Diversity of Cyperaceae Plants in South India: Phytochemical Perspective

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Foreword

It's my pleasure and privilege to introduce the Book on 'Diversity of Cyperaceae in south India: Phytochemical perspective' written collectively by Dr. K. B. Rameshkumar, Dr. B. Sruthy, Dr. A. R. Viji and Dr. T. Dhruvan. I am proud to mention that A. R. Viji, my Ph. D student, took the morphological studies of Cyperaceae members as her Ph.D topic, and T. Dhruvan, who took Ph.D on coastal plants, was my associate in the Plant Systematics Division of KSCSTE- JNTBGRI. It gives me all the more pleasure and gratification to see that Dr. K. B. Rameshkumar and his associate Dr. B. Sruthy has taken the initiative to compile the vast information on Cyperaceae members, adding their innate expertise in Phytochemistry.

The family Cyperaceae, also known as sedge family, is cosmopolitan in distribution and the 10th most species-rich family among the angiosperms and third in the monocotyledons, having 5687 species reported across the globe. The plant group develops many adaptive characters that led to their successful establishment in diverse habitats right from sea level to high mountains. The members of Cyperaceae are ecologically and economically important in respect of their services to mankind but at the same time earned as world's most notorious weeds because of their interference in agriculture. The following four *Cyperus* species; *C. rotundus, C. esculentus, C. difformis* and *C. iria* are listed among the worst 33 weeds of the world. From the evolutionary point of view, however, they are most prominent colonizers, thereby improve the soil health and hence they deserve a better treatment from the conservation point of view.

Though scattered, lot of information are there on the botany, ethnomedicinal uses, phytochemical composition, pharmacological and therapeutic properties of Cyperaceae members. The present book provides a comprehensive and updated report on different aspects including distribution and diversity, morphology, chemistry and pharmacology of Cyperaceae plants, with emphasis on south Indian species. The specific focus on the Phytochemistry of Cyperaceae members is a great contribution to the lesser-known subject the Phytochemistry, especially in India. The authors are experts in their relevant field of research, as revealed by the contents and the in-depth presentation of individual chapters. I have great pleasure to present this elegant work on Cyperaceae plants before the scientific community. I am sure that this book will serve as a useful reference to the researchers of botany, pharmacology, phytochemistry etc.

Dr. A. G. Pandurangan
Former Director, KSCSTE- JNTBGRI
Palode, Thiruvananthapuram

Preface

Nature provided solutions for the sustainable living of human kind, in the form of food, shelter and clothing. As civilizations advanced, humans learned to get more value-added products such as medicines, cosmetics, food additives, fuels, and so on from his immediate environment, especially from plant resources. The curiosity of man gradually turned to isolating the components responsible for the properties of plants, and such phytochemicals have a great role in the day-to-day life of human kind. Though the planet earth is endowed with more than 4.0 lakhs of plant species, literature review revealed that more than 80% of the floristic wealth is yet to be investigated for their chemical constituents, bioactivities or potential utilities. The Cyperaceae family (Sedge family) is one among such least explored group of plants.

The plant family Cyperaceae is the 10^{th} largest families of flowering plants. The family is represented by 5687 species in 95 genera, of which 28 genera and around 500 species are reported from India, and 24 genera and 274 taxa from South India. Even though Cyperaceae members appear seemingly insignificant, they are important source of food material, essential oils, fodder, and raw materials for artisans, in addition to being medicinal plants. Some of the important Cyperaceae members are nutsedge or nutgrass (*Cyperus rotundus*), water chestnut (*Eleocharis dulcis*), papyrus sedge (*Cyperus papyrus*), cotton-grass (*Eriophorum* sp), spike rush (*Eleocharis* sp), saw-grass (*Cladium*sp), white star sedge (*Rhynchospora colorata*) and whitehead spike sedge (*Kyllinga nemoralis*). Though widely represented across the globe, the plant group is least investigated for their constituents, bioactivities or other potential utilities, and the studies are yet in infant stage compared to other plant groups, throughout the world and especially in India. Though few reviews, field guides, illustrated books and checklists are available on Cyperaceae members from different parts of the globe, a comprehensive account of the plant group, emphasizing the phytochemistry is yet to be worked out.The present book gives a comprehensive account of the diversity of Cyperaceae members, their traditional uses, pharmacological activities and phytochemical constituents.

The family Cyperaceae is taxonomically one of the most intricate plant groups, and the first portion of the book is dedicated to the distributional and morphological aspects of Cyperaceae members across the globe, and especially in south India. The world distribution and centres of diversity of Cyperaceae members, major genera in Cyperaceae family in the world, and the common Cyperaceae members in south India were elaborated with authentic pictures, depicting its habit, inflorescence and nuts. The traditional uses, especially the medicinal uses of 42 Cyperaceae members are enlisted in the book, along with the pharmacology of Cyperaceae members, elaborating 24 biological activities in detail.

The major attraction of the book is the compilation of the phytochemistry of Cyperaceae members. Literature review till to date revealed that out of the 5687 Cyperaceae members, only 180 species have been investigated for their phytochemicals, and the major compounds are listed in the book. The chapter on phytochemistry of *Cyperus rotundus* enlist a total of 687 compounds (298 non-volatile compounds and 389 volatile compounds) reported from *Cyperus rotundus* so-far. The volatile chemical profiles of *Cyperus rotundus* reported from 24 countries have been compiled, along with a detailed report on the essential oil and head space volatile organic compounds of *Cyperus rotundus* from south India.

We hope this book will be useful, especially to the botanists, environmentalists, agriculturists, phytochemists and pharmacologists. The compiled data may provide useful clues to promote further investigations on the plant group with respect to chemotaxonomy, phylogeny, chemical ecology, medicinal properties and standardization of economically important Cyperaceae species.

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In addition to the contribution of the authors, this book is a compendium of the scholarly inputs from experts in different fields, and we would like to extend profound gratitude to all the concerned researchers for their original contributions.

Phytochemistry, the fascinating chemistry of plants, is introduced at JNTBGRI by the unequivocal vision of Dr. V. George, and his guidance and blessings inspire us to excel in the field of Phytochemistry.

The enchanting ambience of KSCSTE-JNTBGRI in pursuing excellent research activities in plant sciences needs to be highlighted. The support and guidance of former Directors of KSCSTE- JNTBGRI, Dr. A. G. Pandurangan and Dr. R. Prakashkumar, and the present Director Dr. B. Sabulal are gratefully acknowledged here in bringing the book, along with the contributions of the taxonomists of JNTBGRI.

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Contents

Chapter 1

World Distribution and Centres of Diversity of Cyperaceae Members

Abstract

Cyperaceae is an important group of angiosperms, and a dominant plant cover in wetlands globally.The plant group give an ideal opportunity to explore the processes of diversification in relation to clade age, diversification rate, area and niche space. Although the geographical diversification of Cyperaceae on a global scale remains unexplored, recent studies suggests that the species rich temperate clades have a tropical origin. The literature suggests the probable centre of origin of this plant group as South America and subsequently dispersed throughout the globe. The chapter gives acomprehensive account on the phylogeny and diversification pattern, characteristic features and classification of the plant group Cyperaceae.

Introduction

The family Cyperaceae, commonly known as sedge family, is the 10th most species rich family among the angiosperms and third among the monocotyledons, having 5687 species in 95 genera and 15 tribes with *Carex*(2,003 species) and *Cyperus* (964 species) as the dominant genera (Larridon, 2022). The plants in the family have cosmopolitan distribution and are an important group of angiosperms not only in terms of number of species but also in plant cover. They often form major component of many habitats ranging from marshes to deserts, and dominate many ecosystems including Tundra and Savanna. Some species are habitat-specific, narrowly distributed and of conservation concern, whereas others are ubiquitous weeds that occur in a variety of environments.

Phylogeny of Cyperaceae

Cyperaceae are graminoid herbaceous plants having solid, non-jointed and often triangular culms, linear leaves with parallel venation with inconspicuous flowers and nuts. The rather uniform morphology of the vegetative parts as well as the highly reduced microscopic flowers makes deduction of evolutionary patterns from living sedges difficult. Most theories on the evolution of this group are derived from studies of the morphology and development of the spikelets.

Cyperaceae presents an ideal opportunity to explore the processes contributing to the diversification and maintenance of biodiversity in relation to clade age, diversification rate, area and niche space (Spalink *et al.*, 2016). The pioneer to describe this family was De Jusseu (1789) and the name was originated from the type genus *Cyperus*, from the Greek term *Kuperiros* which means sedges. The systematic position of this family and its origin and affinities are still unresolved, and several hypotheses have been proposed in this regard. Phylogenetically Cyperaceae are closely allied to Graminae. Hutchinson (1959) separated these families into two separate orders *viz*., Cyperales and Graminales. He considered the latter to be more highly advanced and treated both as having been derived from Liliaceous ancestors *via* the Juncaceae complex.

Origin and diversification of Cyperaceae

In spite of proposed tropical origin for the clade, the family shows heterogeneity in temperate regions (Givnish *et al.,* 1999; Bremer, 2002). Although the subsequent geographical diversification of Cyperaceae on a family-wide, global scale remains unexplored, recent research findings suggests that the species rich, temperate clades are derived from a tropical origin. According to the literature, the probable land of origin of the group is expected as South America (Spalink *et al.*, 2016) and subsequently dispersed throughout the globe. The time scale of the probable origin is the early coenozoic, as supported by reliable fossil record back to the Pleocene (Smith *et al.*, 2009; Spalink *et al*., 2016). As per the views of Escudero *et al.*, (2012) the origin of the genus like *Carex* has been marked between the middle and late miocene epoch.

There are two independent Cretaceous migrations to Australia from South America in Cyperaceae, first along the stem of subfamily Mapanioideae and second along the stem of subfamily Cyperoideae (**Chart 1**). Most diversification within the subfamily Mapanioideae occurred within Australia and South America, while migrations to India, Southeast Asia and Africa occurred from an Australian source in subfamily Cyperoideae. Tribes such as Trilepideae, Bisboechelereae, Sclerieae, Rhynchosporeae, and the genus *Cladium* originated within South America and migrated throughout the southern hemisphere with only occasional introductions to the northern hemisphere (Spalink *et al.*,2016).

Monocots

⇩

Commelinids

⇩

Poales

⇩

Cyperaceae

⇩

Subfamily: Cyperoideae

⇩

Tribe

A. Chrysitricheae
B. Hypolytreae

Subfamily: Cyperoideae

⇩

Tribe

A. Trilepideae
B. Caladieae
C. Bisboeckelereae
D. Sclerieae
E. Carpheae
F. Cryptangieae
G. Schoeneae
H. Rhynchosporeae
I. Dulichieae
J. Khaosokieae
K. Calliscripeae
L. Scripeae
M. Trichophoreae
N. Sumatroscirpeae
O. Cariceae
P. Eleocharideae
Q. Abildgaardieae
R. Bolboschoeneae
S. Fuireneae
T. Schoenoplecteae
U. Pseudoschoeneae
V. Cypereae

Chart 1. Diversification of Cyperaceae

Sedge genera vary considerably in richness and geographical extent, ranging from monotypic to containing over 2000 species, and from narrowly restricted to essentially cosmopolitan. Some genera are adapted to long-distance wind dispersal, but the majority lack obvious dispersal adaptations and are carried short distances by gravity, wind, water or animals (Kern, 1974). Members show a wide range of growth forms, the phenotypic diversity ranges from tiny ephemerals (*Isolepis inconspicua* (Levyns) J. Raynal,), climbing herbs (*Scleria boivinii* Steud.) and to the dwarf tree like *Microdracoides squamosa* Hua. (Larridon *et al.*, 2018). Sedges are diverse in their habitats, mostly growing on waterlogged areas, however, the ecological diversity ranges from truly aquatics to fire prone grasslands and forest. Some species like *Carex moorcroftii* found only in high elevation vegetation up to 5700 m (Dai *et al*., 2010). *Coleochloa domensis* is aspecies with a tendency for epiphytism (Larridon *et al.*, 2021).

Habitat specificity of Cyperaceae

The highest diversity of the family is marked in humid and semi humid tropics along with temperate and cold temperate regions of the world, and flourish well in a wide range of habitat especially in wetlands. Some species are highly adapted to a particular habitat such as rocks, high altitudes and large swamps. On the other hand, many species are competitively inferior, restricted to vulnerable habitats, and thus rare, endangered, and important from the point of conservation aspects. Simpson *et al.* (2003) suggests that for ecologically oriented research, sedges are very often useful as phyto-indicators of site properties because many species of the family possess relatively narrow ecological amplitudes in respect to environmental factors such as soil acidity or water chemistry.

Classification of Cyperaceae

The classification and analysis of sedges are somewhat complicated, many reductions and convergence in the inflorescence architecture have obstructed evolutionary remaking and classification. Largest subfamily under the Cyperaceae family is Cyperoideae, which consists of two extreme species diverse clades, Cariceae and Cypereae including two large genera, *Carex* and *Cyperus* respectively. The tribe Cariceae includes predominantly temperate genus *Carex*, widely distributed and diversified throughout the Northern Hemisphere, ranging from the Arctic to temperate and even high mountains at tropical latitudes where it is restricted to montane habitats (Benitez *et al.*, 2018). The tribe

Cypereae corresponds mainly to the tropical genus, with *Cyperus* as the most diverse genus.

Cyperaceae is taxonomically difficult one and this leads to the lumping of many synonyms and changes of names due to different concepts of generic delimitation. There are many interpretations for different genera and it is sometimes difficult to decide what characters constitute the generic status. Thus, the treatment of genera in different floras is based on different opinions according to the author's concept (**Table 1**). According to the latest enumeration of Cyperaceae, the present estimate of the members of Cyperaceae is 5687 species under 95 genera (Larridon, 2022). Mabberley in ‘The plant-book: a portable dictionary of the vascular plants’ reported that the family contains 4350 species belonging to 98 genera. Takhtajan (1997) has estimated that there are about 5300 species under 125 genera, but according to Thorne (1992) the count is more, as many as 5315 species distributed within 146 genera. The estimate by Judd *et al.* (1999) reports 4500 species under 122 genera.

Table1. List of publications on sedge diversity

Sl. No.	Publication	Author, Year	No. of genera	No. of species
1.	An integrated system of classification of flowering plants	Cronquist, 1981	70	4000
2.	Classification and geography of the flowering plants	Thorne, 1992	146	5315
3.	The plant-book: a portable dictionary of the vascular plants	Mabberley, 1997	98	4350
4.	Diversity and classification of flowering plants	Takhtajan, 1997	125	5300
5.	Cyperaceae: The families and genera of vascular plants. Vol.4	Goetghebeur, 1998	104	5000
6.	Plant Systematics: a phylogenetic approach	Judd *et al.*, 1999	122	4500
7.	Cyperaceae: sedge family	Ball *et al.*, 2002	100	5000
8.	World checklist of Cyperaceae (Sedges)	Govaerts *et al.*, 2007	109	5500
9.	World checklist of selected plant families: Cyperaceae	Govaerts *et al.*, 2020	94	5600
10.	A linear classification of Cyperaceae. Kew Bulletin	Larridon, 2022	95	5687

Conclusions

Physical environment and climate patterns play an important role in the distribution of sedge species. Both biotic and abiotic factors, such as soil topography, geology, climate, species evolution and migration will affect their spatial distribution. Most of the species are neither evenly nor randomly distributed, and the physical environment and climate governs their distribution in definite geographical units. Sedges shows remarkable range of adaptability to various ecological conditions, some species were highly specific in their habitat, which finally leads to rarity and local endemism. Knowledge of how ecologically important morphological characters vary within the distributional range of these species, as well as the underlying control mechanisms for such variation, is essential to understand how the plants may respond to environmental changes.

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Chapter 2

Major Genera in Cyperaceae Family in the World

Abstract

The diversity of sedges is marked in a wide range of habitat of tropical, subtropical and temperate regions of the world, with 5687 species reported. The dominant genera within the Cyperaceae family are *Carex* L. (2003 species), *Cyperus* L. (964 species), *Rhynchospora* Vahl. (399 species), *Fimbristylis* Vahl. (320 species), *Eleocharis* R.Br. (302 species), *Scleria* P.J.Bergius (258 species), *Bulbostylis* Kunth. (227species), *Schoenus* L. (149 species) and *Mapania* Aubl. (100 spp.). These nine genera together hold more than 80% of the total species diversity of the family. The general characteristic features and detailed distribution pattern of the dominant genera are described in the chapter.

Introduction

Bruhl (1995) classified Cyperaceae into 2 subfamilies; Cyperoideae and Caricoideae, while Goetghebeur (1998) recognised 4 subfamilies; Mapanioideae, Cyperoideae, Scleroideae and Caricoideae. Subsequently Simpson (2007) recognized only 2 subfamilies; Mapanioideae and Cyperoideae. Larridon (2022) recently proposed two subfamilies, 24 tribes, 10 subtribes, 95 genera and 5687 species, based on a stable phylogenetic framework based on morphological, molecular phylogenetic and phylogenomic studies (**Table 1)**.

The highest diversity of the family is marked in humid and semi-humid tropics along with temperate and cold temperate regions of the world, and the plant group flourish well in a wide range of habitat, especially in marshy areas. The nine dominant genera within the family that hold more than 80% of the total species diversity includes *Carex* L. (2003 species), *Cyperus* L. (964 species), *Rhynchospora* Vahl. (399 species), *Fimbristylis* Vahl. (320 species), *Eleocharis* R.Br. (302 species), *Scleria* P.J. Bergius (258 species), *Bulbostylis* Kunth. (227 species) and *Schoenus* L. (149 species) and *Mapania* (100 species). Most of the remaining genera of Cyperaceae are quite small and many are monotypic.

