetic classification of the family and comprehensive descriptions of all genera was done by Watson & Dallwitz. At more or less the same time Clayton and Renvoize (1986), using a combination of phenetic methods and evolutionary classification, recognized six subfamilies, viz. Arundinoideae, Bambusoideae, Centothecoideae, Chloridoideae, Panicoideae and Pooideae, and also provided diagnostic generic descriptions for all genera of the family. So far this system of grass classification is widely accepted. Recently, a new classification of the family Poaceae has been proposed by the Grass Phylogeny Working Group (GPWG, 2000, 2001) based on molecular data. This classification recognized twelve subfamilies i.e. Anomochlooideae, Aristidoideae, Arundinoideae, Bambusoideae, Centothecoideae, Chloridoideae, Danthonioideae, Ehrhartoideae, Panicoideae, Pharoideae, Pooideae and Puelioideae.

The Andropogoneae is one of the two major tribes in the subfamily Panicoideae (Clayton & Renvoize, 1986), which includes about one-third of all grass species (Mathews et al., 2002). The grass tribe Andropogoneae is a monophyletic tribe that includes both maize (*Zea may* ssp. *mays*) and sorghum (*Sorghum bicolor*), two of the world' most important crop. Clayton (1972, 1973) divided Andropogoneae into "awned" and awnless" taxa. Later, Clayton & Renvoize (1986) divided this tribe into 11 subtribes of 85 genera in the world, based largely on characters of the inflorescence. This tribe distributed throughout the tropics, particularly the savannah zone, extending into warm temperate regions. Most species of this tribe have pairs of spikelets in the inflorescence, one sessile and one on a pedicel, although in some species one or the other of these spikelets appears to be suppressed. Inflorescence form is highly variable, the members of each pair commonly dissimilar; glumes as long as the spikelet, often indurated and always firmer than the hyaline florets scales; florets two per spikelet, the lower male or barren, the upper female or bisexual; lemma of the upper floret often geniculately awned (Clayton, 1986).

In this study, two subtribes, i.e. Ischaeminae and Rottboelliinae which include about 15 genera in Thailand were studied.

The subtribes Ischaeminae and Rottboelliinae belong to the tribe Andropogoneae, which is the one of two major tribes in the subfamily Panicoideae (Clayton & Renvoize, 1986). The both subtribes in Thailand comprising of approximately 21 and 31 species, belonging to 5 genera and 10 genera, respectively. The 15 genera include *Apluda, Coelorachis, Eremochloa, Hackelochloa, Hemarthria, Ischaemum, Kerriochloa, Mnesithea, Ophiuros, Phacelurus, Rottboellia, Sehima, Thaumastochloa, Thelepogon* and *Vossia* (Nanakorn & Norsaengsri, 2001). At present taxonomic study of the family Poaceae in Thailand is slowly carried out, though it is really needed to fulfill our knowledge for the Flora of Thailand Project. This study aims to conduct taxonomic study of the subtribes Ischaeminae and Rottboelliinae in Thailand which are still scanty known. The knowledge gain from this study will be the basis for the Grass Flora of Thailand project as well as can serve as a model for further taxonomic study in Poaceae.

1.3.2 General morphological characteristics of the subtribe Ischaeminae

The first is subtribe Ischaeminae, includes over 60 species in the tropics of both hemispheres, but mainly occur in Asia and Australia. This subtribe is recognized by a single inflorescence, paired or digitate racemes or rarely solitary racemes, these usually terminal, sometimes axillary, rarely spathate; racemes with fragile rachis and linear to obovoid internodes, without homogamous pairs. Spikelets in dissimilar pair at each node of an articulated rachis or rarely becoming solitary through the reduction of the pedicelled spikelets. Sessile spikelet bisexual, dorsally or laterally compressed and composed of 1-2-flowers. The callus blunt and fitting a truncate or shallowly hollowed internode tip; lower glume chartaceous to crustaceous, convex or concave, 2-keeled or rounded on the flanks, with or without a median groove; lower florets male, with palea; upper lemma oblong, bidentate or bifid, nearly always with a glabrous awn. The pedicelled spikelet usually are staminate or neuter flowers, perfect flower are rare. The rachis-joints and the pedicels are either slender and separate or triquetrous and confluent at the base of node into U- or V-shaped structures (Keng, 1933; Clayton & Renvoize, 1986).