Table 1. Genera and number of species in Cyperaceae family (Ref. Larridon, 2022)

Genera	Number of species
Abildgaardia Vahl	9
Actinoschoenus Benth.	2
Actinoscirpus (Ohwi) R.W.Haines& Lye	1
Afroscirpoides García-Madr. & Muasya	1
Afrotrilepis (Gilly) J.Raynal	2
Ammothryon R.L.Barrett, K.L.Wilson&J.J.Bruhl	1
Amphiscirpus Oteng-Yeb.	1
Anthelepis R.L.Barrett, K.L.Wilson&J.J.Bruhl	4
Arthrostylis R.Br.	2
Becquerelia Brongn.	6
Bisboeckelera Kuntze	4
Blysmopsis Oteng-Yeb.	1
Blysmus Panz. ex Schult.	3
Bolboschoenus (Asch.) Palla	15
Bulbostylis Kunth	227
Calliscirpus C.N.Gilmour, J.R.Starr&Naczi	2
Calyptrocarya Nees	8
Capeobolus Browning	1
Capitularina J.Kern	1
Carex L.	2003
Carpha Banks & Sol. ex R.Br.	15
Caustis R.Br.	7
Cephalocarpus Nees	20
Chaetospora R.Br.	3
Chamaedendron Larridon	5
Chorizandra R.Br.	6
Chrysitrix L	4
Cladium P.Browne	3
Coleochloa Gilly	8
Costularia C.B.Clarke	15
Cryptangium Schrad. ex Nees	1
Cyathochaeta Nees	5
Cyathocoma Nees	3
Cyperus L.	964
Didymiandrum Gilly	1
Diplacrum R.Br.	10

Diplasia Pers.	1
Dracoscirpoides Muasya	3
Dulichium Pers.	1
Eleocharis R.Br.	302
Eriophorum L.	18
Erioscirpus Palla	2
Evandra R.Br.	2
Exocarya Benth.	1
Exochogyne C.B.Clarke	2
Ficinia Schrad.	87
Fimbristylis Vahl	320
Fuirena Rottb.	55
Gahnia J.R.Forst. &G.Forst.	41
Gymnoschoenus Nees	2
Hellmuthia Steud.	1
Hypolytrum Pers.	63
Isolepis R.Br.	69
Khaosokia D.A.Simpson	1
Koyamaea W.W.Thomas&Davidse	1
Krenakia S.M.Costa	10
Lagenocarpus Nees	15
Lepidosperma Labill.	80
Lepironia Pers.	1
Machaerina Vahl.	55
Mapania Aubl.	100
Mesomelaena Nees	5
Microdracoides Hua	1
Morelotia Gaudich.	6
Neesenbeckia Levyns	1
Nelmesia Van der Veken	1
Netrostylis R.L.Barrett, J.J.Bruhl&K.L.Wilson	11
Oreobolus R.Br.	17
Paramapania Uittien	7
Phylloscirpus C.B.Clarke	3
Pseudoschoenus (C.B.Clarke) Oteng-Yeb.	1
Ptilothrix K.L.Wilson	1
Reedia F.Muell.	1
Rhodoscirpus Lév.-Bourret, Donadío&J.R.Starr	1
Rhynchocladium T. Koyama	1

Rhynchospora Vahl	399
Schoenoplectiella Lye	63
Schoenoplectus (Rchb.) Palla	16
Schoenus L.	149
Scirpodendron Zipp. Ex Kurz	2
Scirpoides Ség.	4
Scirpus Tourn. ex L.	47
Scleria P.J.Bergius	258
Scleroschoenus K.L.Wilson, J.J.Bruhl & R.L.Barrett	6
Sumatroscirpus Oteng-Yeb.	4
Tetraria P.Beauv.	39
Trachystylis S.T.Blake	1
Trianoptiles Fenzl ex Endl.	3
Trichophorum Pers.	19
Trichoschoenus J.Raynal	1
Tricostularia Nees	11
Trilepis Nees	5
Xyroschoenus Larridon	1
Zameioscirpus Dhooge & Goetgh.	3
Zulustylis Muasya	2
Total species	5687

***Carex* L.**

Carex with a cosmopolitan distribution of 2003 species is the largest genus within the family described by Linneaeus in his ‘Species Plantarum’ with *Carexhirta* as the type species. The tribe Cariceae of subfamily Cyperoideae includes *Carex* L., *Kobresia* Willd., *Uncinia* Pers., *Schoenoxiphium* Nees and *Cymophyllus* Mack. The sister groups in tribe Scripeae are clearly distinguished from *Carex* by the transition from bisexual flowers with a bristle perianth to unisexual flowers without a perianth in *Carex*. Kuekenthal (1909) described four subgenera of the genus based on the structure of the inflorescence; *Carex*, *Psyllophora*, *Vignea* and *Vigneastra*.

Members of *Carex* are perennial herbs with branched, tufted or creeping woody rhizome clothed with remnants of old bladeless sheaths. Culms arise centrally or laterally, erect, mostly triquetrous or trigonous, solid or sometimes hollow (**Figure 1**). Leaves are mostly basal with distinct petiole and ligule at the junction of blade and sheath. Inflorescence paniculate, racemose or spicate, more rarely reduced to a single terminal spike. Involucral bracts are foliaceous, setaceous or glumaceous. Florets are unisexual and devoid of perianth. The male flowers of *Carex* possess three stamens subtended by a glume directly inserted on the axis while the female flowers are enclosed in a sac-like organ, called the utricle or perigynium. The utricle indicates the presence of a lateral axis, often called the rachilla, and is usually short and inhibited at an early stage in the genus (Kunth, 1835; Kuekenthal, 1909). The adaxial side of a lateral branch of *Carex* possess three kinds of prophylls: the swollen (or inflorescence) prophyll, the cladoprophyll and the glumaceous prophyll. The swollen prophyll is at the base of paracladia in the core *Carex* clade (Reznicek 1990). It is same as that of empty perigynium, and referred as the perigynium-like prophyll (Snell 1936). The cladoprophyll is a tubular sheath near the base of peduncles of pseudospikes. The prophyll that appears at the basal position on the bud is membranous, glume like, shorter and colourless (Kukkonen, 1994).

Figure 1. *Carexbaccans***-** Inflorescence, spikelet, utricle and nut

***Cyperus* L.**

The type genus *Cyperus* L. is the second largest genus included under the tribe Cypereae of subfamily Cyperoideae, with about 964 species reported globally, and it was described by Linneaeus in his ‘Species Plantarum’ with *Cyperus esculentus* as the type species (Bruhl, 1995).The genus occurs worldwide from tropical to temperate regions, with a concentration of species and presumed origin in tropical Africa (Goetghebeur, 1998; Spalink *et al.*, 2016). *Cyperus* shows remarkable ranges of adaptability to varied ecological conditions, mostly growing on damp, marshy and waterlogged places.

Cyperus is a taxonomically complex genus and the status of infra generic divisions are still under confusion among the taxonomists. The genus can be easily recognized by its nature of inflorescence with conspicuous involucral bracts, absence of perianth and distichous spikelets with several fertile glumes (**Figure 2**). Most of the species are annual or perennial herbs. Annuals are with fibrous roots only, but perennials are with short or long stolons, sometimes emitting tubers (*Cyperus rotundus*). Leaves alternate, spirally arranged in a basal rosette, terminal simple to decompound inflorescence, as anthelodia, glomerules, spikes, subdigitate spikes, digitate clusters or fascicles.

Figure 2.*Cyperus pilosus***-** Inflorescence, spikelet and nut

The first attempt to classify the genus was done by Nees (1834), and divided the genus into eight sections. In 1935-36 Kuekenthal made a comprehensive revision of the genus and divided into 6 subgenera, 61 sections and 8 sub sections. Classification of the genus is controversial due to the morphological diversity and the presence of several convergent evolutionary lines. The latest molecular works reveal that the core genus *Cyperus* includes several segregate genera. Taxonomic complexity of the genera resulted in the accumulation of 79 subdivisional names of which 20 are not validly published and two are illegitimate (Wim Huygh*et. al.*, 2010). Nees in 1834 proposed the first infra generic classification and divided the genus into eight sections. According to Kunth (1837) and Steudel (1834), *Mariscus* and *Kyllinga* are segregated genera. Recently Larridon *et al.* (2011, 2014, 2022) recognized a new classification of the genus *Cyperus* and elucidated the phylogenetic relationships and generic delimitation in C4 *Cyperus*, combining the genera like *Ascolepis*, *Kyllinga* and *Pycreus*.

***Rhynchospora* Vahl**

Rhynchospora Vahl, commonly known as 'beaked sedge or beak-rush', with 399 species worldwide, is predominantly distributed in warm temperate zones and the neotropics but its centre of distribution is the Americas. The diagnosis is primarily based on characters of the 2-sided achene including style base and bristles (**Figure 3**). The terminal portion of the achene is crowned by the persistent style base which is often termed to as the nut-beak.

Figure 3. *Rhynchospora corymbosa*-Inflorescence and nut

***Fimbristylis* Vahl.**

The genus *Fimbristylis* Vahl has about 320 species and distributed widely in pantropical and warm temperate regions of the world with the highest concentration of species in tropical Asia (Viji *et al*., 2016). The genus was described by Martin H. Vahl (1805) with *Fimbristylis dichotoma* as the type species. The members can be easily recognized with many flowered spikelets, bisexual florets without hypogynous bristles and deciduous style-base (**Figure 4**).

Figure 4. *Fimbristylis dichotoma*-Inflorescence, spikelet and nut

Fimbristylis, *Bulbostylis* and *Abildgaardia* are morphologically confusing genus and are under wide debate. Based on embryo type, Lye and Haines (1983) placed *Abildgaardia* and *Bulbostylis* within a single genus. Based on the fact that style base persists or not, Clarke (1893), Barros (1947) and Kern (1974) included *Abildgaardia* as a section under *Fimbristylis* and treated *Bulbostylis* as a separate genus. However, based on morphological similarities, Bentham (1883) and Koyama (1961) recognized *Abildgaardia, Bulbostylis* and *Fimbristylis* as a single genus namely *Fimbristylis*. Molecular phylogeny supports the division of *Abildgaardia, Bulbostylis* and *Fimbristylis*, but the relationship among these genera is still unclear (Ghamkar *et al.*, 2007).

***Eleocharis* R. Br.**

The genus *Eleocharis* R. Br., commonly known as 'spike sedge', is a cosmopolitan genus with marked concentration of taxa in subtropical America (Goetghebeur, 1998) and a presumed origin in North America (Spalink *et al.*, 2016). *Eleocharis* species are distributed in seasonally wet to permanently flooded habitats from tropical to temperate regions of both the hemispheres with 302 species. Classification of *Eleocharis* is difficult because relatively few macroscopic characters such as unbranched culms, rudimentary leaves with basal, tubular sheaths, reduced inflorescence to a simple terminal spikelet and absence of involucral bracts are provided as characteristic of the genus (**Figure 5**).

Figure 5. *Eleocharis* dulcis**-** Habit, spike and nut

***Scleria* Bergius**

The genus *Scleria* Bergius, with a presumed origin in South America, is distributed in tropical and warm-temperate regions of both the hemispheres with about 258 species globally (Spalink *et al.*, 2016). There are some peculiar structures providing taxonomical delimitation to this genus such as hypogynium, hardened disc at the base of the achene and contra-ligule (**Figure 6**). The flap like structure is present on the rim of the leaf sheath on the opposite side from the blade and is membranous. The nature of hypogynium may be a prominent collar or an inconspicuous ridge around the point of attachment of the achene. Before the abscission of achene, the hypogynium is attached to a concave disc, the cupula, which remains with the inflorescence when the achene is shed.

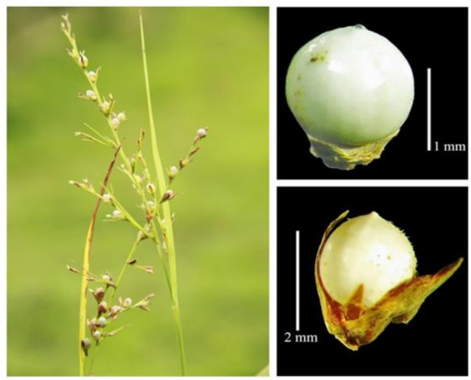

Figure 6. *Scleria levis*- Inflorescence and nut

***Bulbostylis* Kunth.**

The genus *Bulbostylis* Kunth. emerges as monophyletic within tribe Abildgaardieae and comprises 227 species, distributed mainly in the tropical and subtropical regions of the world (Larrindon *et al.*, 2021).

Figure 7. *Bulbostylis barbata* and *Bulbostylis densa*

The genus is mainly recognized by the achenes crowned by a persistent, button-like style-base, apical leaf-sheath trichomes, trifid or bifid styles, the trigonous or rarely biconvex nutlets, and the stylopodium that varies from persistent to deciduous on the nutlet apex (**Figure 7**). Species inhabit varied habitats from open to non-forested areas, growing on sandy substrates and are important components of natural open herbaceous vegetation (Goetghebeur, 1998).

Conclusions

Only a limited number of researchers have taken up the study of Cyperaceae group and as such the status of knowledge on the sedge flora of various regions of the world is not of the required level of perfection. Despite of the economic and ecological significance and wide occurrence, sedges receive little attention from flora workers because of the minute flowers enclosed in glumes and arranged in complicated inflorescence of spikelet, along with inadequate herbarium collections, and the need for basic taxonomic surveys is often emphasized for this plant group.

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Chapter 3

Diversity of the Genus *Cyperus* L.

Abstract

The genus *Cyperus* L. is widely distributed in tropical and temperate regions of the world and flourishes in soils along the waterlogged areas or soils with reasonable moisture content. World over, 964 *Cyperus* species are reported and the genus has remarkable species richness in India with 92 taxa, of which 58 species are reported in south India. The infrageneric classification of the genus is controversial and several assumptions have been made by various taxonomists. The general morphological features of the genus, dominant *Cyperus* species of the world and a detailed view on the world's worst sedge *Cyperus rotundus* are discussed in this chapter.

Introduction

Cyperus L., the taxonomically complex genus included under the tribe Cypereae of the subfamily Cyperoideae, is distributed widely from tropical to temperate regions with a concentration of species and presumed origin in tropical Africa (Goetghebeur, 1998; Spalink *et al.*, 2016). Presence of both C3 and C4 species is a favourable factor for the genus to expand their diversity to tropical as well as temperate regions of the world. However, the genus is species rich in tropics where it exhibits remarkable species richness. Thegenus shows a wide range of distribution, while other genera are somewhat habitat specific. In terms of their wide distribution and occurrence, *Cyperus* species are generally characterised as weed. Bryson and Carter (2008) cited 147 species of *Cyperus* as weeds. The most important weeds of this genus in terms of their adverse effect on agriculture include *C. rotundus, C. esculentus, C. difformis* and *C. iria* ranking 1^{st}, 16^{th}, 32^{nd} and 33^{rd} respectively among the world's worst weeds (Bryson and Carter 2008; Holm *et al.*, 1977).

Cyperus species are major natural constituents of wetlands and riverside vegetation and become the chief primary producers of grasslands and marshlands. Densely tangled rhizome of these species helps in erosion control and water purification. Some of them are serving as important indicators of environmental damages, especially to lowering of water table. In swampy areas sedges forms dense beds, which provides food and shelter for birds and animals. Several species of *Cyperus* are cultivated as ornamentals including *C. involucratus* and *C. albostriatus*. The genus has considerable economic importance as well. Several species under the genus provides food, fodder, medicines, weaving materials and perfumery materials.The historically important paper making plant *C. papyrus* is also used in horticulture for planting along the waterways. *Cyperus pangorei*is exclusively used for making of mats and is highly stable and the peculiar arrangement of fibro vascular bundles in the culms is of great advantage contributing to the productivity of mat industry (Ravichandran *et al*., 2005).

Infra generic delimitation of *Cyperus* species

The status of infra generic divisions of this genus is still under confusion among the taxonomists due to the morphological diversity and the presence of several convergent evolutionary lines. Nees (1835) proposed the primary infra generic classification and divided the genus into eight sections. In line with Kunth (1837) and Steudel (1855), *Mariscus* and *Kyllinga* are segregated genera. Kükenthal (1936), Haines and Lye (1983) and other subsequent workers accepted *Cyperus sensulato* and treated *Kyllinga* Rottb. and *Pycreus* P. Beauv. as of infrageneric rank. Recent molecular studies reveal that the core genus *Cyperus* includes several segregate genera. Goetghebeur (1998) included *Kyllinga*, *Pycreus* and other related taxa at generic level and proposed *Cyperus sensustricto* encompassing two subgenera. Taxonomic complexity of the genera resulted in the accumulation of 79 subdivisional names within the taxa, of which 20 are not seems to be validly published and two are illegitimate (Wim Huygh *et al*., 2010). Recent molecular phylogenetic analysis, following the classification of Goetghebeur (1998) and Govaerts *et al*. (2007) revealed that the *Cyperus* clade is a monophyletic clade including the paraphyletic genus *Cyperus sensustricto* encompassing at least 12 segregate genera (Simpson *et al*., 2007; Muasya *et al*., 2009). Larridon *et al*. (2011, 2013) proposed two subgenera under the genus *viz*., *Cyperus* subgenus *Anosporum* with C3 photosynthesis and eucyperoid anatomy (paraphyletic but forming a clearly circumscribed natural group) and *Cyperus* subgenus *Cyperus* with C4 photosynthesis and chlorocyperoid anatomy (monophyletic). He also presented a new sectional classification for *Cyperus* subgenus *Anosporum* based on a well resolved phylogeny and a new classification of the genus

Cyperus and elucidated the phylogenetic relationships and generic delimitation in C4 *Cyperus*, combining the sedge genera like *Ascolepis*, *Kyllinga* and *Pycreus*.

General morphology of *Cyperus* species

Species under *Cyperus* are mostly annuals or perennials and growing in a tuft, which forms dense vegetation in the areas where they grow. The members are recognized by the presence of a rosette of linear leaves, formed as the result of the combination of short internodes with spirally alternate leaves, terminal inflorescence, distichously arranged glumes, bisexual flowers, trifid style and trigonous nuts. The inflorescence is compound, essentially a panicle of spikelets with the main axis called a culm (**Figure 1**). The ultimate branch is always a lateral spikelet, consisting of a rachilla and spirally to distichously placed glumes, each subtending a bisexual flower. Lateral spikelets are subtended by a bract and have a prophyll (Goetghebeur, 1998). Several species are highly variable and shows polymorphism even within the species, leading to ambiguity to distinguish them based on the morphological features, and the specific delimitations are done by minute floral features. As a result, there has been intermixing of taxa, which further result into species complexes.

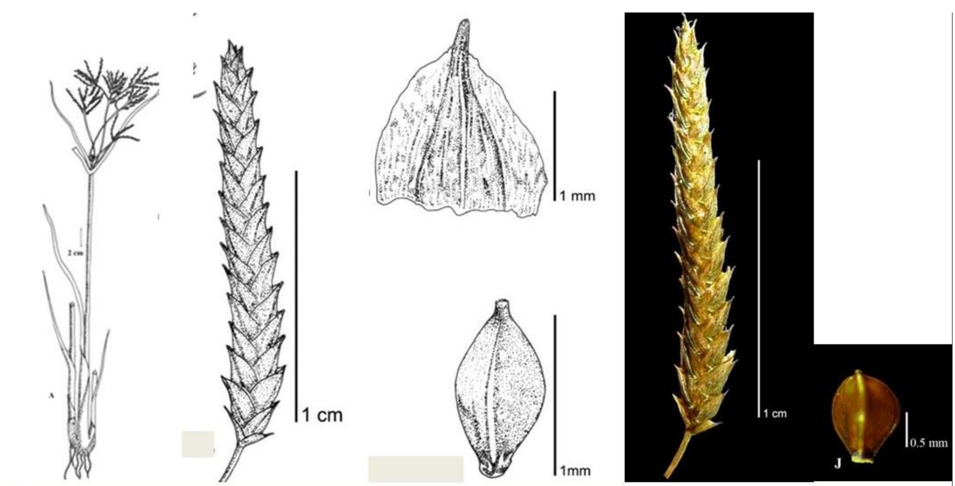

Figure 1. Habitat and floral organs of *Cyperus*

Distribution of *Cyperus* species

Studies proved that sedges flourish in soils with moderate to high moisture regimes as they have ability to adapt to such situations. The seeds are produced in large quantities and dispersed by means of wind, rain or slow water current along the nutrient rich muddy substrate. Species such as *C. haspan and C. pilosus* showed strong affinity towards alkaline rich soils while *C. iria, C. difformis* and *C. rotundus* showed affinity for acidic soils with rich organic matter content. Most of the *Cyperus* species are hygrophilous or moisture-loving and abundantly located in the water-logged areas such as ponds, canals, lakes, tanks, rivers and rice fields. Some are found in areas of low water availability or seasonally mesic or moderate growing conditions. Species such as *C. stoloniferous* and *C. arenarius* are arenophilous and confined to coastal areas. Some of the high altitude *Cyperus* species are petrophilous or cremnophilous. Species such as *C. diffuses* and *C. macrostachyos* are distributed in wet forest margin.

***Cyperus rotundus* L.**

Cyperus rotundus L. is one of the highly variable taxa of the genera *Cyperus*, forming species complexes, suggested having origin in Asia. The species belongs to the section rotundii andis a perennial herb, commonly known as ‘puple nut sedge’ due to its characteristic reddish-brown-purple spikelet. They have an unfavourable effect on natural ecosystems by displacing native plants or by reducing the availability of food or shelter for native animals. It can tolerate highest temperatures and grows in cultivated fields, waste areas, roadsides, pastures and natural areas. The rapid growing plant can quickly develop dense colonies due to its ability to produce an extensive system of rhizomes and tubers. The mass production of tubers is an efficient means of dispersal mechanism and reproduction and these characters along with the ineffectiveness of herbicides make this weed nearly indestructible.

Taxonomy of *Cyperus rotundus* L.

The plant usually grows 20-50cm tall, and occasionally taller under favourable conditions. Culms usually erect, solitary, smooth and trigonous with terminal inflorescence. Leaves are dark to bright green, glossy, slightly serrated, and generally shorter than the culm. There are up to 22 leaves per plant, emerging in three vertical rows near ground level. Inflorescences simple to compound corymb, loose and variable in size, consisting of 3-9 rays of different length. Spikes densely to sub-loosely bearing 3-12 spikelets with glabrous rachis (**Figure 2**). Spikelet is spicately arranged, suberect to spreading, compressed, linear and 10-14 flowered. The nuts are trigonous, oblong-obovoid and brownish. Nutgrass may be distinguished from other common *Cyperus* species by the darker green leaves, the umbrella shape rather than a dense or bottlebrush-style, and reddish brown or purplishbrown flower heads. Sub-globose shaped tubers will help the plant to easily distinguish from closely allied species.The species exhibits plasticity and are morphologically different under different conditions and this led to description of ecotypes.

Figure 2. *Cyperus rotundus*-Habit, spikelet and nut

Synonyms for *Cyperus rotundus* L.

Chlorocyperus rotundus (L.) Palla
Cyperus olivaris Targioni Tozzetti
Cyperus purpurovariegatus Boeckeler
Cyperus stoloniferumpallidus Boeckeler
Cyperus tetrastachyos Desf.
Cyperus tuberosus Roxb
Pycreus rotundus (L.) Hayek

Common names for *Cyperus rotundus* L.

Arabic: Sa'ed
Burmese:Vomonniu
Chinese: Suo cao, Xiang fu zi

English: Coco grass, Ground almond, Java grass, Nut sedge, Nut grass, Purple nutsedge, Purple nutgrass, Red nut sedge
French: Souchet rond
German: Knolliges Zypergras
Indian: Motha, Mutha, Musta,
Italian: Zigoloinfestante
Japanese: Hamasuge
Korean: Hyangbuja
Malayan: Mushkezamin
Persian: Mushkzenezamin
Portuguese: Alho-bravo, Capimalho, Capimdandá, Tiririca, Tiririca-vermelha
Spanish: Castañuela, Cipero, Coquito, Juncia real
Swedish: Nötag
Urdu: Saad kufi

Distribution of *Cyperus rotundus*

Though India is considered as the centre of origin of purple nutsedge, it is yet to be ascertained (Holm *et al*., 1977; Molin *et al*., 2019). This species occasionally occurs in more temperate regions but widely distributed throughout the warmer regions of the world. It is estimated to be distributed in more than 92 countries in;

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Chad, Cote D'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Kenya, Libya, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zaire, Zambia, Zimbabwe

Asia: Afghanistan, Armenia, Azerbaijan, China, India, India, Indonesia, Iran, Iraq, Japan, Kazakhstan, Korea, Kyrgyzstan, Lebanon, Malaysia, Myanmar, Nepal, Pakistan, Palestine, Philippines, Russia, Saudi Arabia, Sri Lanka, Syria, Taiwan, Thailand, Turkey, Turkmenistan, Uzbekistan, Vietnam, Yemen

Europe: Albania, Austria, Bulgaria, Croatia, France, Greece, Marshall Islands, Micronesia, Northern Mariana Islands, Portugal, Romania, Serbia, Slovenia, Spain, Switzerland

North America: USA and Mexico

South America: Argentina, Bolivia, Brazil, Colombia, Ecuador and Peru

A recent investigation of the genetic diversity among geographically separated *C. rotundus* accessions based on RAPD markers and morphological characteristics revealed that the global population of purple nutsedge consisted of two clades. Accessions from USA, Taiwan, Western Samoa, New Zealand, Malaysia, Japan, El Salvador, Columbia, Australia, Thailand and West Indies formed one cluster, while the second cluster included accessions from Sudan, Greece, Iran, Brazil, Argentina, Mauritius, Philippines, Indonesia and Tanzania. The lack of genetic diversity among accessions supported the hypothesis that the spread and propagation into new environments were largely by tubers which preserved genetic identity. The lack of diversity particularly among New World and USA accessions may also reflect a relatively recent introduction of the species into the Americas and a low level of outcrossing (Molin *et al*., 2019).

Seasonality, soil types and climate preference of *Cyperus rotundus*

Nutgrass is a perennial sedge species that favours tropical and subtropical climates and shows abundant growth in low-lying areas where water accumulates, and the plant is distributed in more than 92 countries. The species infests at least 52 different crops worldwide, and hence got the notorious designation as “world’s worst” weed (Holm *et al*., 1977). Below 20°C, plant growth is slow and tuber sprouting is inhibited. In temperate areas, new seedlings will commence in spring, once temperatures start to increase. In more arid conditions, an increase in soil moisture appears to be more stimulant for its growth. Flowering more commonly occurs during summer, and under favourable conditions, flowering may occur in 3-6 weeks after emergence. Plant growth can be restricted by shade as well as by lower temperatures and saline soils. The plant appears to be susceptible to extended dry conditions. When tubers are dried out until their water content reaches 15%, the tubers will not survive. Plant growth rate is high in hot weather, high light and high temperatures. During drought or flooding, tubers that are commonly found several centimeters underground, can remain dormant and viable for future regrowth once conditions suit.Normally the plant prefers moderate to high fertility soils, and moderate moisture levels. However, around the world it has been observed that it can tolerate almost every soil type, moisture level and soil pH.

Growth, development and impact of *Cyperus rotundus*

Cyperus rotundus is perennial and producing short rhizomes and emitting long, slender stolons clothed with brownish scales. Rhizomes are white and fleshy with scale leaves during their production and as they mature, become ligneous or wiry. Later the rhizomes grow upwards and reach the surface, swell to form a basal bulb, or corm that grows into a new plant producing shoots, roots and rhizomes (Wills, 1987). Rhizomes that do not grow towards the surface may produce chains of tubers, each of which may separate from the parent plant and lie dormant for years before growing into a new plant (Hauser, 1962; Holm *et al.*, 1977). They are prolific in disturbed soil due to their tuber production which can remain as dormant for several months. Production from rhizomes and tubers is the most common method adapted to increasing numbers and quantity. Rochecouste (1956) reported that *C. rotundus* produces 6 and 14 times more tubers in humid conditions (1250 to 2500 mm of annual rainfall) than in sub-humid (less than 1250 mm of rain) and super-humid (greater than 2500 mm of rain) conditions. He also observed that in humid regions the abundant growth of this sedge severely restricts water availability to sugarcane and other crops. These tubers are resilient and can survive extreme conditions of flooding, drought, heat and lack of aeration (Holm *et al.*, 1977).

The organic substances released from the decay of dead subterranean tissues of *Cyperus rotundus* may be allelopathic and reduce crop production. Under experimental conditions, barley yield was reduced by 15 to 25% by *C. rotundus* residues in the soil (Horowitz and Friedman, 1971). Rhizomes and tubers are produced extensively and most tubers are found growing in 15 to 20 cm of soil, a few penetrate more than 40 below the soil. Rao (1968) reported that under favourable conditions, a single tuber could produce 99 tubers in 90 days. They produce flowers abundantly but rarely produce viable seeds. Tubers and basal bulbs help in vegetative propagation. *Cyperus rotundus* is C4 plant, which is an adaptation to assimilating CO_2 at higher temperatures and higher light intensities compared to C3 pathway plants. Wills (1987) suggest that the leaf anatomy is Krantz-type and sheaths of cells that form around the vascular bundles serve to compartmentalize the photosynthetic events.

Cyperus rotundus is considered as the world’s worst weed and they are known to produce allelochemicals that hinder the crop growth. It is one of the most significant weed species and competes vigorously with most crops for soil moisture, nutrients and light, and the competition is remarkable with crops that do not form dense canopy. Rhizomes and tubers from nutgrass plants may also interfere with harvesting operations for root crops and it can also increase postharvest processing costs.

Being a notorious weed, the possibility of producing huge quantity of *C. rotundus* tubers in various geoclimatic conditions across the globe is high. During active growing periods, 2-3 million tubers/ha/week can be produced yielding 30-40 million tubers/ha (Horowtz, 1972). *Cyperus rotundus* produces up to 40,000 kilograms of subterranean plant material per hectare in a year. In addition, tuber has 16 months half-life and 42 months predicted longevity (Neeser *et al*., 1997). The rich biomass is yet to be exploited to its full potential.

***Cyperus esculentus* L.**

Cyperus esculentus L**.,** commonly known as 'yellow nut sedge, is a potential perennial weed with a worldwide distribution. Holm *et al*. (1977) regarded it as the world's 16th worst weed. Although yellow nutsedge produces viable seeds, the weed usually spreads by means of the small tubers produced on the rhizomes, and hence a population in a single field may be the progeny of one or only a few genotypes (Horak and Holt 1986). Its centre of origin is undetermined, but it is believed to be originated from the Mediterranean and Southwest Asia. The first study of the infraspecific taxonomy of *Cyperus esculentus* was done by Boeckeler (1870) and he recognized a cultivated taxon, *C. esculentus* var. *sativus*, known as earth almond, tiger nuts, or chufa, which is distinguished by its large edible tubers. *Cyperus esculentus* is perennial with usually long fleshy rhizomes producing new shoots or with one persistent tuber at the end. Leaves are linear, clustered, pale green with triangular culms. Spikes compound, with secondary peduncles branched, with 30-50 compressed spikelets. Tigernut is used as a source of food, medicine and perfumes and it can be eaten raw, roasted, dried, baked or made into a refreshing beverage called 'Horchata De Chufas' or tigernut milk which is very nutritive (De Vries, 1991). The tubers are very nutritious, containing proteins, fats, starch, glucose, fibre, vitamins, enzymes and minerals (Burden, 2003). The nuts have medicinal values and are reported to be aphrodisiac, carminative, diuretic, stimulant and tonic which can be used in the treatment of constipation, high blood pressure and diarrhoea (Oladele and Aina, 2007).

The ancient Egyptians first recognized the importance of this plant in culinary and medicinal purposes (Negbi, 1992). Nowadays the species has been widely cultivated in

Spain, Africa, Australia, South and North America. The annual value of *Cyperus esculentus* production in Spain is around 3.3 million Euros (Zhang *et al*., 2022). The species has strong allelopathic effect on many crops such as corn and soybean and found that the tuber residues reduced the dry weight of corn and soybean, and as the concentration increased, the growth decreased, affecting soybean more than corn (Zhang *et al*., 2022).

Cyperus esculentus is closely related to *C. rotundus* and their separation is based on distinction between vegetative characters (**Figure 3**). Both the species are variable in nature; the propagation is almost vegetatively by means of tubers. For their proper identification, the underground parts are necessary, and also the species can be identified by the colour of the inflorescence. *C. rotundus* having purple to red-brown flowers and ellipsoid tubers are borne in chains along the rhizomes. The culm arises from the nodule of the rhizome; rest of the portion is slender and wiry. The nodule or the tubers are much starchy. *C. esculentus* is golden-yellow flowered and tubers borne singly at the tip of rhizomes, which are globose in shape and covered by a grey tomentum and the stolons are very slender.

Figure 3. *Cyperus rotundus* and *Cyperus esculentus*

***Cyperus difformis* L.**

Cyperus difformis L., is an annual sedge species, commonly known as ‘variable flat sedge’ or ‘small flower umbrella-sedge’. This plant is native to southern Europe and naturalized throughout the world (Holm *et al*., 1991). It is a prolific seed producer with short life span and complete the vegetative and reproductive cycle within a month. The species grows well in flooded or moist fertile soils and common in lowland. They can thrive well in poorer sandy or clay soils in fallow lands but cannot tolerate deep flooding. It is frequently found in water logged areas such as pools, along rivers, canals, streams and in open wet places and in grassy swamps. Jacometti (1912) reported that one plant could produce 50,000 seeds, with about 60% germination. Like rice, *C. difformis* has the C3 photosynthetic pathway, which favours its growth in submerged soils. According to Holm *et al.* (1977), *C. difformis* is a serious weed of rice in various countries in the world and resistant to rice field herbicides.

C. difformis varies in height from 5 to 60 cm. The culms are smooth, triangular, and slightly winged with numerous, fibrous and reddish roots. The leaves are smooth flat, linear or sometimes reduced to green to reddish-brown tubular sheaths.The inflorescence consists of dense, globose, umbellate heads, simple or compound with stellately spreading spikelets and subtended by 1-4 leaf like bracts (**Figure 4**). Spikelets are linear to oblong-linear, compressed but slightly swollen with 6-30 flowers. Glumes obovate, pale-yellowish to dark reddish-brown with yellow or white margins and a green midrib ending in a short mucro. Stamens 1-2, achenes triangular, obovate-elliptic, yellowish-brown or pale-brown with minutely papillose.

Figure 4.*Cyperus difformis*- Inflorescence and nut

***Cyperus haspan* L. and *Cyperus tenuispica* Steud.**

Cyperus haspan L. is common weedy species distributed in tropics and subtropics in Africa, through Asia to Australia.The plant grows abundantly in wet open places, swamps, pastures, rice fields, wet grassland, as well as on thin wet soil over rock and in ditches and serves as the indicator of water. *Cyperus haspan* is an annual to perennial sedge with soft, almost succulent growth. The roots are fibrous when the plant is an annual, with slender, horizontal, short or elongated rhizomes being produced when the plant perennates. Culms are slender, compressed triquetrous, and smooth with shorter leaves, sometimes sheathed only and bladeless; sheath pale green, base purplish brown to reddish purple. Inflorescence simple, compound, or decompound anthela with digitately arranged, linear to narrowly linear-ovoid, 6-28flowered spikelets in wingless rachilla. It is an economically useful plant species, and often used as food and fodder species by the people of Tropical and East Africa. Culm of this plant is used to make baskets and mats. Milliken (1997) has reported the medicinal use for *C. haspan*, particularly rhizome, used with other febrifuge plants by Wayapi, the indigenous peoplein French Guiana.

C. haspan L. and *C. tenuispica* Steud. belonging to the section *Haspani*, are morphologically similar in appearance (**Figure 5**). *C. haspan* forms creeping rhizome and the culms are tufted or scattered, whereas the culms of *C. tenuispica*are always tufted (Goetghebeur, 1998). For *C. haspan*, the leaves are very short, often reduced to mere short appendages of the sheaths and the involucral bracts are short and less in number.

Figure 5.*Cyperus tenuispica* and *Cyperus haspan*

***Cyperus pilosus* Vahl., *Cyperus iria* L. and *Cyperus distans* L.f.**

Species like *C. pilosus*, *C. iria* and *C. distans* are highly variable in nature (**Figure 6**). *C. pilosus* is centred in Southeast Asia, from where itextends to other regions of the world, and is a common rice weed. This species is more frequent in the habitats of South India especially in Kerala, and can be easily identified by the nature of the inflorescence with the hairy rachilla of the spikelet. Culms usually triquetrous and having antrose prickle hairs on wings edges.

Cyperus iria, commonly known as 'rice flatsedge,'is a tufted annual or perennial herb with short yellowish-red fibrous roots. Culms sharply 3-angled, smooth, yellowish red with linear to lanceolate leaves. Involucral bracts are leafy with spicate inflorescence. Spikelets are erect and spreading. It reproduces by means of seeds which may be dormant but can germinate about 80 days after shedding. One plant may produce more than 3000 seeds.

Cyperus distans, also known as 'slender cyperus', is distributed throughout the pantropical and subtropical regions of the world. It is an annual herb, found commonly in damp locations along rivers, roadside ditches, coastal and midland areas. The leaves are long and narrow, with scabrous margin. The stem is trigonous and carries a diffuse, compound inflorescence subtended by leafy bracts. Terminals peduncle carries cylindrical and elongated linear, reddish-brown spikelets which are spread out more or less at right angles.

Figure 6.*Cyperus pilosus*, *Cyperus iria* and *Cyperus distans*

***Cyperus compressus* L. and *Cyperus sphacelatus* Rottb.**

Cyperus compressus and *C. sphacelatus* are morphologically alike and are difficult to discern (**Figure 7**). *C. compressus*is pantropical in its distribution and are common in grasslands, waste places and cultivated areas. Rhizome of this species is used as vegetable and also fodder for animals. Rhizomeshave characteristic *Cyperus* odour and are used for scenting oil. In India, roasted tubers of *C. compressus* is made into a paste and mixed with coconut oil and is used for killing lice (Deokule and Magdum, 1992; Simpson and Inglis, 2001).

Figure 7. *Cyperus compressus* and *Cyperus sphacelatus*

C. sphacelatus is assumed to be originated in Tropical Africa and Tropical America, from where the species was introduced to elsewhere. It is a common weed in cultivated lands and waste places, and consumed by grazing animals. Both the species are annuals with fibrous roots and very similar in external features. However, *C. sphacelatus* is unique in having a purplish spot on one or both sides of the glumes which gives an impression of a purplish stripe along the centre of the spikelet.

***Cyperus paniceus* (Rottb.) Boeckeler, *Cyperus cyperoides* (L.) Kuntze and *Cyperus cyperinus* (Retz.) Sur.**

Cyperus paniceus is morphologically similar to *C. cyperoides* and *C. cyperinus*, and often difficult to distinguish between (Prasad and Singh 2002). Among the three species, *C. paniceus* has a narrower distribution from Indian subcontinent to Indo-China region, and are widely distributed across Asia and Oceania. They are usually found in open, wet to seasonally wet areas and slightly shaded areas. These species can be easily separated from each other by the nature of spikelets and number of nuts per spikelet (**Figure 8**). *C. paniceus* always bears only one nut per spikelet and the plant emits slender stolons.

Figure 8.*Cyperus cyperoids* and *Cyperus cyperinus*

In *Cyperus cyperoides*, the spikelets are at right angles to the rachis, and the appearance of spikelet is exactly cylindrical. But in *Cyperus cyperinus*, the spikelets are obliquely erect and the spikes are attenuate at the base and are almost sessile. Among the three species, *C. cyperoides* is used for medicinal purpose. The plant ash is used to heal wounds in Nepal (Manandhar, 1989; Simpson and Inglis, 2001). In Philippines, the infusions of nutlets are used for toothache (Siri von Reis Altschul, 1973; Simpson and Inglis, 2001).

Conclusions

Though most of the *Cyperus* species are serious agricultural weeds, they also have considerable economic, ecological and ethnobotanical importance. Inspite of the wide distribution, utilities and ecological importance, the plant group is considered as a taxonomically complex genus and the status of infra generic divisions are still under confusion among the taxonomists. Taxonomic complexity of the genera resulted in the accumulation of several subdivisional names of which many are illegitimate. Further, there is no systematic study performed till date to evaluate the phytogeographical variation and genetic differences of *Cypeus* species, especially in India. An intense and in-depth study of this group with proper taxonomic clarity may lead to better understanding of conservation and utilization prospects.

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Chapter 4

Diversity of Cyperaceae Members in South India

Abstract

South India is a peninsula in Asia having divergent ecosystems. The hot and moist climate, high rainfall and variety of microclimates support luxuriant growth of sedges in this biodiversity rich area. The sedge members show a wide variety of distribution pattern including low land, wet land, shallow open water bodies, forest margins and even high-altitude grasslands and rocky slopes. In south India, 274 taxa in 24 generaare distributed, among which, *Fimbristylis* (78 species) and *Cyperus* (58 species) are the dominant genera. The chapter deals with diversity and distribution of sedges in South India.