This subtribe composed of 8 genera in the world but occurs only 5 genera and 21 taxa in Thailand (Table 1.2) (Clayton & Renvoize, 1986; Nanakorn & Norsaengsri, 2001).

Table 1.2 List of genera in subtribe Ischaeminae of the World (Clayton & Renvoize, 1986) and Thailand (Nanakorn & Norsaengsri, 2001).

Genera	(Clayton & Renvoize, 1986)	(Nanakorn & Norsaengsri, 2001)
1. *Ischaemum* L.	✓	✓
2. *Thelepogon* Roem. & Schult.	✓	✓
3. *Apluda* L.	✓	✓
4. *Kerriochloa* C.E. Hubbard	✓	✓
5. *Triplopogon* Bor	✓	–
6. *Pogonachne* Bor	✓	–
7. *Sehima* Forssk.	✓	✓
8. *Andropterum* Stapf	✓	–
Total	**8**	**5**

1.3.3 General morphological characteristics of the subtribe Rottboelliinae

The subtribe Rottboeliinae contains 19 genera which includes 120 species or more. This subtribe is mainly found in the tropics of the Old World, with some genera extend to tropical America (Keng, 1933). This subtribe is recognized by a single inflorescence or sometimes with digitate racemes, these terminal, axillary or spathate; racemes fragile, though sometimes tardily so and rarely tough, the internodes variously thickened or swollen, without homogamous pairs. Spikelets usually in dissimilar paired, rarely ternate through the development of two sessile spikelets or solitary through the reduction of the pedicelled spikelet at each node of an articulated rachis. Sessile spikelets are dorsally compressed, bisexual and composed of 1-2-flowers. The callus sometimes obtuse with oblique scar, more often transversely truncate and then commonly reinforced by a central peg; lower glume herbaceous to crustaceous, convex, often sculptured, mostly 2-keeled; lower floret male or barren; upper lemma narrowly ovate and entire. In each floret of the spikelet, upper lemma usually has no awn. Lodicules are truncate, retuse or toothed from one corner. The

pedicelled spikelet usually are staminate or neuter; the rachis-joints and the pedicels are mostly thickened and glabrous, they are often connivent or united to the internode and forming one or two cavities for the reception of the sessile spikelets (Keng, 1933; Clayton & Renvoize, 1986). This subtribe composed of 21 genera in the world but occur only 10 genera and 31 taxa in Thailand (Table 1.3) (Clayton & Renvoize, 1986; Nanakorn & Norsaengsri, 2001).

Table 1.3 List of genera in subtribe Rottboelliinae of the World (Clayton & Renvoize, 1986) and Thailand (Nanakorn & Norsaengsri, 2001).

Genera	(Clayton & Renvoize, 1986)	(Nanakorn & Norsaengsri, 2001)
1. *Urelytrum* Hack.	✓	–
2. *Loxodera* Launert	✓	–
3. *Elionurus* Kunth ex Willd	✓	–
4. *Phacelurus* Griseb.	✓	✓
5. *Vossia* Wall. & Griff.	✓	✓
6. *Hemarthria* R. Br.	✓	✓
7. *Lasiurus* Boiss.	✓	–
8. *Rhytachne* Desv.	✓	–
9. *Coelorachis* Brongn.	✓	✓
10. *Eremochloa* Büse	✓	✓
11. *Chasmopodium* Stapf	✓	–
12. *Rottboellia* L. f.	✓	✓
13. *Heteropholis* C.E. Hubbard	✓	–
14. *Hackelochloa* Kuntze	✓	✓
15. *Glyphochloa* Clayton	✓	–
16. *Manisuris* L.	✓	–
17. *Ophiuros* Gaertn.	✓	✓
18. *Oxyrhachis* Pilger	✓	–
19. *Mnesithea* Kunth	✓	✓
20. *Ratzeburgia* Kunth	✓	–
21. *Thaumastochloa* C.E. Hubbard	✓	✓
Total	**21**	**10**