Introduction

The geography of South India is divergent and embraces floristically rich mountain ranges and varied ecosystems of wetlands and dry area. The region also haswide variation in the seasonal rainfall pattern, temperatureand edaphic factors, and the species richness and endemism are not uniform.However, the general topography of south India is favourable for Cyperaceae members to thrive. In south India, the family Cyperaceae is represented by 274 taxa in 24 genera, among which *Fimbristylis* (78 species) and *Cyperus* (58 species) are the dominant genera, followed by *Carex* (28 species), *Pycreus* (21 species) and *Scleria* (20 species) (**Table1**) (Nayar *et al.*, 2014; Nayar *et al.*, 2006; Prasad and Singh, 2002; Karthikeyan *et al.*1989).

Table1. Cyperaceae genera and species in South India

Sl. No.	Cyperaceae genus	Cyperaceae species
1.	*Actinoscirpus* (Ohwi) R. W. Haines & Lye	1. *A. grossus* (L.f.) Goetgh. &D.A.Simpson
2.	*Bulbostylis* Kunth.	1. *B. barbata* (Rottb.) Kunth ex Clarke in Hook. f. 2. *B. barbata* (Rottb.) Kunth ex Clarke ssp. *Pulchella* (Thw.) Koyama 3. *B. densa* (Wall. ex Roxb.) Hand.-Mazz. 4. *B. puberula* (Poir.) Clarke in Hook.f., 5. *B. Subspinescence* C.B.Clarke

3.	*Bolboschoenus* (Asch.) Palla.	1. *B. maritimus* (L.) Palla. ssp. *maritimus* 2. *B. maritimus* ssp. *affinis* (Roth) T. Koyama
4.	*Carex* L.	1. *C. baccans* Nees in Wight. 2. *C. breviculmis* R. BR. 3. *C. brunnea* Thunb. 4. *C. capillacea* Boott. 5. *C. christii* Boeck. 6. *C. filicina* Nees in Wight 7. *C. foliosa* D. Don. 8. *C. hebecarpa* ssp. *ligulata* (Nees) T.Koyama 9. *C. indica* L. 10. *C. jackiana* Boott. 11. *C. lateralis* Kuek. 12. *C. lenta* D.Don. 13. *C. leucantha* Arn. ex Boott. 14. *C. lindleyana* Nees in Wight 15. *C. longicruris* Nees in Wight 16. *C. longipes* D. Don. 17. *C. maculate* Boott 18. *C. myosurus* Nees in Wight 19. *C. nubigena* D.Don 20. *C. phacota* Spreng. 21. *C. pseudoaperta* Boeck. 22. *C. raphidocarpa* Nees. 23. *C. rara* Boott. 24. *C. speciosa* Kunth. 25. *C. stramentitia* Boott ex Boeck. 26. *C. vicinalis*Boott. 27. *C. walker* Arn. Ex Boott. 28. *C. wightiana* Nees in Wight
5.	*Courtoisiana* Sojak.	1. *C. cyperoides* (Roxb.) SojÃ¡k
6.	*Cyperus* L.	1. *C. alopecuroides*Rottb. 2. *C. alternifolius* L. 3. *C. alulatus* J. Kern. 4. *C. amabilis* Vahl. 5. *C.arenarius* Retz. 6. *C. articulates* L. 7. *C. bulbosus* Vahl. 8. *C. castaneus* Willd. 9. *C. cephalotes* Vahl. 10. *C. clarkei* Cooke 11. *C. compressus* L. 12. C. *conglomerates* Rottb. 13. *C. conglomerates* Rottb. ssp. *pachyrrhizus* (Nees ex Boeck.) Koyama

		14. *C. coonoorensis* Viji, Pandur., Deepu &G.C.Tucker 15. *C. corymbosus* Rottb., 16. *C. cuspidatus* Kunth. 17. *C. cyperinus* (Retz.) Sur. 18. *C. cyperoides* (L.) Kuntze 19. *C. difformis* L. 20. *C. diffusus* Vahl. 21. *C. digitatus* Roxb. 22. *C. distans* L. f. 23. C. *dubius* Rottb. 24. *C. elatus* L., 25. *C. esculentus* L. 26. *C. exaltatus* Retz. 27. *C. haspan* L. 28. *C. imbricatus* Retz. 29. *C. iria* L. 30. *C. javanicus* Houtt. 31. *C. karthikeyanii* Wad. Khan & Lakshmin. 32. *C. laevigatus* L. 33. *C. macer* C. B. Clarke. 34. *C. longus* L. 35. *C. maderaspatanus* Willd. 36. *C. malaccensis*Lam. 37. *C. mollipes* C.B.Carke. 38. *C. niveus* Retz. 39. *C. nutans* Vahl ssp. *eleusinoides*(Kunth) Koyama 40. *C. nutans* Vahl ssp. *nutans* Koyama in Dassan. & Fosb. 41. *C. papyrus* L. 42. *C. pangorei* Rottb. 43. *C. paniceus* (Rottb.) Boeck. 44. *C. pilosus* Vahl. 45. *C. platystylis* R. Br. 46. *C. procerus* Rottb. 47. *C. prolifer* Lam. 48. *C. pseudokyllingioides* Kuek. 49. *C. pulchellus* R. Br. 50. *C. pulcherrimus* Willd. ex Kunth. 51. *C. rotundus* L. 52. *C. rubicundus*Vahl. 53. *C. sphacelatus* Rottb. 54. *C. stoloniferous* Retz. 55. *C. squarrosus* L. 56. *C. tenuiculmis* Boeck. 57. *C. tenuispica* Steud.

		58. *C. zollingeri* Steud.
7.	*Diplacrum* R. Br.	1. *D. africanus* (Benth.) C. B. Clarke. 2. *D. caricinum* R. Br.
8.	*Eleocharis* R. Br.	1. *E. acutangula* (Roxb.) Schult. 2. *E. atropurpurea* (Retz.) Presl. 3. *E. congesta* D. Don. 4. *E. dulcis* (Burm. f.) Trimen ex Hensch. 5. *E. geniculata* (L.) Roem. & Schult. 6. *E. lankana* Koyama 7. *E. ochrostachys* Steud. 8. E. *ranganathensis* Viji, G.C.Tucker, Deepu & Pandur. 9. *E. pellucid* C.Presl. 10. *E. retroflexa* (Poir.) Urban ssp. *Chaetaria* (Roem. & Schult.) Koyama 11. *E. Sphacelata* R. Br. 12. *E. spiralis* (Rottb.) Roem. & Schult. 13. *E. Swamyi* Govind. 14. *E. tetraquetra* Nees
9.	*Eriophorum* L.	1. *E. comosum* (Wall.) Palla
10.	*Fimbristylis*Vahl.	1. *F. acuminata* Vahl. 2. *F. aestivalis* Vahl. 3. *F. agasthyamalaensis* Viji & Preetha. 4. *F. aggregata* C. E.C. Fisch. 5. *F. alboviridis* Clarke in Hook.f. 6. F. *angamoozhiensis* Ravi & Anil Kumar 7. *F. aphylla* Steud. 8. *F. argentea* (Rottb.) Vahl. 9. *F. arnottiana* Boeck. 10. *F. bispicula* Govind. 11. *F. bisumbellata* (Forssk.) Bubani 12. *F. carpopoda* Govind. 13. *F. cinnamometorum* (Vahl) Kunth. 14. *F. complanata* (Retz.) Link 15. *F. consanguinea* Kunth. 16. *F. contorta* C. E.C. Fisch. 17. *F. crystallina* Govind. 18. *F. cymosa* R.Br. 19. *F. dauciformis* Govind. 20. *F. dichotoma* (L.) Vahl. 21. *F. dichotoma* (L.) Vahl ssp. *glauca* (Vahl) Koyama 22. *F. dichotoma* (L.) Vahl ssp. *podocarpa* (Nees & Meyen) Koyama 23. *F. dimorphonucifera* Govind. 24. *F. dipsacea* (Rottb.) Clarke in Hook. f. 25. *F. dura* (Zoll. & Moritz.) Merr.

		26. *F. eragrostis* (Nees & Meyen) Hance 27. *F. falcata* (Vahl) Kunth. 28. *F. ferruginea* (L.) Vahl. 29. *F. hirsutifolia* Govind. 30. *F. hookeriana* Boeck. 31. *F. humerosa* Govind. 32. *F. hyalina* Govind. &Sasidh. 33. *F. insignis* Thw. 34. *F. kingie* Gamble ex Boeck. 35. *F. latinucifera* Govind. 36. *F. latiglumifera* Govind. 37. *F. lawiana* (Boeck.) J. Kern. 38. *F. littoralis* Gaudich 39. *F. longistigmata* Govind. 40. *F. manilaliana* Govind. 41. *F. matthewii* Murug., V. Balas. & Nagarajan 42. *F. merrilli* Kern. 43. *F. microcarya* Muller 44. *F. monospicula* Govind. 45. *F. monticola* Hochst. ex Steud. 46. *F. narayanii* C.E.C. Fisch. 47. *F. obtusata* (Clarke) Ridley 48. *F. ovata* (Burn. f.) Kern 49. *F. pandurata* Govind. 50. *F. paupercula* Boeck. 51. *F. perspicua* Govind. &Sasidh. 52. *F. polytrichoides* (Retz.) Vahl. 53. *F. pseudomicrocarya* Govind. 54. *F. pseudonarayanii* Ravi & Anil Kumar 55. *F. pubisquama* Kern. 56. *F. pustulosa* Govind. 57. *F. quinquangularis* (Vahl) Kunth. 58. *F. rigidiuscula* Govind. 59. *F.* rugosa Govind. 60. *F. salbundia* (Nees) Kunth ssp. *pentaptera* (Nees) Koyama 61. *F. schoenoides* (Retz.) Vahl. 62. *F. semidisticha* Govind. 63. *F. sieberiana* Kunth. 64. *F. simpsonii* Kunth. 65. *F. squarrosa* Vahl. 66. *F. stigmatotecta* Govind. 67. *F. swamyii* Govind. 68. *F. tenera* Schult. 69. *F. tetragona* R. Br. 70. *F. tortifolia* Govind.

		71. *F. tristachya* R. Br. 72. *F.tuckeri* Viji, Pandur. & Deepu 73. *F. tumida* Govind. 74. *F. uliginosa* Hochst. ex Steud. 75. *F. umbellaris* (Lam.) Vahl. 76. *F. velliangiriensis* Murug., V. Balas. & Nagarajan 77. *F. woodrowii C*. B. Clarke. 78. *F. zatei* Wad. Khan & D. P. Chavan
11.	*Fuirena* Rottb.	1. *F. ciliaris* (L.) Roxb. *2.* *F. cuspidate* (Roth) Kunth 3. *F. ponmudiensis* Ravi & Anil Kumar 4. *F. simpsonii* Ravi 5. *F. trilobites* C. B. Clarke. 6. *F. umbellate* Rottb. 7. *F. uncinata* (Willd.) Kunth
12.	*Hypolytrum* Rich. ex. Pers.	1. *H. nemorum* (Vahl) Spreng
13.	*Isolepis* R. Br.	1. *I.fluitans* (L.) R.Br.
14.	*Kyllinga* Rottb.	1. *K. brevifolia* Rottb. 2. *K. brevifolia* Rottb. var. *stellulata* (Sur.) Hooper 3. *K. bulbosa* P. Beauv. 4. *K. eglandulosa* Govind. 5. *K. melanosperma ssp. bifolia* (Miq.) Karthik. 6. *K. melanosperma*Nees, *K. nemoralis* (J. R & G. Forst.) Dandy ex Hutch. &Dalz. 7. *K. odorata* Vahl ssp. *cylindrica* (Nees ex Wight) Koyama 8. *K. polyphylla* Willd. ex Kunth. 9. *K. pumila* Michx. 10. K. *squamulata* Vahl.
15.	*Lepironia* Pers.	1. *L. articulata* (Retz.) Domin
16.	*Lipocarpha* R. Br.	1. *L. chinensis (*Osbeck) Kern 2. *L. gracilis* (Rich. ex Pers.) Nees 3. *L. hemispherica* (Roth) Goetgh. 4. *L. kernii* (Reymond) Goetgh. 5. *L. squarrosa* (L.) Goetgh.
17.	*Pycreus* P. Beauv.	1. *P. diaphanous* (Schrad. Ex Roem. & Schult.) S.S. Hooper & T. Koyama. 2. *P. flavescens* (L.) Rchb.f. 3. *P. flavidus* (Retz.) Koyama 4. *P. intactus* (Vahl) J.Raynal 5. *P. kanarensis* V. P. Prasad & N.P Singh. 6. *P. macrostachyos* (Lam.) Raynal 7. *P. mahadevanii* Govind. 8. *P. malabaricus* Clarke 9. *P. membranaceus* (Vahl) Govind.

		10. *P. opulentus* Govind. 11. *P. palghatensis* Govind. 12. *P. plurinodosus* (Govind.) P. Singh & V. Singh 13. *P. plicatus* Govind. 14. *P. polystachyos* (Rottb.) P. Beauv. 15. *P. pumilus* (L.) Nees 16. *P. puncticulatus* (Vahl) Nees in Mart. 17. *P. sanguinolentus* (Vahl) Nees ex Clarke in Hook. f. 18. *P. similinervulosus* Govind. 19. *P. stramineus* Clarke in Hook. f. 20. *P. sulcinux* (Clarke) Clarke 21. *P. unioloides* (R. Br.) Urb. var. *angulatus* (Nees) Domin
18.	*Queenslandiella* Domin.	1. *Q. hyalina* (Vahl) Ballard in Hook.
19.	*Remirea* Aubl.	1. *R. maritime* Aubl.
20.	*Rhynchospora* Vahl.	1. *R. corymbosa* (L.) Brit. 2. *R. graciliima* Thwaites & Hook. 3. *R. rubra* (Lour) Makino. 4. *R. rugosa* (Vahl) Gale ssp. *brownii* (Roem. & Schult.) Koyama 5. *R panduranganii* Viji, Shaju & Geetha Kum. 6. *R. submarginata* Kuk. 7. *R. wightiana* (Nees) Steud.
21.	*Schoenoplectiella* (L.) Lye.	1. *S. articulata* (L.) Lye 2. *S. juncoides* (Roxb.) Lye 3. *S.lateriflora* (Gmel.) Lye 4. *S. litoralis* (Schrad.) Palla ssp. *thermalis (*Trab.) S.S.Hooper in C.J.Saldanha& D.H. Nicolson 5. *S. mucronatus* (L.) Palla in Engl. 6. *S. senegalensis* (Hochest. Ex Steud.) Lye.
22.	*Schoenoplectus* (Rchb.) Palla.	1. *S. corymbosus* (Roth ex Roem. & Schult.) J. Raynal. 2. *S. subulatus* (Vahl.) Lye.
23.	*Scleria* L.	1. *S. annularis* Nees ex Steud. 2. *S. biflora* Roxb. 3. *S. corymbosa* Roxb. 4. *S. laevis* Retz. 5. *S. lithosperma* (L.) Sw. var. *linearis* Benth. 6. *S. lithosperma* (L.) Sw. 7. *S. neesii* Kunth 8. *S. mikawana* Makino. 9. *S. multilacunosa* T. Koyama. 10. *S. oblata* Blake 11. *S. parvula* Steud.

		12. *S. pergracilis* (Nees) Kunth. 13. *S. Poiformis* Retz. 14. *S. psilorrhiza* C. B. Clarke. 15. *S. rugosa* R. Br. 16. *S. sumatrensis* Retz. 17. *S. stocksiana* Boeck. 18. *S. terrestris* (L.) Fassett. 19. *S. swamyi* Govind. 20. *S. tessellata* Willd.
24.	*Trichophorum* Pers.	1. *T. subcapitatum* (Thw. & Hook.) D. A. Simpson

***Fimbristylis* Vahl.**

Fimbristylis Vahl is the fourth largest genus within the family Cyperaceae, and includes several homogenous subunits (Bruhl and Wilson 2007). The genus shows worldwide distribution, especially in the tropics and subtropics, a few species are found in the warmer parts of the temperate region also. About 320 species have been reported from all over the world, and majority are distributed in tropical Asia. More than 128 taxa have been reported from India (Prasad *et al.*, 2020), of which 37 are endemic, and peninsular India has maximum number of endemic species (Prasad and Singh, 1997). In south India, 78 *Fimbristylis* species are reported.

Figure 1. Common *Fimbristylis* species in south India; *F. aestivalis, F. dichotoma, F. dipsacea* and *F. miliaceae*

The genera *Fimbristylis* accommodate sedges with spirally imbricated glumes, each subtending a bisexual floret, with a biconvex or trigonous achene carrying a basally expanded, usually fimbriate margined, 2-3 branched style and with sub-distichous basal glumes and a trigonous, persistent style base in the latter. Indian species extend to south and south-east Asian countries, and many species found in India have worldwide distribution; *F. dichotoma* (L.) Vahl, *F. complanata* (Retz.) Link, *F. ferruginea* (L.) Vahl and *F. cymosa* R. Br. are a few examples. *Fimbristylis aestivalis, F.dichotoma, F.dipsacea* and *F.miliaceae* are the common species in South India (**Figure 1)**.

***Cyperus* L.**

In India the genus *Cyperus*is represented by about 118 taxa (Govaerts *et al*., 2021) of which 58 species are from south India. Several State floras have variably recorded the diversity of this genus, of which Tamil Nadu is the most diverse in terms of species richness. Even though this diversity is not reflected in the endemism status of the genus, as only a few species are reported as endemic. *C. haspan* L, *C. distans* L., *C. pilosus* Vahl, *C. compressus* L., *C. difformis* L. and *C. iria* L. are the most common species under the genus, widely distributed in South India (**Figure 2)**.

Figure 2. Common *Cyperus* species in South India; *C. haspan*, *C. distans*, *C. pilosus, C. compressus*, *C. difformis* and *C. iria*

Distribution pattern of sedges in south India

Most of the sedges are found in the low-lying wetland areas and certain species are usually found partly submerged in shallow open water bodies like lakes, reservoirs and ponds (**Figure 3)**. Species under the genera *Eleocharis, Schoenoplectus, Cyperus, Rhynchospora* and *Actinoscirpus* are often form large patches in open water areas by means of vegetative propagation. *Carex, Scleria* and *Hypolytrum* are confined to forest margins. Many *Cyperus* and *Fimbristylis* species grow in grassland along with grasses and forms an important constituent of herbage. Some sedges prefer high altitude grasslands and rocky slopes. Most of Cyperaceae species possess well developed root systems or highly developed rhizomatous stolons to grow in sandy soil.

Figure 3. Sedges in different habitats in south India

Conclusions

Around 274 taxa of sedges in 24 genera were identified from South India through extensive field study and literature review. The members are occurring in various habitats, with dominance in wetlands. Except the common species, most of the Cyperaceae species are competitively inferior, restricted to vulnerable habitats, and thus rare and endangered. With the support of diverse adaptive characters, Cyperaceae members are widely seen in south India, ranging from sea level to high mountains. Most of the species of this family are used traditionally in south India as medicines, food, fodder, thatching materials and ornamentals, however only a few are scientifically investigated. Proper identification, documentation and conservation of the Cyperaceae species in south India for the sustainable utilisation of the plant wealth.

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Chapter 5

Traditional Uses of Cyperaceae Members

Abstract

Being one of the wide spread group of plants across the globe, Cyperaceae members have extensive traditional applications in various sectors such as medicines, aroma, perfumery, cosmetics, food and art craft. The first writing paper was made from papyrus (*Cyperus papyrus* L.), a species of the Cyperaceae family in ancient Egypt. *Cyperus rotundus*, the most important Cyperaceae member, is one of the oldest known medicinal plants, widely used to treat stomach disorders, inflammatory diseases, dysmenorrheal and menstrual irregularities and, also for controlling thirst. *Cyperus rotundus* had also been used in perfumery and as a carbohydrate rich food in the period of scarcity. Literature review revealed that in addition to *Cyperus rotundus*, several other members from the family are also being used for various purposes traditionally.The chapter elaborates the traditional applications of Cyperaceae members across the globe.

Introduction

In spite of the developments in modern medicine, and the tremendous advances in synthetic drugs, nearly 80% of the world populations still rely on the use of traditional medicines, which are mainly derived from plant material. The fact is well recognized by the WHO, which has recently compiled an inventory of medicinal plants listing over 20,000 species.

Different Cyperaceae members across the globe has been used to treat various diseases and ailments such as indigestion, constipation, dysentery, abdominal distention, neurogenic gastralgia, chest pains, irregular as well as painful catamenia, skin diseases, furuncle infections, staphylococcal infections, leprosy, sprains and bruises, fever and stomach ache. Among the various Cyperaceae members, *Cyperus rotundus* is the widely used one across the globe. The major traditional applications of *Cyperus rotundus* were for the treatment of stomach disorders, inflammatory diseases, controlling thirst, and are also one of the oldest known medicinal plants used for the treatment of dysmenorrheal and menstrual irregularities. In addition to the documented traditional medicinal practices, various Cyperaceae members have been used world over in different folklore practices to treat various ailments. In the Peruvian Amazon, reportedly there is a native species of *Cyperus* used widely by the tribal women as a natural contraceptive. This property has been attributed to a certain mold that grows on the root of the Amazonian species that has oxytoxic (abortive) properties similar to Ergot, a fungus that grows on rye.

In addition to the medicinal properties, the tubers of Cyperaceae members also have good nutritive values, and reputed as one of the earliest known edible plant products. The tubers and rhizomes are recognized as a food in scarcity. *Cyperus esculentus* is cultivated for its edible tubers, called earth almonds or tiger nuts. The tubers of *Cyperus rotundus* is recommended as famine food. Moreover, the seeds and tubers of Cyperaceae members are important food for many small birds and mammals. The rhizomes of various species such as *Cyperus rotundus* and *Cyperus scarious* are being used as source of aromatic products. In addition, the plants are being used as source of various artifacts and paper (**Figure 1)**. The first writing paper was made from papyrus (*Cyperus papyrus* L.), a species of the Cyperaceae family, and this highlight the importance of this plant group in human civilization. The chapter gives a glimpse of the diverse utilities of various Cyperaceae plants across the world.

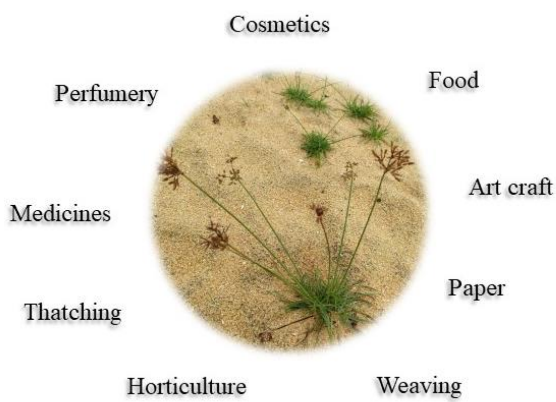

Figure 1. Traditional uses of Cyperaceae members

History of the traditional medicinal uses of Cyperaceae plants

Cyperaceae members had been used in different cultures across the globe for various curative purposes, the most widely used one being *Cyperus rotundus* (**Table 1**).The plant had been used since pre-historic times, as evidenced by the detection of characteristic compounds in archeological remaining dating back to Mesolithic or Middle Stone Age period that extended from 15,000 BCE to 5,000 BCE (Buckley *et al*., 2014). The plant was used as both medicine and perfume by ancient Greek physicians Theophrastus (4^{th} century BC), Pliny the Elder (1^{st} century AD) and Dioscorides (1^{st} century AD). The plant, known as 'xiang fu' is considered as a qi-regulating herb in traditional Chinese medicine, and well known for the gynecological applications. In West Asia, the roots are used for the treatment of leprosy, thirst, fever and blood ailments (Tsoy *et al*., 2011; Ito *et al*., 2012). Arabs in the Mediterranean region used the burned tubers of the plant to treat bruices, carbuncles and wounds. In Egyptian folk medicine, the tubers are used for stomach ache (Boulos and Hadidi, 1984). In Morocco, the plant is of traditional reputation in medicine and cosmetics (Siroua *et al*., 2022). *Cyperus rotundus* is used in Japanese 'Kampo' formulations. In the Island of Borneo (Kalimantan), *C. rotundus* have been used for decades as a medicine for the treatment of toothache, swollen gums and mouth ulcers, in the form of a mouth wash (Berniyanti *et al*., 2019).

In Ayurveda, the plant is considered as kashaya, tikta and kadu (Rasa), laghu and rooksha (guna), sheeta (virya), and katu (vipaka). As per ancient Ayurvedic concepts, the tubers are beneficial in the treatment of fever caused by aggravated pitta, anorexia, diarrhea, fatigue and thirst burning sensation (Raut and Gaikwad, 2006; Jeong *et al*., 2000). The plant has been mentioned in Charaka Samhita as *lekhaniya* (antiobesity), *trishnanigrahana* (thirst quenching), *sthanyashodhana* (breast milk cleansing) and *kandughna* (relieving itching). In *Sushruta Samhita*, the plant has been mentioned as *Vachadi* and *Mustadi*. The plant has also been mentioned in classical texts such as Ashtanga Hridaya, Bhavaprakasa Nighantu and Dhanvantari Nighantu. *Cyperus rotundus* tubers are incorporated in various types of Ayurvedic preparations such as arishta, kvatha, churna and lehyaas in the case ofMustakarishta, Mustakadikvatha, Mustakadichurna, Mustakadilehya, and also several Ayurvedic formulations such as Chyawanprash and Ashokarishtahave *Cyperus rotundus* as one of the ingredients (**Table 2**).

As per ancient Ayurvedic texts Amarkosha, Brihatrayees and Bhavaprakash Nighantu, different varieties of musta such as Nagarmusta, Bhadramusta, Kaivarta or Kshudramusta, Kuruvinda, Chudalamusta and Musta are mentioned. According to Kirtikar and Basu (1918), Nagarmusta is *Cyperus scariosus* Br., Bhadramusta is *Cyperus rotundus* L. and Kshudramusta is *Cyperus esculentus* L.

According to Bhaishajya Ratnavali, Musta is classified to 3 types of as per the habitat.

1) Anupadeshastha Musta (Marshy land)-Best quality

2) Mishrit Deshajanya Musta (Mixed type of lands)-Medium quality

3) Jangal Deshajanya Musta (Dry land)-Poor quality

Cyperaceae members in Hortus Malabaricus

Hortus Malabaricus is a treatise on the medicinal plant wealth of Malabar, Kerala, compiled by Hendrik Adriaan van Rheede, the Dutch Governor of Cochin, and published from Amsterdam during 1678-1693. The technical information contained in the book was mainly provided by Itty Achuthan, a Malayalee physician lived in Cherthala region of Kerala State. The work consists of 12 volumes, with 793 illustrations describing about 679 species of plants in 742 chapters. Hortus Malabaricus is a source of more than 2789 prescriptions for more than 210 diseases which were rampant in the 15th to 17th century (Manilal, 2003). The original text in Latin has plant names in Malayalam, Roman and Arabic scripts (**Figure 2)**. The treatise elaborates the following Cyperaceae members (the Malayalam name is in parenthesis);

1. *Cyperus exaltatus* (Wara pullu): against stomach pains
2. *Cyperus michelianus* (Pee muthanga): against itches
3. *Cyperus michelianus* sbsp. *pygmaeus* (Pee muthanga): against itches
4. *Cyperus pilosus* (Eera): against itches
5. *Cyperus malaccensis* (Pottapullu)
6. *Fimbristylis argentea* (Mullen pullu): against heat of the body
7. *Hypolytrum nemorum* (Beera kaida)
8. *Kyllinga nemoralis* (Muthenga): controls thirst, dry fever, cures diabetes, and hepatic disordres
9. *Mariscus javanicus* (Eera): leaves used against stomach pains, rouses menstruation
10. *Mariscus sumatrensis* (Kol pullu)
11. *Rikliella squarrosa* (Motta pullu): whole plant against hepatic disorders and vitiligine
12. *Scirpus articulates* (Chelli): root used ascathartic syrup
13. *Scleria lithosperma* (Kadan pullu): rootused as anti nephretus

14. *Scleria* sp. (Cholapullu): whole plant and leaves, rewarm contracted nerves, mitigates the pain of bones and fever
15. *Scleria terrestris* (Kaatucholam): fruit used to treat aphtha

Figure 2. Cyperaceae member*Cyperus exaltatus* as depicted in Hortus Malabaricus

In Siddha medicinal system, *Cyperus rotundus* is known as '*koraikkizhangu*', and used in several preparations such as Athimathuramathirai, Adathodaichooranam, Civataichooranam, Cukkutailam, KapadaIlakam, Sanjeevitheenir, Chandraprakasamathirai, Thathupushtikulikai, Parangichakkaichooranam, Milaguthailam, Kapacurakkudineer, Kabasutrakudineer and Nilavembukudineer (Sidha formulary 2011, Mattummal *et al*., 2018; Arasi *et al*., 2013; Vincent *et al*., 2020; Samraj *et al*., 2014).

In Unani medicinal system, the plant is known as 'Sa'ad ku'fi', and has been attributed with effects on gastric mucus, spasm, nausea and epilepsy. Sa'ad ku'fi is a major component in several Unani formulations such as *Anqaruya Sagheer, Jawarish Jalinoos* and *Dawa e Bawaseer* (Kabir and Abbasi, 2018).

Table 1. Ethnomedicinal applications of Cyperaceae members

Sl. No.	Cyperaceae member	Traditional medicinal use	Traditional medicinal formulation	Reference
1.	*Bulbostylis barbata*	Dysentery	Decoction of whole plant	Cheema *et al.*, 2017
2.	*Cyperus acuminatus*	Snake bite	Hot water extract of the rhizome	Juliana *et al*., 2017; Sulochana *et al.*, 2015; Otero *et al*., 2000
3.	*Cyperusalter nifolias*	Dysentery	Hot water extract of the plant	Wasuwat,1967
4.	*Cyperus angolensis*	Constipation in children	Hot water extract of the root	Gelfand, 1959
5.	*Cyperus articulatus*	Snake bite	Entire plant	Duke,1994
		Abortion Hemostatic Vulnerary	Hot water extract of the plant	
		Headache and migraine	Tubers	Shamkuwar *et al.*, 2012
		Fever	Dried rhizome of the plant	Milliken and Albert, 1996
		Influenza Intestinal infection	Hot water extract of the plant	Duke, 1994
		Epilepsy	Decoction of the plant	Bum, *et al.*, 2001 Mongelli *et al.*, 1995
		Malaria	Root of the plant	Etkin, 1997
6.	*Cyperus brevifolius*	Sore legs	Leaves with those of several other herbs	Holdsworth, 1990
7.	*Cyperus canescens*	Amenorrhea	Hot water extract	Saha *et al*., 1961
8.	*Cyperus compressus*	Wound	Dried rhizome of the plant	Dangol and Gurung, 1991
		Helminthiasis	Powdered roots	Soren *et al.*, 2019
		Cuts and scabies	Powdered roots	Dangol and Gurung, 1991

9.	*Cyperus corymbosus*	Contraceptive	Whole plant	Amer, 1977
10.	*Cyperus cyperoides*	Tooth ache	Hot water extract of the plant	Altschul, 1973
11.	*Cyperus diffusus*	Head ache Fever	Hot water extract of the root	Duke, 1994
12.	*Cyperus erectus*	Foot swelling	Ground plant	Thornton-Barnett, 2013
13.	*Cyperus esculentus*	Cholic epilepsy Fever Cough Body ache Vomiting Stomach ache	Whole plant	Zamora, 1992 Dimayuga, 1998
		Depression	Root extracts	Guzmán Gutiérrez *et al.*, 2014
		Polymenorrhagia	Hot water extract of the root	Samuelsson, 1992
		Menstrual delay	The entire plant	Bryant, 1966
14.	*Cyprus exaltatus*	Swollen breast	Rhizome of the plant with *Saccharum officinarum*	Haerdi, 1964
15.	*Cyperus flavescens*	Depression	Roots	Guzmán Gutiérrez *et al.*, 2014
16.	*Cyperus incompletus*	Asthma Cough Ulcer	Dried leaf and stem	Dini *et al.*, 1992 Haerdi, 1964
17.	*Cyperus iria*	Indigestion	Dried rhizome of the plant	Zagari, 1992
		Amenorrhea	Hot water extract of the plant	Dragendroff, 1898
		Stomach ache	Hot water extract of the plant	Uphof, 1968
18.	*Cyperus ixiocarpus*	Cold and Chest infection	Hot water extract of the plant	O'Connell and Barnett, 1983

19.	*Cyperus javanicus*	Fracture	Crushed wet leaves	Holdsworth, 1990
		Irregular menstrual	Leaves with those of several other herbs	Holdsworth *et al*., 1990
20.	*Cyperus kyllingia*	Tissue damage by snake bite	Hot water extract of the plant	Juliana *et al.*, 2017
		Oral thrush	*C. kyllinga* entire plant, *Aleurites moluccana* nut and ariel root of *Ficus prolixa*	Holdsworth, 1990
		Gonorrhoea	Decoction	Hafiz *et al*., 1982
21.	*Cyperus laevigatus*	Asthma	Water extract of the plant	Hope *et al.*, 1993
22.	*Cyperus latifolius*	Tuberculosis and related ailments	Extract made from the roots	Tabuti *et al.*, 2010
23.	*Cyperus longus*	Indigestion	Hot water extract of the plant	Zagari, 1992
		Tumour	Hot water extract of the plant	Tackholm *et al.*, 1941
24.	*Cyperus luzulae*	Diarrhoea Stomach ache	Hot water extract of rhizome	Duke, 1994
		Haemorrhage	Decoction of the whole plant	Barrett, 1994
		Ophthalmic infections	Hot water extract of root	Gupta *et al.,*1996
25.	*Cyperus maculatus*	Cattle worms	Tubers	Blench and Dendo, 2006
26.	*Cyperus monocephalus*	Dermatosis	Decoction of tuber and root	Holdsworth, 1990
		Ringworm	Decoction of tubers	Holdsworth, 1990
27.	*Cyperus mundii*	Evacuation of the placenta Tuberculosis Paludism	Whole plant extract	Razafindraibe *et al.*, 2013

28.	*Cyperus natalensis*	Gynaecology and obstetrics complaints	Decoction of the roots	De Wet and Ngubane,2014
29.	*Cyperus nitidus*	Respiratory and digestive disorders	Rhizomes	Moteetee*et al.*, 2019
30.	*Cyperus obtusatus*	Indigestion	Rhizome of the plant	Bandoni *et al.*, 2008
31.	*Cyperus officinalis*	Amenorrhea	Hot water extract of the plant	Dragendroff, 1898
32.	*Cyperus papyrus*	Female sterility	Decoction with leaf juice of *Mayenes senegalensis*	Haerdi, 1964
		Cancer	Hot water extract of the plant	Hamidi and Gengaihi 1975
		Ulcer Fistula Tumour Wounds	Hot water extract of the plant	Tackholm *et al.*, 1941
33.	*Cyperus pedunculatu s*	Infections	Dried root of the plant	Taptiang *et al.*, 1984
		Diarrhoea Kidney disease Fever Pain Inflammations	Stem and leaves	Rabelo *et al.*, 2013
34.	*Cyperus prolifer*	Women sterility	Hot water extract of the plant	Rabelo, 1964
35.	*Cyperus rotundus*	Blood dysentery	Juice of the macerated flowers of *C. rotundus* with honey	Jahan *et al.*, 2011
		Bone fracture	Dried powder of *Cyperus rotundus, Cissus quadrangularis, Evolvulus nummularius* and ginger	Shahidullah *et al.*, 2009
		Bronchitis	Fruits of *Pergularia daemia* with rhizomes of *Cyperus rotundus*and leaves of *Tinospora cordifolia*	Kumar *et al.*, 2011

		Cholera	Boiled rhizomes of *Cyperus rotundus* and *Mentha piperita*	Qureshi *et al.*, 2010
		Constipation	Juice obtained from macerated tubers	Jahan *et al.*, 2011
		Cough	Tubers of *Cyperus rotundus*	Holdsworth *et al.*, 1990
		Dermatitis	Rhizomes of *Cyperus rotundus*, stem bark of *Azadirachta indica* and leaves of *Trichosanthes anguina* in the form of paste	Das and Misra, 1988
		Diabetes	Dried powdered tuber	Zaman, 1989
		Dysentery	Mixture of the rhizomes of *Cyperus rotundus*, bark of *Holarrhena pubescens*, fruits and leaves of *Punica granatum*, dried young fruits of *Aegle marmelos* and flowers of *Woodfordia fruticose*	Bora *et al.*, 2012
		Dyspepsia	Dried rhizomes of *Cyperus rotundus*	Das and Misra, 1988
		Dyspnea	Dried rhizomes of *Cyperus rotundus*	Kirtikar and Basu, 1918 Jahan *et al.*, 2011
		Epilepsy	Decoction of *Cyperus rotundus* with honey	Kirtikar and Basu, 1918
		Eczema	*Lawsonia inermis* and *Azadirachta indica* leaves are macerated with *Cyperus rotundus* for topical application	Jahan *et al.*, 2011
		Gonorrhoea	Dried powdered leaves of *Cyperus rotundus*	Bhattacharya *et al.*, 1987

		Gynaecological disorder	Dried powder of rhizome of *Cyperus rotundus* and juice of *Citrus maxima* fruit	Bora *et al.*, 2012
		Headache	Dried leaves of *Cyperus rotundus*	Kirtikar and Basu, 1918
		Hyperacidity	Dried leaves of *Cyperus rotundus*	Ahmad, 2012
		Hypoglycemia	A mix of the seeds of *Syzygium cuminii* and *Momordica charantia*, and dried powder of *Cyperus rotundus* and *Rosa alba* leaves	Uddin *et al.*, 2006
		Reduced lactation	Paste of the roots	Qureshi *et al.*, 2010
		Intermittent fevers	Decoction prepared from *Cyperus rotundus* roots and fresh ginger	Dangwal*et al.*, 2010 Das *et al.*, 1988
		Jaundice	A paste of fresh roots of *Cyperus rotundus* and fruits of *Phyllanthus emblica*	Suneetha *et al.*, 2013
		Kidney stone	Rhizome of *C rotundus*, roots of *Mimosa pudica* and flintstone for oral use	Nanda *et al.*, 2013
		Leukorrhea	*Cyperus rotundus* tubers with *Abutilon indicum* leaves and *Cuminum cyminum* seeds for oral use	Reddy *et al.*, 2010
		Loss of libido in men	Leaves of *Psidium guajava*, leaves of *Punica granatum*, and whole plants of *Cyperus rotundus*	Jahan *et al.*, 2011
		Malaria	Decoction of *C. rotundus* rhizomes and *Azadirachta indica* bark	Paul *et al.*, 2013