1.3.4 Taxonomic historical reviews of the Poaceae

Previously, taxonomic works of the Poaceae were published in many Floras by various taxonomists (Table 1.4). The first major comprehensive study of Asian Gramineae was accomplished by Sir Joseph Hooker (1897) in his Flora of the British India. Standard works by other botanists related to the Grass flora include: Flora of tropical Africa (Stapf, 1917); the Poaceae in Laos, Cambodia and Vietnam was included in Flora Génerale de L' Indochine (Camus & Camus, 1922); Malay Peninsula (Ridley, 1925); Grasses of China was performed by Keng (1933); Burma by Rhind (1945); Flora of western Austrailia (Gardner, 1952); Notes on Malaysian Grasses (Jansen, 1953); Grasses of Ceylon (Senaratna, 1956); Grasses of Burma, Ceylon, India and Pakistan (Bor 1960); Grasses for Flora of Japan (Ohwi, 1965); Grasses of Hawai (Rotar, 1968); A manual of the Grasses of New Guinea (Henty, 1969); Flora of Malaya (Gilliland et al., 1971); Grasses in Malayan plantations (Wycherley, 1974); the Tropical Grasses of Southeast Asia (Lazarides, 1980); Flora of Pakistan (Cope, 1982); Grasses of Japan and neighbouring regions was also studied by Koyama (1987); Flora of Kerala-Grasses (Sreekumar, 1991); Flora of Ceylon (Dassanayake et al., 1994); Grasses of North-Eastern India (Shukla, 1996); the Grasses and Bamboo of India (Moulik, 1997). Recently by Duistermaat (2005) in Field Guide to the Grasses of Singapore; Flora of China (Chen et al., 2006) (Table 2.3).

1.3.5 History of Species Diversity of Poaceae in Thailand

The first taxonomic account of the family Poaceae in Thailand was prepared by Craib in 1913. He primarily reported species of Monocots in "Contribution to the Flora of Siam", which included mainly species collected by Kerr during 1907-1913. Twenty years later, Craib and Kerr published part of the Poaceae in Flora Siamensis Enumeratio. Since then all international activities were diminished due to the Second World War and the death of the authors. The Thai-Danish Botanical Projects carried over in 1957 have inspired the study on the Thai flora. Specimens collected in these expeditions were identified and species were published in Dansk Botanisk Arkiv by Bor & Larsen during 1962-1965, under the cooperation of Thai-Danish project "Studies in the Flora of Thailand" (Nanakorn, 1990).

From the last nine decades, taxonomic works on Thai grasses are rather scant. Only some accounts were reported by botanists who worked in some specific areas or

in some taxa, for example Jaroenchai (2007) worked at Phu Ruea National Park, Norsaengsri (2000) at Phu Phan National Park, *Germainia* (Chai-anan, 1972), *Paspalum* (Poo-ngarm, 1982), *Setaria* (Tannukit, 1983), *Eragrostis* (Poodpong, 1984), Andropogoninae, Anthistiriinae and Saccharinae (Nanakorn, 1990), *Digitaria* (Chaiwiratnukul, 1988), *Panicum* (Prukpramool, 1992), *Aristida* (Chaisongkram, 2005) and subtribe Setariinae (Norsaengsri, 2006).

So far, the grass Flora of Thailand is rather in a slow process. It is probably due to lack of interested young botanists as well as lacking taxonomic resources such as references and type specimens. Prior to this study, little attention has been paid to the grasses of Thailand. The identification and distribution of grasses from Thailand have come from the literature of neighboring countries.

Table 1.4 List of species in subtribes Ischaeminae and Rottboelliinae in some Floras.