		Menstruation problem	Juice of *Citrus maxima* fruit and dried powder of *Cyperus rotundus*	Bora, 2016
		Pimples	Roots along with turmeric and curd are made into a paste	Qureshi *et al.*, 2010
		Puerperal fever	Juice of *Cyperus rotundus* whole plant mixed with *Psidium guajava* and *Punica granatum* leaves	Jahan *et al.*, 2011
		Rheumatic pain Bile problems Body ache	A mix of the rhizomes and roots of *Cyperus rotundus*, the stem bark of *Gmelina arborea*, root of *Asparagus racemosus*, leaves of *Adhatoda zeylanica*, *Aerva lanata*, honey and *Piper longum*	Das *et al.*, 1988
		Skin eruptions	Decoction of the ash of leaves of *Ammannia baccifera* and *Cyperus rotundus* roots and fresh ginger in sesame oil	Dangwal *et al.*, 2010
		Snake bite	Paste of rhizome of *C. rotundus*,leaf and root bark of *Albizia amara* and root bark of *Jasminum angustifolium* heated with neem oil for topical application	Ayyanar *et al.*, 2005
		Stomach ache	Sun dried rhizomes of *Cyperus rotundus*, stem bark of *Holarrhena antidysenterica* and *Zingiber officinale* for oral administration, along with buttermilk	Rao *et al.*, 2014

		Syphilis	Dried powdered leaves of *Cyperus rotundus*	Bhatnagar *et al.*, 2001
		Tonsillitis	The paste of *Cyperus rotundus* rhizome with turmeric powder is rubbed inwards of the tongue	Sharma and Gupta, 2011
		Urinary trouble Stone removal	Decoction of the whole plant	Lokendrajit, 2011; Kumar *et al.*, 2014
		Vaginal discharge	Tubers crushed with *Abutilon indicum* leaves and *Cuminum cyminum* seeds	Reddy *et al.*, 2010
		Vomiting Nausea Flatulence Diarrhoea Intestinal parasites Fever Renal and vesical calculi Urinary tenesmus Wounds Amenorrhoea Dysmenorrhoea Deficient lactation Loss of memory Insect bites Food poisoning Indigestion Infertility Cervical cancer	Dried rhizome	Kirtikarand Basu, 1918; Yeung Him-Che, 1985; Duke and Ayensu,1985; Bown, 1995; Chopra *et al.*, 1986
36.	*Cyperus scariosus*	Urinary infection	Hot water extract of the plant	Mukerjee, 1984
		Liver damage Diarrhoea Syphilis Epilepsy Gonorrhoea	Decoction of the plant	Gilani *et al.*, 1994
		Diabetes	Seeds of the plant	Rajurkar and Hande, 1997

37.	*Cyperus sexangularis*	Asthma Fatigue Fever Pneumonia TB	Rhizomes	Semenya *et al.*, 2020
38.	*Cyperus tegetum*	Diabetes	Decoction of the plant	Selvanayahgam*et al.*, 1994
39.	*Fimbristylis dichotoma*	Hair loss	Crushed leaves	Cheema *et al.*, 2017
40.	*Fimbristylis miliaceae*	Fever	Poultice	Roy *et al.*, 2022
			Decoction of leaves	Sen and Behera, 2018
41.	*Kyllinga brevifolia*	Diarrhoea Tumours Stomach and intestinal problems	Aerial parts of plant macerated in cold water	Cheema *et al.*, 2017
		External sores and swellings	Paste of rhizome	
42.	*Kyllinga nemoralis*	Malarial chills Pruritus of the skin Thirst due to fever Diabetes Snake bite	Leaves of the plant	Quisumbing *et al.*, 1978 Manju *et al.*, 2010

Cyperus rotundus is an important candidate drug for several herbal formulations in Ayurveda, as mentioned in classical texts such as *Bhaishajya Ratnavali*, *Yoga Ratnakara, Ayurveda Sangraha* and *Ashtanga Hrudayam* (**Table 2**).

Table 2. Herbal formulations in Ayurveda containing *Cyperus rotundus*

Sl. No.	Herbal formulation	Traditional use	Herbal ingredients
1.	Musthadi Kwatha	Diabetes Stress Hyperlipidemia	*Cedrus deodara, Citrullus colocynthis, Curcuma longa, Cyperus rotundus, Emblica officinalis, Marsdenia tenecissima, Symplocos racemose, Terminalia bellerica, Terminalia chebula*
2.	Kutajashtaka Kwatha	Burning sensation Diarrhoea	*Aconitum heterophyllum, Cycleapeltata, Cyperus rotundus,*

		Colicky pain	*Holarrhena antidysenterica, Punica granatum, Santalum album, Symplocos racemose, Woodfordia fruticose*
3.	Darvyadi Kwatha Choorna	Excessive vaginal discharge	*Adathodavasica, Aegle marmelos, Berberis aristate, Cyperus rotundus, Nerium indicum, Semecarpus anacardium, Swertia chirata*
4.	Dhanyapanchaka Kwatha	Colicky pain Diarrhoea due to indigestion Tastelessness	*Aegle marmelos, Coriandrum sativum, Cyperus rotundus, Pavonia odorata, Zingiber officinale*
5.	Arimedadi Thailam	Oil pulling for oral health Diseases of mouth, tooth and noes	*Acacia catechu, Acacia leucophloea, Alhagi pseudalhagi, Berberis aristate, Caesalpinia sappan, Cinnamomum camphora, Cinnamomum tamala, Cinnamomum zeylanica, Coleus vettiveroides, Curcuma longa, Cyperus rotundus, Elettaria cardamomum, Ficus benghalensis, Glycyrrhiza glabra, Lacca laccifera, Mesua ferrea, Mimosa pudica, Myrica esculenta, Myristica fragrans, Nardostachys jatamansi, Nelumbo nucifera, Piper cubeba, Prunus avium, Prunus cerasoids, Pterocarpus santalinus, Rubia cordifolia, Santalum album, Sesame oil, Symplocosracemosa, Syzygium aromaticum, Vetiveria zizanoides, Woodfordia fruticosa*
6.	Mustaka Arishta	Improves appetite and digestion Dysentery Obesity Dyspepsia Digestive impairment Malabsorption	*Cuminum cyminum, Cyperus rotundus, Piper longum, Plumbago zeylanica, Syzygium aromaticum, Trachyspermum ammi, Trigonella foenumgraecum, Woodfordia fruticose, Zingiber officinale*

		syndrome Gastro-enteritis with piercing pain	
7.	Ashoka Arishta	Dysmenorrhoea Pain in female genital tract Leucorrhoea Fever Bleeding disorders Piles Dyspepsia Tastelessness Polyuria Inflammation	*Adhatoda vasica, Berberis aristate, Cuminum cyminum, Cyperus rotundus, Emblica officinalis, Mangifera indica, Nymphaea stellata, Santalum album, Saraca asoca, Terminalia bellerica, Terminalia chebula, Woodfordia fruticose, Zingiber officinale*
8.	Stanyashodhana Kashaya	Detoxing breast milk	*Cedrus deodara, Cyclea peltata, Cyperus rotundus, Hemidesmus indicus, Holarrhena antidysenterica, Marsdenia tenacissima, Picrorhiza kurroa, Swertia chirata, Tinospora cordifolia, Zingiber officinale*
9.	Gulmakatanala Rasa	Abdominal lump	*Achyranthes aspera, Acorus calamus,Cyclea peltate, Cyperus rotundus,Fumaria indica, Piper chaba, Piper longum, Sausserea lappa, Terminalia chebula, Zingiber officinale*
10.	Piyushvalli Rasa	Diarrhoea Fever Diarrhoea with bleeding Malabsorption syndrome Inflammation Intestinal colic due to indigestion Constipation Nausea Tastelessness Emesis	*Aconitum heterophyllum, Berberis aristate, Cinnamomum zeylanicum, Coriandrum sativum, Cuminum cyminum, Cyclea peltate, Cyprus rotundus, Datura metel, Eclipta alba, Holarrhena antidysenterica, Holoptelea integrifolia, Mimosa pudica, Myristica fragrans, Punica granatum, Santalum album, Saussurea lappa, Symplocos racemosa, Syzygium aromaticum, Woodfordia fruticose*

		Prolapse of the rectum Splenomegaly Abdominal lump Ascites Puerperal disease Menorrhagia Jaundice Anaemia Diabetes Urinary disorders	
11.	Mahalakshadi Taila	Fever Intermittent fever Cough Dyspnoea/Asthma Coryza Itching Pain in sacral region Backache	*Anethum sowa, Cedrus deodara, Curcuma longa, Cyperus rotundus, Glycyrrhiza glabra, Laccifer lacca, Marsdenia tenacissima, Picrorhiza kurroa, Santalum album, Saussurea lappa, Sesame oil, Vitex agnus, Withania somnifera*
12.	Shadanga Paneeya	Fever Thirst	*Cyperus rotundus, Fumaria indica, Pavonia odorata, Santalum album, Vetiver zizanioides, Zingiber officinale*
13.	Vatsakadi Kwatha Churna	Dysentery Diarrhoea Ulcerative colitis	*Aconitum heterophyllum, Aegle marmelos, Cyperus rotundus, Holarrhena antidysenterica, Pavonia odorata*
14.	Bahushala Guda	Haemorrhoids Abdominal lump Urinary disorders Anaemia Chlorosis Advanced stage of jaundice Ascites Chronic rhinitis Sinusitis Coryza Gout	*Amorphophallus campanulatus, Argyrea speciosa, Baliospermum montanum, Cinnamomum zeylanicum, Citrullus colocynthis, Cyperus rotundus, Elettaria cardamom, Embelia ribes, Hedychium spicatum, Operculina turpethum, Piper nigrum, Plumbago zeylanica, Scindapsus officinalis, Semicarpus anacardium, Teminalia chebula, Tribulus terrestris, Zanthoxylum alatum, Zanthoxylum armatum, Zingiber officinale*

15.	Chandraprabha Vati	Anaemia Bronchitis Cough Diabetes Digestive Diuretic General tonic Rasayana Haematinic Antimicrobial Jaundice Reducing weight Skin diseases Urinary tract disorders	*Aconitum heterophyllum, Baliosperumum montanum,* Bamboo manna, *Barberis aristate, Cedrus devadara, Cinnamomum tamala, Cinnamomum zeylanicum, Commiphora mukul, Coriandrum sativum, Curcuma longa, Elettaria cardmomum, Embelia ribes, Emblica officinalis, Hordeum vulgare, Operculina turpethum, Piper chaba, Piper longum, Piper nigrum, Plumbago zylanicum, Scindapsus officinalis, Terminalia bellirica, Terminalia chebula*
16.	Yogaraja Guggulu	Almost all joint disorders Rheumatism Nervous disorders For healthy digestion and metabolism	*Alpinia galanga, Apium graveolens, Cedrus deodar, Cinnamomum tamala, Cinnamomum zeylanicum, Commiphora mukul, Coriandrum sativum, Cuminum cyminum, Cyperus rotundus, Elettaria cardamomum, Embelia ribes, Emblica officinalis, Hordeum vulgare, Hyoscyamus niger, Nigella sativa, Pedalium murex, Piper chaba, Piper longum, Piper nigrum, Plumbago zeylanica, Saussurea lappa, Taxus baccata, Terminalia bellirica, Terminalia chebula, Vetiveria zizanioides, Zinziber officinale*
17.	Ardraka Khanda	Cough Respiratory disorders Allergic skin disorders	*Cinnamomum tamala, Cinnamomum zeylanicum, Curcuma zedoaria, Cyperus rotundus, Elettaria cardmomum, Apium graveolens, Embeliaribes, Mesua ferrea, Piper longum, Plumbago zeylanica, Zingiber officinale*

18.	Brahma Rasayana	Lassitude Fatigue Lethargy Tiredness without exertion Langour Mental weakness Senility Progeriasis Wrinkles in skin Graying of hair Impairment of memory	*Acorus calamus, Aegle marmelos, Aquilaria agallocha, Asparagus racemosus, Boerhavia diffusa, Centella asiatica, Cinnamomum zeylanicum, Clitoria ternatea, Curcuma longa, Cyperus rotundus, Desmodium gangeticum, Elettaria cardamomum, Embelia ribes, Emblica officinalis, Glycirrizha glabra, Gmelina arboera, Leptadenia reticulata, Litsea monopetala, Malaxis acuminata, Manikara hexandra, Mesua ferrea, Nyctanthusarbor-tristis, Oroxylum indicum, Oryza sativa, Phaseolus trilobus, Piper longum, Premna corymbose, Ricinus communis, Saccharum officinarum, Saccharum spontaneum, Santalum album, Serratophyllum submersom, Sesame oil, Sida cordifolia, Solanam xanthocarpum, Solanum indicum, Stereospermum suaveolens, Terminalia chebula, Uraria picta*

Cyperaceae members as source of food material

Plant resources remained as an integral part of human society throughout history to fulfil one of the basic needs, food. Plant parts like roots, leaves and fruits constitute their food. Various civilizations across the globe used Cyperaceae members as food. Among Cyperaceae members, *Cyperus*, *Carex*, *Scleria*, *Scirpus* and *Fimbristylis* species were the most common food sources. In Asia, the leaves of *Cyperus rotundus* were used as a food flavouring agent, while the rhizomes and tubers were widely used in curries, pickles and bakery products (Nima *et al.*, 2008). The rhizomes and tuberswere also used to purify water, and as a thirst quencher. It is a staple carbohydrate in tropical regions especially during the famine seasons. *Cyperus rotundus* and *Cyperus esculentus* can be eaten raw or processed in the form roasting, drying, baking and extract with milk (Oladele and Aina, 2007). The edible tubers of *Cyperus esculentus* are eaten as vegetables, made into sweets or used to produce horchata of the Valencia region. *Cyperus bulbosus* are eaten to a smaller extent. *Cyperus articulatus* is one of the traditional spices of the Amazon region used as food, and its reddish essential oil is used commercially as a flavouring for food. In Nigeria, *Cyperus articulatus* is mostly eaten raw as snacks. Other than Cyperus species, *Scirpus maritimus* inner rhizome portions are used as an occasional food source for ethnic group Maori in New Zealand, and *Scirpus paludosu* nutlets are found to be edible and used as a cooked vegetable (Jhonson 1989).

Several *Carex* species like *Carex coriacea, C. chlorosaccus, C. canescens, C. brevipes, C. brevior, C. bigelowii, C. bella, C. athrostachya, C. aquatilis, C. amplifolia, C. albonigra, C. demissa, C. divulsa, C. eleocharis* and *C. festivella* were grazed by animals and are important animal food. *Fimbristylis littoralis* is also used as animal food (Uranie *et al.*,1829*).* In wetlands, terrestrial birds such as francolin feed almost exclusively on some of *Cyperus* species. *Scleria ciliate* fruits are generally classed as desirable food for quail, doves and other birds.

***Horchata de chufa*- Popular natural drink from tiger nut tubers (*Cyperus esculentus*)**

Since ancient times the tuber of *Cyperus esculentus* has been considered a foodstuff, and was used in ancient Egypt according to the references of Theophrastus and Pliny (Negbi 1992; Serrallach, 1927). Its dry tubers have been found in tombs from pre-dynastic times (Serrallach, 1927). The chufa is a crop of early domestication which was added to those of the Nile Valley (Zohary, 1986). In Europe, chufa has been introduced during the middle ages by the Arabs after their expansion across the north of Africa. The small tuberous rhizomes were used both as food and medicine by the Native Americans. In the United States, chufa plots are favorite sites of food for the wild turkeys and also used as hog feed and pork feed to improve the taste of pork meat. Tubers of chufa have also been identified as valuable food for waterfowl, ducks and cranes in wetland fields.

There are written records from the 13th century about the consumption of a drink made from chufa in the Mediterranean areas of the present-day Valencian community in Spain. *Horchata*, a natural drink obtained from the yellow nutsedge, could be considered as developed from this drink. *Horchata* has a pleasant milky aspect and nutty flavor, along with some health benefits such as gluten-free (Pascual *et al*., 2000). The popularity of this drink has recently extended to other countries such as France, Great Britain and Argentina. Horchata de chufa is considered as an effective remedy for diarrhea, according to popular traditional knowledge in Valencia, Spain.

The caramel from malted tubers of *Cyperus esculentus* can be used to add body, flavor and color to certain baked products, non-alcoholic malt beverages and dark beers, and in the production of condiments. The starch can be used in many starch-based foods as well as in the cosmetic industry, and for laundry, glazing and stiffening. The waste residue after oil extraction could be further modified producing syrups, flours or livestock feeds. The tubers of *C. esculentus* may be consumed raw, roasted, or ground. The tiger nuts are first fried, and then soaked in water, and the taste is similar to hazelnuts. The tubers contain protein, carbohydrates, sugars, oil and fiber. The chufa nut is good for human health, containing high levels of iron and potassium, and no sodium. Chufa tubers have a relatively high total antioxidant capacity as they contain considerable amounts of water-soluble flavonoid glycosides. Chufa is potentially a commercial source of oleic acid vegetable oil that could be exploited in the same way as olive oil. The oil may also be used as biodiesel fuel.

In parts of Africa, Europe and Asia, chufa is grown for its edible tubers. *Cyperus esculentus* is cultivated in Niger for export, and the revenues from this weed exceed those from the typical cash crops such as cowpea and groundnut. The African Nigeria and Ghana Togo Ivory Coast, export 2300 tons of tubers every year to Spain. The chufa is also a representative crop of the Spanish Mediterranean region, where tubers are used to make the beverage horchata or horchata de chufas.

Cyperaceae members in perfumery

In addition to the use in traditional medicinal systems, the tubers of various Cyperaceae members were used traditionally in perfume, cosmetic and spice applications in African, Arab and Asian countries for centuries, utilizing the floral-woody aroma of the rhizome (Sharma and Gupta, 2007). Numerous accounts of various Cyperaceae members for aromatic purposes from ancient Egypt, Mycenean Greece, Indian and elsewhere exist. *C. rotundus* had been mentioned by Hippocratic (5^{th} century BC), Theophrastus (3^{rd} century BC), Pliny and Dioscorides (1^{st} century AD), as a source of perfume (Negbi,1992).

The mystic kyphi of Egypt

Kyphi is the ancient perfume of Egypt, that had an important role as a sacred fragrance in many ceremonies.For ancient Egyptians, burning incense was a daily celebration of fragrance, and their favorite incense was Kyphi. On a daily basis, the ritualized burning of incense in ancient Egypt consisted of frankincense in the morning, myrrh during the day, and Kapet (Kyphi) in the evening. Dioscoridesmentions the use of *C. rotundus* tubers as an ingredient of kyphi, and the ingredients described by Dioscoridesis similar to one in the Ebers papyri, demonstrating its continuity over 1600 years. Kyphi, the scented preparation from ancient Egypt, was made from myrrh, sweet rush, Cyperus grass, wine, honey, raisins, resin and juniper. The incense has medicinal properties and also used to perfume goose or pork fat.

***Sugandha musthaka* of India**

Cyperus rotundus is known in Ayurveda as *sugandhamusthaka* (aromatic Cyperus) and also being suggested as substitute for *karpura* (*Cinnamomum camphora*) based on the concept of drug substitution (*Abhava Pratinidhi Dravya*) (Venkatasubramanian *et al.*, 2010). Ancient India had attained the highest proficiency in the manufacture of scents, perfumes and cosmetics.Varahamihira, the famous astrologer of the 6th Century AD, in his monumental work ‘Brihat Samhita’ devotes an entire chapter on perfumery under the title ‘Gandhayukti’. He mentions that using just 16 ingredients, 1,74,720 varieties of scents and perfumes can be made, by mixing them in specified proportions, permutations and combinations. The fragrance of the perfume depended on the purpose for which it was used and accordingly the ingredients were selected. Musta (*Cyperus rotundus*) is one of the 16 aromatic ingredients mentioned by Varahamihira in Brihat Samhita.