No.	Species \ Publications	Stapf, 1917 Africa	Rotar, 1968 Hawai	Hooker, 1897 British India	Sreekumar, 1991 Kerala (India)	Shukla, 1996 Northeastern	Moulik, 1997 India	Senaratna, 1956 Ceylon	Dassanayake et al., 1994 Ceylon	Cope, 1982 Pakistan	Rhind, 1945 Burma	Bor, 1960	Chen et al., 2006 China	Camus & Camus, 1922 Indo-China	Bor, 1962a, 1965a Thai	Nanakorn & Norsaengsri, 2001	Duistermaat, 2005 Singapore	Jansen, 1953 Malaysian	Gilliland et al., 1971 Malaya	Wycherley, 1974 Malayan	Backer & Bakhuizen , 1968	Lazarides, 1980 Southeast Asia	Henty, 1969 New Guinea	Gardner, 1952 Australia
1	*Apluda aristata* L.			✓				✓			✓													
2	*Apluda mutica* L.					✓	✓			✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	
3	*Apluda varia* Hack.	✓		✓																				
4	*Ischaemum angustifolium* Hack. ex Oliv	✓														✓								
5	*Ischaemum aristatum* L.			✓							✓		✓			✓								
6	*Ischaemum barbatum* Retz.				✓	✓	✓		✓		✓		✓		✓	✓		✓	✓		✓	✓	✓	
7	*Ischaemum barbatum* var. glaberrimum														✓	✓								
8	*Ischaemum barbatum* var. lodiculare (Nees) Jansen														✓	✓		✓				✓		
9	*Ischaemum ciliare* Retz.			✓									✓	✓		✓	✓							
10	*Ischaemum fieldingianum* Rendel															✓								
11	*Ischaemum hansenii* Bor															✓						✓		
12	*Ischaemum hirtum* Hack.			✓		✓	✓					✓				✓								
13	*Ischaemum hubbardii* Bor.					✓	✓					✓												
14	*Ischaemum imbricatum* Stapf ex. Ridl										✓													
15	*Ischaemum indicum* (Houtt.) Merr.		✓		✓	✓	✓		✓			✓		✓		✓			✓	✓	✓	✓		
16	*Ischaemum lacei* Stapf ex Bor					✓	✓					✓				✓								
17	*Ischaemum laxum* R. Br.			✓								✓				✓								
18	*Ischaemum magnum* Rendle			✓		✓						✓	✓			✓	✓	✓	✓	✓		✓		

Table 1.4 List of species in subtribes Ischaeminae and Rottboelliinae in some Floras (Cont.).

No.	Species \ Publications	Stapf, 1917 Africa	Rotar, 1968 Hawai	Hooker, 1897 British India	Sreekumar, 1991 Kerala (India)	Shukla, 1996 Northeastern	Moulik, 1997 India	Senaratna, 1956 Ceylon	Dassanayake et al., 1994 Ceylon	Cope, 1982 Pakistan	Rhind, 1945 Burma	Bor, 1960	Chen et al., 2006 China	Camus & Camus, 1922 Indo-China	Bor, 1962a, 1965a Thai	Nanakorn & Norsaengsri, 2001	Duistermaat, 2005 Singapore	Jansen, 1953 Malaysian	Gilliland et al., 1971 Malaya	Wycherley, 1974 Malayan	Backer & Bakhuizen, 1968	Lazarides, 1980 Southeast Asia	Henty, 1969 New Guinea	Gardner, 1952 Australia
19	*Ischaemum mangaluricum* (Hackel) Stapf ex C.E.C.Fisch.															✓								
20	*Ischaemum muticum* L.			✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
21	*Ischaemum rugosum* Salisb			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		
22	*Ischaemum tenuifolium* A. Camus															✓								
23	*Ischaemum timorense* Kunth			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓		
24	*Kerriochloa siamensis* C.E. Hubbard															✓						✓		
25	*Sehima nervosum* (Rottler) Stapf	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		✓					✓	✓	✓	✓
26	*Sehima sulcatum* A. Camus															✓								
27	*Thelepogon elegans* Roem. & Schult.	✓		✓			✓			✓	✓	✓				✓						✓		
28	*Coelorachis cancellata* Ridl.														✓	✓			✓			✓		
29	*Coelorachis foveolata* (Holtt.) Jansen															✓		✓	✓			✓		
30	*Coelorachis glandulosa* (Trin.) Stapf. ex. Ridl.										✓	✓			✓	✓		✓	✓	✓	✓	✓		
31	*Coelorachis helferi* (Hook.f.) Henr.											✓				✓		✓	✓			✓		
32	*Coelorachis mollicoma* (Hance) Bor														✓	✓								
33	*Coelorachis pratensis* (Balansa) A. Camus													✓		✓								

Table 1.4 List of species in subtribes Ischaeminae and Rottboelliinae in some Floras (Cont.).

No.	Species \ Publications	Stapf, 1917 Africa	Rotar, 1968 Hawai	Hooker, 1897 British India	Sreekumar, 1991 Kerala (India)	Shukla, 1996 Northeastern	Moulik, 1997 India	Senaratna, 1956 Ceylon	Dassanayake et al., 1994 Ceylon	Cope, 1982 Pakistan	Rhind, 1945 Burma	Bor, 1960	Chen et al., 2006 China	Camus & Camus, 1922 Indo-China	Bor, 1962a, 1965a Thai	Nanakorn & Norsaengsri, 2001	Duistermaat, 2005 Singapore	Jansen, 1953 Malaysian	Gilliland et al., 1971 Malaya	Wycherley, 1974 Malayan	Backer & Bakhuizen, 1968	Lazarides, 1980 Southeast Asia	Henty, 1969 New Guinea	Gardner, 1952 Australia
34	*Coelorachis striata* (Nees ex Steud.) A. Camus					✓	✓				✓	✓		✓	✓	✓						✓		
35	*Coelorachis striata* var. *pubescence* (Hack.) Bor					✓	✓				✓	✓		✓		✓						✓		
36	*Eremochloa attenuata* Stapf ex Buitenhuis																							
37	*Eremochloa bimaculata* Hack.			✓							✓	✓	✓		✓	✓						✓	✓	
38	*Eremochloa ciliaris* (L.) Merr.										✓	✓	✓	✓	✓	✓			✓			✓	✓	
39	*Eremochloa ciliatifolia* Hack.											✓				✓						✓		
40	*Eremochloa eriopoda* C.E. Hubbard															✓						✓		
41	*Eremochloa lanceolata* Buitenhuis																							
42	*Eremochloa maxwellii* Veldkamp																							
43	*Eremochloa muricata* (Retz.) Hack.			✓			✓	✓	✓			✓	✓			✓						✓		
44	*Eremochloa peltelotii* Merr.															✓						✓		
45	*Eremochloa zeylanica* Hack.															✓								
46	*Hackelochloa granularis* (L.) O. Kuntze		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓	✓	✓
47	*Hackelochloa porifera* (Hack.) D. Rhind					✓	✓				✓	✓	✓			✓								
48	*Hemarthria altissima* (Poir.) Stapf&C.E. Hubbard						✓					✓	✓			✓						✓		

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49	*Hemarthria compressa* (L. f.) R. Br.					✓		✓	✓	✓	✓	✓	✓	✓		✓			✓			✓		
50	*Hemarthria debilis* Bor.														✓	✓						✓		
51	*Hemarthria fasciculata* Kunth													✓		✓						✓		
52	*Hemarthria longiflora* (Hook.f.) A. Camus					✓	✓				✓	✓	✓		✓	✓			✓			✓		
53	*Hemarthria longiflora* var. tonkinensis													✓		✓			✓			✓		
54	*Hemarthria pratensis* (Balansa) Clayton														✓	✓						✓		
55	*Hemarthria protensa* Steud.					✓						✓		✓	✓							✓		
56	*Hemarthria stolonifera* Bor.															✓						✓		
57	*Hemarthria subulata* Reeder														✓	✓							✓	
58	*Manisuris granularis* L.	✓		✓										✓										
59	*Mnesithea geminata* Ridl.															✓								
60	*Mnesithea glandulosa* (Trin.) Koning & Sosef.						✓									✓	✓							
61	*Mnesithea granularis* (L.) Koning & Sosef.															✓	✓							
62	*Mnesithea laevis* (Retz.) Kunth				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓	✓		
63	*Mnesithea merguensis* (Hook.f.) A. Camus											✓			✓	✓						✓		
64	*Mnesithea mollicoma* (Hance) A. Camus												✓	✓		✓		✓	✓		✓	✓		
65	*Mnesithea striata* (Nees ex Steud.) Koning & Sosef.					✓							✓	✓		✓		✓	✓		✓	✓		

Table 1.4 List of species in subtribes Ischaeminae and Rottboelliinae in some Floras (Cont.).