Cyperus oil has the guanine sesquiterpene rotundone with a peppery note as one of the characteristic odoriferous compounds. Rotundone is an important component of agarwood scent and patchouli scent, and recently Cyperus oil with rotundone is emerging as an alternative to the costly agarwood and patchouli oils.The popular Australian Shiraz wines have the characteristic spicy black pepper aroma, and rotundone was identified as the major contributor to peppery characters in Shiraz grapes and wine, with an odor threshold of 8 ng/L in water and 16 ng/L in red wine.

The tubers of *Cyperus scariosus* is the source of the much acclaimed 'cypriol oil', widely used in the perfume industry. The tuber, commonly known as nagarmotha, nagarmustaka, or nut grass, has a long history of traditional use in both medicine and perfumery. The essential oil has a tenacious, woody-earthy smell with a spicy note. Priprioca (*Cyperus articulatus*) is one of the traditional spices of the Amazon region and its reddish essential oil is used commercially by the cosmetic industry, and also as a flavoring for food.

Cyperus papyrus and the history of paper

The term paper has its origin from the marshy sedge plant *Cyperus papyrus* belonging to the family Cyperaceae. The plant is commonly known as papyrus sedge, paper reed, Indian matting plant or Nile grass. The history of paper making can be traced back to around 3000 BC. The most extensive account of papyrus production occurs in the encyclopaedic work by Pliny the Elder (23-79 AD) in his 'Naturalis Historia', written around 77 AD (Lewis, 1974). The oldest evidence of papyrus was unearthed from the Hemaka tomb in Saqqara, Egypt, which is approximately 5,100 years old (Braidwood *et al.*, 1951). Papyrus made from *Cyperus papyrus* was mainly used for documenting information in ancient Egypt and then was adopted by the Greeks, and was used extensively in the Roman Empire (**Figure 3)**. The famous 'Ebers Papyrus' that dates back to around 1500 BC, and extends to 110 pages, gave vivid descriptions of 876 plant medicines of that period (Bryan, 1930). The papyrus stem pitch was cut into thin strips and pitch was softened in the river watersover days, and layered to form a thick mat. The true papyrus sedge of Ancient Egypt, *C. papyrus* subsp. *hadidii,* is very rare due to draining of its wetland habitat. Bausch *et al*. (2022) has investigated in detail on the papyrus making process and the constitution of ancient papyrus sheets through two-dimensional nuclear magnetic resonance spectroscopy, derivatization followed by reductive cleavage, and pyrolysis-gas chromatography-mass spectrometry along with microscopy and tests for surface pH and sodium content.

The plant is often cultivated as an ornamental plant. The flowering heads were made into garlands for the gods in gratitude. The pith of young shoots was eaten both cooked and raw. The highly buoyant stems can be made into reed boats. Further the fibrous plant was used for making baskets, mats, cloth, cordage and sandals.

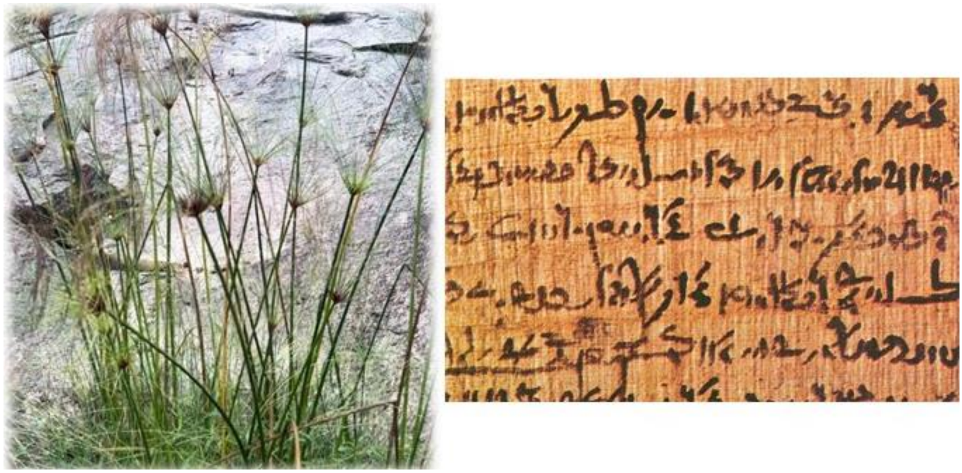

Figure 3.*Cyperus papyrus* and the ancient papyrus

Other uses of Cyperaceae members

In addition to the usage of Cyperaceae members in food and medicinal sector, many other traditional uses have been reported for the plant group. The plants in Cyperacea family are traditionally used for thatching, and for weaving household items such as mats, baskets, and other utensils.*Cyperus papyrus* is used in horticulture for water side planting. In the garden, sedges are generally used as 'architectural' plants, especially in wet places. The densely tangled rhizomes contribute to erosion control and water purification. The dense sedge beds in swampy regions provide food and shelter for birds, animals and other aquatic life, thus encouraging ecotourism.

Cyperus giganteus, locally known as cañita, is used by the Yokot'an Maya of Tabasco, Mexico, for weaving variety of mats. *Cyperus textilis* and *Cyperus pangorei* are traditionally used to produce the typical mats of Palakkad in India. The makaloa mats of Niihau were made from *Cyperus laevigatus*.

Conclusions

Review of the traditional uses of Cyperaceae members reveals wide applications for the plant group, and especially to the commonly used species such as *Cyperus rotundus, C. scariosus, C. papyrus, C. conglomeratus, C. esculentus, C. distans, C. iria, C. alternifolius, C. alopecuroides, C. articulates, C. longus, Scleria striatonux* and *Kyllinga nemoralis.* Traditional medicinal plants are widely accepted because of the time-tested efficacy and safety, and Cyperaceae members have wide applications in traditional medicinal field. Validation of the therapeutic efficiency using modern pharmacological tools and the elucidation of the responsible constituents through phytochemicals analyses could lead to the development of value-added botanical products, with commercial potential. Being a notorious weed, the possibility of producing huge quantity of *Cyperus rotundus* or other Cyperaceae tubers in various geoclimatic conditions across the globe is high, and efforts should be directed to translate the traditional information to value-added products by the skilful application of modern science and technology tools.

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Chapter 6

Pharmacological Activities of Cyperaceae Members

Abstract

Cyperaceae species include widely used medicinal plants across the world, and numerous experimental evaluations have scientifically validated the pharmacological activities of Cyperaceae plants along with the identification of active compounds, especially of the most important species, *Cyperus rotundus.* However, still most of the Cyperaceae members are considered as problematic weeds, and translation of the research findings to value added products is the need of the hour, and several attempts have been initiated in this regard. The major pharmacological properties of the Cyperaceae species are updated in the chapter, of which antimicrobial, anti-inflammatory, antioxidant, anticancer, anti-obesity, oral hygiene and wound-healing activities are the prominent ones. The pharmacological properties of the major isolated compounds from Cyperaceae species are also discussed in the chapter.

Introduction

Most of the modern medicines can be traced back to traditional medicinal plants, where the scientific validation of the traditional information using modern scientific tools has led to the discovery of bioactive molecules as drugs (Petrovska, 2012). The diversity of secondary metabolites is immense in medicinal plants, and therefore the pharmacological assays also need to be diverse to assess the activities of the compounds. Basically, the assays can be either cell-free (biochemical) or cell-based procedures. The wide range of bioassay approaches such as bio-guided fractionation, micro-fractionation bioactivity-integrated fingerprint, HPLC biochemical detection, biochromatography and electrophoretic enzyme assays enables rapid screening and identification of compounds from complex mixtures.

Though the pharmacological activities of *Cyperus rotundus*, the most important Cyperaceae member, have been reviewed extensively, a comprehensive review of the pharmacological efficacy of other Cyperaceae members is rare (Bajpay *et al*., 2018). The present chapter elaborates the pharmacological properties of the crude extracts and isolated pure compounds from Cyperaceae members (**Figure 1**). The general therapeutic activities are elaborated first, followed by the potential applications of isolated compounds from various Cyperaceae plants. Among the various therapeutic potentials attributed for Cyperaceae plants,antibacterial, antiviral, anti-inflammatory, antioxidant, anticancer, antiulcer, analgesic, antiarthritic, antipyretic, wound healing, hepatoprotective, anti-obesity, antidepressant, anti-androgenic,anticonvulsant, antidiarrheal, antigenotoxic, neuroprotective, nootropic, anti-dysmenorrhea and antiparasitic activities are discussed in detail.

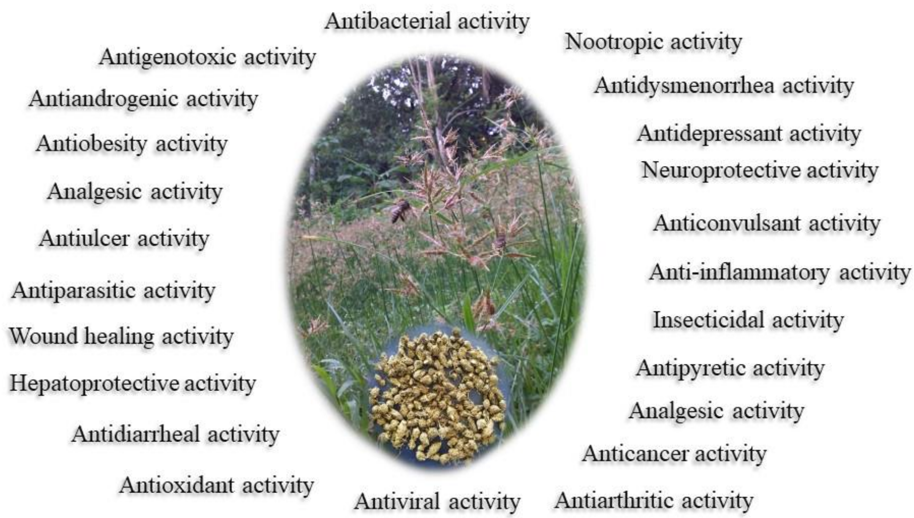

Figure 1. Pharmacological activities reported for Cyperaceae members

Antibacterial activity

Bacteria are the most common reason of infectious diseases and can be treated with antibiotics.Resistance to antibiotic agent is emerging in a wide variety of pathogens and multiple drug resistance is becoming common in differentbacterial strains. Plant based drugs play a major role in curing bacterial infections and there have been a lot of investigations of plants as sources of antibacterial agents, especially against drug resistant strains, and several Cyperaceae members also have been investigated in this direction (Karamolah *et al*., 2017). Essential oils, solvent extracts and isolated pure compounds of the plant group have been investigated in detail.

The essential oils and extracts of various *Cyperus* species are reported to possess antibacterial activity on both Gram-positive and Gram-negative bacterial strains.The phytochemicals in *Cyperus rotundus* showed antibacterial activity against several food borne pathogens, and the ability of *Cyperus rotundus* to inhibit *Streptococcus mutans* may have contributed to the low level of dental caries in certain prehistoric populations (Buckley *et al*., 2014). The essential oil components of *Cyprus rotundus* exhibited strong antibacterial activity against *Streptococcus aureus* (Liang *et al*., 2017). *Cyperus kyllinga* oil exhibited high activity against *Streptococcus aureus* and moderate activity against *Escherichia coli*, *Pseudomonas aeruginosa*, *Aspergillus flavus* and *Candida albicans* (Khamsan *et al.*, 2011). The antibacterial activity of *Cyprus papyrus* oil was assayed using agardisc diffusion and brothmicro dilution methods. The MIC values revealed that the oil samples inhibited the growth of *Streptococcus aureus*, *Escherichia faecalis* and *Escherichia coli* significantly (Lawal *et al*., 2016). Swamy *et al.* (2016) reported *Cyperus longus* essential oil as effective against the food-borne pathogens *Streptococcus aureus, Listeria monocytogenes, Escherichia faecium, Streptococcusenteritidis, Escherichia coli* and *Pseudomonas aeruginosa*.

Various extracts of *Cyperus rotundus* were evaluated for antibacterial activity against both Gram-positive and Gram-negative bacteria and found to be highly effective. The activities were also evaluated against numerous clinical isolates and the major observation was that the ethanol extract exhibited highest activity. The methanol extract of the plant *Cyperus conglomerates* showed activity against both Gram-positive and Gram-negative bacterial strains (Hisham *et al*., 2012). Ethanol extract of *Cyperus esculentus* possess activity against different bacterial strains including *Staphylococcusaureus, Bacillus subtilis, Escherichia coli* and *Enterococcus faecalis* (Dimayuga *et al*., 1998). Dini *et al*. (1992) reported that *Cyperus incompletes* possess weak activity against various Gram-positive and Gram-negative bacteria strain. Ethanol extract of *Cyperus scariosus* showed strong activity against *Staphylococcus aureus* strain but found to be inactive against various other bacterial strains (Lahariya, 1979). The methylene chloride extract of the rhizomes of *Cyperus sphacelatus* showed anti salmonella activity (Mfonku *et al*., 2021).

Along with the *Cyperus* species, other members of the Cyperaceae family also showed remarkable antibacterial activities. *Scleria striatinux* is one among the most active African botanicals against *Helicobacter pylori* infections (Nayim *et al.*, 2022). Antibacterial activity of the crude extract of *Scleria striatinux* supports their use in traditional medicine (Mbah *et al.*, 2012). Ethyl acetate extract of *Scirpus holoschoenus* showed anti-bacterial effect against *Staphylococcus aureus* and *Bacillus subtilis* with MIC values 0.4 and 0.6 µg/mL respectively (Saliha *et al*., 2017). *Carex* species are reported to have activity against various bacterial strains. *Carex cruciata, Carex alopecuroides* and *Carex baccans* exhibited antibacterial activities (Bogucka-Kocka *et al*., 2011). *Carex humilis* extract has been identified as an active ingredient in an anti-microbial composition and is harmless to the human body and has no side effects (Seo, 2015). In the discdiffusion antimicrobial assay, the crude extract of *Fimbristylis aphylla* produced moderate to strong antimicrobial activity against the test organisms and the strongest zone of inhibition was found against *Shigella dysenteriae* (Islam *et al*., 2011). The dichloromethane-methanol (1:1) extract of the whole plant of *Rhynchospora corymbosa* exhibited variable MICs and significant antimicrobial activity (Pagning *et al*., 2016).

Oral hygiene

Cyperus rotundus extract can be considered as a suitable candidate for the treatment and prevention of periodontitis and tooth decay, and the tubers have traditionally been used for oral hygiene in various cultures across the globe (Khojaste *et al*., 2018). The microbes *Streptococcus mutans*, *Aggregatibacter actinomycetemcomitans* and *Candida albicans* have major roles in damaging oral hygiene. Among the various solvent extracts, alcoholic extract of *Cyperus rotundus* had the greatest effect on the inhibition of growth of *Streptococcus mutans* and *Aggregatibacter actinomycetemcomitans* (Khojaste *et al*., 2018). The adherence of *S. mutans* to salivacoated hydroxyapatite beads was completely inhibited at the concentration of 4 mg/ml of the tuber extract of *Cyperus rotundus* (Yu *et al*., 2007). *Cyperus rotundus* root extract effectively increased the expressionof TGF-β1, triggered migration and increased the proliferation of fibroblasts, which ultimately increased the quantity of fibroblasts in the wound area of the oral mucosa traumatic ulcer in Wistar rats (Berniyanti *et al*., 2019). An extractive of *Cyperus rotundus* has been indicated as an active mouthwash (Abbas *et al*., 2019). Further, patent search reveals different kinds of oral hygiene products from *Cyperus rotundus* tuber extracts such as mouth wash, tooth paste,tooth powder andthroat lozenge.

Antiviral activity

Viral infections commonly include respiratory infections, digestive system infections, viral haemorrhagic fevers, sexually transmitted infections, neurological infections and congenital infections. Traditional medicines use a multitude of medicinal plants and formulations that shows antiviral activity and may be of benefit in treating emerging viral diseases including COVID 19. Antiviral activity, as measured by inhibitory effects of viral replication in cell culture, has commonly been used to evaluate *in vitro* pharmacologic activity of plant extracts and isolated compounds (Samuel, 2001).

Cyperaceae species are reported as good source of antiviral agents. *Cyperus rotundus* extracts exerted virucidal effect against HS, HB, hepatitis A, hepatitis B, Coxsackie and herpes simplex type 1 viruses (Soltan and Zaki, 2009; Parvez *et al*., 2019; Xu *et al*., 2020). However, the rhizome essential oil showed only negligible activity against hepatitis A, herpes simplex type 1, and coxsackie viruses with percent protection 7.9, 14.2 and 8.7 %, respectively (Samra *et al.*, 2020). A recent study has proved that the green synthesized silver nanoparticles of *Cyperus rotundus* could have antiviral activity against infectious laryngotracheitis virus (ILTV) and infectious bronchitis virus (IBV) in chickens (Abo-El-Yazid *et al*., 2022). *Cyperus niveus*ethanol extract showed antiviral activity against Ranikhet virus. *Cyperus pangorei* ethanol-water extract showed antiviral activity against *Vaccinia* and *Ranikhet* viruses.

Coronavirus disease 2019 (COVID-19) is a viral respiratory disease that has spread across the globe recently as a pandemic. The treatment of COVID-19 has been hampered due to the lack of effective therapeutic efforts. Main Protease (M^{pro}) is a key enzyme in the viral replication cycle and its non-specificity to human protease makes it a potential drug target. *Cyperus rotundus*, which belongs to the Cyperaceae family, is a traditional herbal medicine that has been widely studied for its antiviral properties. The plants as well as isolated compounds are reported as potential against SARS CoV-2 (Khuntia *et al*., 2021). On docking analysis, it has been observed that the phytochemicals α-cyperone and patchoulane derivatives possess excellent inhibitory activity against proteins of SARS CoV-2 virus

(Vincent *et al.*, 2020). Sugetriol-3,9-diacetate from *Cyperus rotundus* exhibited high binding affinity to PL^{pro} of SARS CoV-2, suggesting the utility of this plant in the treatment of SARS-CoV-2 (Wu *et al.*, 2020; Birendra Kumar *et al*., 2021).

Anti-inflammatory activity

Inflammation is a process by which the body's white cells protect the body from outside invaders such as bacteria and viruses. Inflammation can be either short lived (acute) or long-lasting (chronic). Conditions linked to chronic inflammation include cancer, heart disease, diabetes, asthma and Alzheimer's disease. Medicinal plants, their extracts and isolated compounds are always interesting targets for anti-inflammatory drug development (Ghasemian *et al*., 2016).