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66	*Mnesithea striata* var. *pubescens* (Hack.) S.M. Phillips & S.L. Chen					✓							✓	✓		✓		✓	✓		✓	✓		
67	*Ophiuros bombaiensis* Bor															✓								
68	*Ophiuros exaltatus* (L.) O. Kuntze.					✓	✓		✓		✓	✓	✓	✓	✓	✓						✓	✓	✓
69	*Ophiuros megaphyllus* Stapf & Haines															✓								
70	*Phacelurus cambogiensis* (Balansa) Clayton															✓						✓		
71	*Phacelurus zea* (C.B.Clarke) Clayton					✓	✓						✓			✓						✓		
72	*Pseudovossia combogiensis* (Balansa) A. Camus	✓												✓		✓						✓		
73	*Rottboellia cochinchinensis* (Lour.) Clayton				✓	✓	✓		✓				✓				✓							
74	*Rottboellia compressa* L. f.			✓	✓				✓				✓				✓							
75	*Rottboellia exaltata* L. f.	✓		✓				✓		✓		✓		✓		✓					✓	✓		
76	*Rottboellia glandulosa* Trin.	✓		✓				✓				✓		✓		✓					✓	✓		
77	*Rottboellia helferi* Hook.f.	✓		✓				✓				✓		✓		✓					✓	✓		
78	*Rottboellia longiflora* Hook.f.	✓		✓				✓				✓		✓		✓					✓	✓		
79	*Rottboellia protensa* Hack.	✓		✓				✓				✓		✓		✓					✓	✓		
80	*Rottboellia striata* Nees ex Steud.	✓		✓				✓				✓		✓		✓					✓	✓		
81	*Vossia cuspidata* (Roxb.) Griff.	✓				✓	✓					✓		✓		✓						✓		
82	*Vossia procera* Wall. & Griff.			✓																				

1.4 Objectives

1. To accomplish a taxonomic revision of the subtribe Ischaeminae and Rottboelliinae in Thailand.

2. To examine the anatomical and molecular characters of the selected groups.

3. To develop a phylogeny of the genera and species in the subtribes Ischaeminae and Rottboelliinae in Thailand based on molecular characters.

1.5 Scopes of study

The study of the subtribes Ischaeminae and Rottboelliinae in Thailand was conducted between June 2004 and August 2007, morphological ecological and distributional data of the two subtribes were obtained from field collected specimens and herbarium specimens kept at main herbaria in Thailand and Europe. Molecular biology, leaf and culm anatomy were studied.

1.6 Anticipated benefits

This research will be the basis for the Grass Flora of Thailand project. The outcome from this research could be a model for further taxonomic study in Poaceae.

1.7 Places of study

1. Department of Botany, Faculty of Science, Chulalongkorn University, Bangkok and Applied Taxonomic Research Center, Department of Biology, Faculty of Science, Khon Kaen University.

2. Main herbaria in Thailand and Europe: Department of Systematic Botany, University of Aarhus (AAU), Kasin Suvatabandhu Herbarium, Chulalongkorn University, Bangkok (BCU); Bangkok Herbarium, Department of Agriculture, Bangkok (BK), Forest Herbarium, Bangkok (BKF), British Natural History Museum Herbarium (BM), Botanical Museum, University of Copenhagen (C), Chiangmai University Herbarium (CMU), Royal Botanic Garden, Edinburgh (E), Khon Kaen University Herbarium (KKU), Royal Botanic Gardens, Kew (K), National Herbarium Netherland University of Leiden branch (L); Linnean Society Herbarium (LINN),

Prince of Songkhla University Herbarium (PSU), Queen Sirikit Botanic Gardens Herbarium (QBG), Muséum National d' Histoire Naturelle, Paris (P), Trinity College, University of Dublin (TCD) and Department of Biology Herbarium, Chiang Mai University.

3. The molecular research was undertaken at the Jodrell laboratory, Royal Botanic Gardens, Kew, Richmond, Surrey, England.