Species of the family Cyperaceae are used in traditional medicine in several countries for the treatment of some illness that have associated inflammatory complications. The anti-inflammatory action of the extract from *Cyperus rotundus* rhizome was first described in 1971 by Gupta *et al*., and since then investigations have been ongoing to understand the anti-inflammatory effect of different extracts or active constituents of *C. rotundus*. The phytochemicals found in *C. rotundus* oil were found to inhibit lipopolysaccharide (LPS) stimulated inflammatory response in a murine BV-2 microglial cell line and suppressing the nuclear factor kappa light chain enhancer of the activated B cell (NF-κB) pathway (Huang *et al*., 2018). Moreover, recent evidence has shown that the topical application of *C. rotundus* rhizome extract in a rat model with chronic and acute dermatitis lead to a reduction in ear oedema and inflammatory cell infiltration generated by exposure to 12-O-tetradecanoylforbol-acetate (TPA). This ultimately suggested that the extract could be a potential therapeutic tool for the treatment of inflammatory skin disorders (Rocha *et al.*, 2020). The compounds nootkatone, α-cyperone, β-selinene and valencene contribute to anti-inflammatory activity through their action on hemeoxygenase-1 pathway (Khan *et al*., 2011; Tsoyi *et al.*, 2011). The ethanol extract as well as volatile compounds of *Cyperus rotundus* were antiallergic both *in vivo* and *in vitro* by inhibiting the production of leukotrienes and B-hexosaminidase in basophilic leukemia cells of rat (Jin *et al.*, 2011). Mardiana *et al*. (2020) studied the activity of *Cyperus rotundus* against psoriasis and found that the plant has the potential of repairing the skin.

Various extracts of *Cyperus iria* are reported to possess anti-inflammatory activity. Vera *et al*. (2022) showed the anti-inflammatory activity of the ethanol extract of *Cyperus iria*. *Cyperus conglomeratus* extract exerted promising anti-inflammatory actions *via* suppressing the serum levels of TNF-α and galactin-3 in a dose-dependent manner (El-Shamy *et al*., 2020). *Scirpus* is an important genus in Cyperaceae with potent anti-inflammatory effects. *Scirpus yagara* tubers have long been used as traditional Chinese medicine. Li *et al*. (2014) reported the anti-inflammatory activity of the tubers of *Scirpus yagara* both *in vitro* and *in vivo*. *Fimbristylis aestivalis* is proved as a potential source of cyclooxygenase-2 (COX-2) inhibitors. The methanol extract of *Carex humilis* has anti-inflammatory activity against the prostaglandin H2 synthase (Lee *et al*., 1998). *Carex cruciata, C. alopecuroides* and *C. baccans* exhibited anti-inflammatory activities (Bogucka-Kocka *et al*., 2011).

Antioxidant activity

Oxidative stress is an important risk factor in the pathogenesis of numerous chronic diseases. Free radicals and other reactive oxygen species are recognized as agents involved in the pathogenesis of ailments such as asthma, inflammatory arthropathies, diabetes, Parkinson'sdisease, Alzheimer's disease, atherosclerosis as well as various types of cancers. Reactive oxygen species are also said to be responsible for the human aging. Antioxidants are compounds that inhibit oxidation, a chemical reaction that can produce free radicals. Plants are considered as good antioxidants, and plant phenolic acids, poly phenols and flavonoids trap free radicals such as peroxide, hydroperoxide or lipid peroxides and thus inhibit the oxidative mechanisms that lead to degenerative diseases (Wu *et al*., 2011).

Cyperaceae members are well known for its antioxidant potential. *Cyperus, Remirea, Rhynchospora* and *Scleria* and are the major genus in Cyperaceae family with antioxidant activity. Among these, *Cyperus* species received much attention. *Cyperus rotundus* was found to be a natural antioxidant and a free radical terminator (Kilani *et al*., 2008). Jihan *et al*., 2021 observed that *Cyprus rotundus* act as a protective agent against oxidative stress, neurotoxicity and inflammation induced by esfenvalerate. The flavonoids in the methanol extract of *Cyperus rotundus* significantly inhibited lipoperoxidation by maintaining the live antioxidative defense system, in addition to ROS and NO scavenging, and ultimately reducing the activities of transaminases and alkaline phosphatase as well as the levels of glucose and bilirubin in the blood serum.

Rakotonirina *et al*. (2001) observed that the methanol extract of *Cyperus articulates* showed antioxidant activity with IC_{50} 171.8 µg/ml. The essential oils of *Cyperus articulates* rhizome encapsulated in chitosan nanoparticles revealed a high potential to eliminate free radicals. The encapsulation improves the stability and also the efficiency of extracts of *Cyperus* spp. (Kavaz *et al.,* 2019). Hot water extract of *Cyperus esculentus* possess antioxidant activity (Cook *et al*., 1998). The milk extracted from *Cyperus esculentus* tubers increased the activity of antioxidant enzyme superoxide dismutase (SOD), while malondialdehyde concentrations were lowered compared to the control group, thus demonstrating good antioxidant activity (Onuoha *et al*., 2017). Ethanol and n-hexane extracts of *Cyperus esculentus* showed superior antioxidant activity (Nwosu *et al*., 2022). Antioxidant activity of the volatile oil of *Cyperus alternifolius* was tested using DPPH free radical assay and found to exhibit significant antioxidant activity (Ahmed, 2012). *Cyperus compressus* is an excellent source of antioxidant-based phytonutrients, validating its traditional use (Datta *et al.,* 2018). An experiment, assessing the antioxidant activity of the extracts of *Cyperus tegetum* demonstrated significant DPPH radical, superoxide anion and hydrogen peroxide scavengingactivities compared to the standards, such ashydroxybutylanisol, butylhydroxytoluene and ascorbic acid (Chatterjee and Khanra, 2019). Alif *et al*. (2018) reported the antioxidant potential of *Cyperus odoratus*.

The ethyl acetate fraction of *Scirpus holoschoneus* showed highest antioxidant activity among various species tested (Saliha *et al*., 2017). The methanolic extracts of seeds of *Scirpus articulates* showed good antioxidant potential in ABTS assay (Bhardwaj *et al*., 2014). The methanol extract of *Fimbristylis miliacea* and *Fimbristylis dichotoma* showed significant antioxidant activity (Ramli *et al.,* 2022). The novel feruloyl monoglyceride macrocycles isolated from the leaves of *Carex distachya* displayed strong antioxidant activity against reactive oxygen species and inhibited malondialdehyde synthesis (Fiorentino *et al*., 2007). The IC_{50} of the root methanol extract of *Carex distachya* was 4.2 µg/mL for DPPH radical scavenging assay, and the resveratrol derivatives, lignans and phenylethanoids were identified as the responsible compounds for the antioxidant activity (Fiorentino *et al*., 2008).

Anticancer activity

Despite the developments in understanding the mechanism of cancer cells and treatments, the ailment remains uncurable to a large extent, and the situation demands for an alternative treatment solution (Gilbert, 2000). Herbal medicine provides a feasible alternative to western medicine against cancer, and in fact most of the chemotherapeutic drugs for cancer treatment are molecules identified and isolated from plants or their synthetic derivatives.Plants play an important role in anticancer treatment through regulating signalling pathways. The main mechanism of anticancer activity of plant extracts is by inhibiting the cell proliferation or by inducing apoptosis in the cancerous cells.

The anticancer activity of *Cyperus rotundus* extracts has been assessed, and the mechanism of action also elucidated. Human cervical cancer (HeLa) cell lines exposed to different doses of *Cyperus rotundus* extracts revealed morphological modifications and changes in the degree of chromatin condensation. *Cyperus rotundus* ethanol extracts were used to evaluate its effects on triple-negative breast cancer cells (TNBC) (negative for estrogen, progesterone receptors, and human epidermal growth factor receptor 2 (HER2) protein over expression). The extracts inhibited the TNBC cell proliferation, which might be related to cell cycle arrest at the G0/G1 phase, thus inducing apoptosis by promoting Bcl-2associated X protein (Bax) expression and inhibiting B cell lymphoma (Bcl) expression. The n-hexane extract from *Cyperus rotundus* rhizomes showed activity on MCF-7 breast cancer cell lines, by inducing apoptosis and halting them in G0-G1 stages of the cell cycle (Simorangkir *et al*., 2019). Samra *et al*. (2021) studied the petroleum ether and methylene chloride extracts of *Cyperus rotundus* and reported remarkable cytotoxic activity against the HepG2. The phenolic compounds in *Cyperus rotundus* were found to be significant antiproliferative agents, and arrest the cell cycle, inhibit DNA binding, regulate carcinogenic metabolism and ontogenesis expression, prevent cell adhesion, migration, and differentiation, and block signal pathways to induce apoptosis (Huang *et al*., 2020). Both the ethanolic and methanolic extracts showed higher antiproliferative activity associated with apoptosis induction through upregulation of death receptor 4 (DR4), DR5, and BAX (Park et al., 2014). Various extracts of aerial parts of *Cyperus rotundus* were assayed by *Salmonella typhimurium* assay system and found to possess antimutagenic activity. *Cyperus rotundus* essential oils showed promising level of inhibition on Ehrlich ascites carcinoma cells while on human brain tumor cell lines U 251 and Hela, the activity was negligible (Bisht *et al.*,2011). *Cyperus rotundus* rhizome was found to inhibit cell growth in ovarian cancer cell lines A2780, SKOV3 and OVCAR3. It was observed that the sesquiterpenoid from the plant induces caspase dependent apoptosis in human ovarian cancer cells (Ahn *et al.*, 2015). Wang *et al.* (2021) isolated novel sesquiterpenoids from *Cyperus rotundus* that exhibited inhibitory activity on NF-κB pathway. The petroleum ether fraction of *Cyperus rotundus* rhizome was found to be active against HepG2, PC3 and MCF-7 cell lines using MTT assay and the isolated ceramides from the fraction showed promising anticancer activity (Samra *et al*., 2021).

The anticancer activity of *Cyperus conglomeratus* extracts was tested using silver nanoparticles in MCF-7 breast cancer cells and normal fibroblasts using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide (MTT), and a selective cytotoxicity against MCF-7 was observed, while in fibroblasts, no toxic effect was reported (Al-Nuairi *et al*., 2020). Methanol extract of the rhizome of *Cyperus tegetum* on MTT assay on Hela cell line showed IC_{50} for the extract at 300µg/mL (Chatterjee *et al.*, 2022). The ethanol extract of *Cyperus exaltatus* exhibited cell cycle dysregulation, ERK1/2/p38 MAPK/AKT phosphorylation, and reduced MMP-9-mediated metastatic capacity in prostate cancer models *in vitro* and *in vivo* (Kim *et al.*, 2022). Phytochemicals in *Carex folliculata* and *Carex gynandra* inhibited the growth of human colon tumorigenic cells mediated by cell cycle arrest, indicating its anticancer potential (Sarrias *et al*., 2011). *Carex cruciata, Carex alopecuroides* and *Carex baccans* also exhibited antiproliferative activities (Bogucka-Kocka *et al*., 2011).

Anti ulcer activity

Gastric ulcer is a prevalent gastrointestinal multi-etiological disorder. Ulcer can be developed inside the inner lining of the stomach (gastric ulcer) or the small intestine (duodenal ulcer). Both the ulcers are also cumulatively referred as peptic ulcers. It affects nearly 10% of world population. The conventional drugs used in the treatment of ulcer include histamine receptor antagonists, prostaglandins analogues, proton pump inhibitors, cytoprotective agents, antacids and anticholinergics, but most of these drugs produce undesirable side effects or drug interactions and may even alter biochemical mechanisms of the body upon chronic usage. Hence, herbal medicines are generally suggested in such chronic cases, wherein drugs are required to be used for long periods (Bandyopadhyay *et al*., 2002).

The petroleum ether and methanol extracts of *Cyperus rotundus* showed antiulcer activity. **(**Rahman *et al.*1986; Daswani *et al*., 2001). Ethyl acetate fractions of tubers and aerial parts from *Cyperus alternifolius* showed significant antiulcer activity (Farrag *et al.*, 2019). The antiulcer activity of *Cyperus conglomeratus* was confirmed by histopathological, histochemical examinations as evidenced by amelioration of inflammation and preservation of the gastric mucosa against ethanol deleterious effects. The results suggest *Cyperus conglomeratus*as a promising gastroprotective natural remedy and can be incorporated in nutraceuticals (El Shamy *et al*., 2020).

Anti diabetic activity

Diabetes mellitus is one of the common metabolic disorders affecting around 2.8% of the world's population and is anticipated to cross 5.4% by the year 2025. The ailment has caused significant morbidity and mortality due to microvascular (retinopathy, neuropathy, and nephropathy) and macrovascular (heart attack, stroke and peripheral vascular disease) complications. Currently available therapies for diabetes include insulin and various oral antidiabetic agents such as sulfonylureas, biguanides and glinides. Many of them have a number of serious adverse effects; therefore, the search for more effective and safer hypoglycemic agents is one of the important areas of investigation. One of the promising bio activities of *Cyperus rotundus* is its antidiabetic activity, and it has been used from ancient time to treat hyperglycemic disorders such as diabetes. Administration of *Cyperus rotundus* extract in rats with hyperglycemia lowered their blood glucose level significantly (Raut and Gaikwad, 2006). The aqueous-ethanol fractions of *Cyperus rotundus* showed significantantidiabetic activity, and the phytochemicals of *Cyperus rotundus* have promisingrole in preventing glucose-induced cataractogenesis, visual impairment, orclouding of eye lens which result from diabetes (Ramya *et al.*, 2012; Rautand Gaikwad, 2012). Methanol extract of rhizomes of *Cyperus tegetum* exhibited significant anti-hyperglycemic activities in alloxan-induced diabetic rats (Chaulya *et al.*, 2011). Sudipta *et al.* (2011) investigated the anti-diabetic activity of *Cyperus kyllinga* and concluded that polar part of the plant extract possesses the capacity to reduce the fasting blood sugar and this ability might be due to the reduced insulin secretion in the body.

Analgesic activity

Analgesics relieve pain by acting in the CNS and peripheral pain mediators without changing consciousness. Strong analgesics are more likely to cause side effects such as dependence, addiction and withdrawal symptoms (Mustaffa *et al.*, 2010). Use of medicinal plants is one of the most primary ways of fighting diseases and relieving pain, and plant extracts possessed peripheral analgesic activity and central pain inhibition potential (Parsaei *et al.*, 2016).

One of the major pharmacological activities of the *Cyperus* species is the painrelieving potential. The ethanol extract of *Cyperus rotundus* showed significant analgesic activity by tailflick method on mice (Imam *et al*., 2014). The phytochemicals cyperene and β-caryophyllene oxide in the rhizome essential oil of *Cypeus rotundus* showed excellent analgesic activity in acetic acid induced mice stretching model (Chen *et al*., 2011). The rhizome essential oil of *Cyperus eleusinoides*showed strong analgesic activity (Kokate and Varma, 1982) The ethanol extract of *Cyperus odoratus* produced analgesic activity due to the inhibition of prostaglandin synthesis by blocking of lipooxygenase and cyclooxygenase activities, and showed a comparable writhing inhibition to diclofenac, the standard analgesic drug (Alif *et al*., 2018).

Anti arthritic activity

The anti-arthritic activity is mainly effected by decreasing the activity of membrane marker enzymes such as alkaline phosphatase, serum glutamic oxaloacetic transaminase (SGOT), serum glutamate pyruvate transaminase (SGPT) and by the prevention of leucocytes migration in the inflamed area. Traditional medicinal plants are practiced worldwide for treatment of arthritis especially in developing countries where resources are meagre to access the modern medicines. The anti arthritic activity of *Cyperus rotundus* essential oils were evaluated and results showed dose dependent antiarthritic activity. Treatment with *Cyperus rotundus* significantly reduced the swelling in the injected area as compared to reference standard. The essential oil of *Cyperus eleusinoides* showed hypothermic effect (Kokate and Varma, 1982).

Antipyretic activity

Antipyretics are the agents which reduce the elevated body temperature. Many plants are being traditionally used in the treatment of fever and their antipyretic activities have been confirmed scientifically (Sultana *et al.*, 2015). The alcoholic extract of *Cyperus rotundus* showed significant antipyretic activity against pyrexia induced in rats, and the active ingredients nootkatone and valencene were confirmed as having antipyretic activity in sepsis animal model *in vivo* (Pal *et al.*, 2009). Methanol extract of leaves of *Fimbristylis miliacea* showed antipyretic activity in mice model (Roy *et al.*, 2019).

Wound healing activity

Wound healing refers to a living organism's replacement of destroyed or damaged tissue by newly produced tissue. In undamaged skin, the epidermis and dermis form a protective barrier against the external environment. After injury, an inflammation response occurs and there are three stages to the process of wound healing: inflammation, proliferation and remodeling (Garg *et al.*, 2011). The wound healing efficacy of various plant extracts have been studied in detail and several plants have been reported with accelerated wound healing activity (Garg and Paliwal, 2011).

The alcoholic extract of *Cyperus rotundus* rhizomes showed considerable variation in wound closure time and tensile strength in different wound models as compared to standard drug nitrofurazone (Puratchikody *et al.,* 2006). An alcoholic extract of the tuber of *Cyperus rotundus* showed wound healing activity in different types of wounds compared with the standard drug nitrofurazone (Imam *et al.*, 2014). Decoction of *Cyperus articulatus* is found to be effective in treating wounds (Mongelli *et al.*, 1995).

Hepatoprotectiveactivity

The liver performs a vital role in metabolism, secretion, storage and detoxification of endogenous and exogenous substances. Oxidative stress and free radicals enhance the severity of hepatic damage, which can be overcome by the antioxidant mechanism. In spite of the scientific advancement in the field of hepatology during recent years, liver problems are on the rise. Only a few drugs are available for the treatment of liver, and in view of the undesirable side effects of the synthetic agents, there is growing demand for the therapeutic evaluation of medicinal plants using systematic research methodology.

Cyperaceae species are reported to exhibit hepatoprotective activity. The ethyl acetate extract of *Cyperus rotundus* was found effective against CCl_4-induced hepatotoxicity in rats (Sureshkumar and Mishra, 2005). Parvez *et al*. (2019), reported the hepatoprotective and hepatic CYP450 enzyme (CYP3A4) modulatory potential of *Cyperus rotundus*. Further, the hexane fraction of *Cyperus rotundus* rhizome reduced the elevated transcription levels of sterol regulatory element binding protein-1c (SREBP-1c) in primary hepatocytes following exposure to the liver X receptor α (LXRα) agonist and ameliorated fatty liver disease and reduced the expression levels of hepatic lipogenic genes in high sucrose diet fed mice. The results suggested that the hexane fraction of *Cyperus rotundus* might be an effective therapeutic agent for fatty liver disease (Yoon *et al*., 2015). *Cyperus alternifolius* showed significant hepatoprotective activity against CCl_4 induced hepatotoxicity in rats (Awaad *et al.*, 2012). *Carex cruciata*, *C. alopecuroides* and *C. baccans* also exhibited hepatoprotective activity (Bogucka-Kocka *et al*., 2011).

Anti obesity activity

Obesity has become an epidemic worldwide that increase the risk of other diseases like diabetes, cardiovascular diseases and fatty liver disease. It is a complex disease involving an excessive amount of body fat. Usually obesity results from inherited, physiological and environmental factors, combined with diet, physical activity and exercise. Anti-obesity drug act through several potential mechanisms including increased energy expenditure, appetite suppression, inhibition of digestive enzymes or interference in the absorption of fat or sugar from food at the intestinal tract (Muller *et al*., 2022).

Various plant extracts act as potent anti-obesity agents (Fathima *et al*., 2019). Majeed *et al*. (2022) studied the anti-obesity potential of *Cyperus rotundus* hexane extract and showed a reduction in body weight with significant decrease in waist circumference and Body Mass Index. *Cyperus rotundus* hexane extract showed a dose-dependent adipogenesis reduction *in vitro* with an IC_{50} value of 9.39μg/mL. The efficacy was associated with reduced levels of leptin, corticosteroids and serum lipid levels (Majeed *et al.*, 2022). Further, the stilbenoidspiceatannol, scirpusin A and scirpusin B were identified as the pharmacologically active molecules responsible for the anti-obesity properties in *Cyperus rotundus*.The tuber extract of *Cyperus rotundus* contains activators of β-adreno receptors that reduce obesity by stimulating thermogenesis of brown adipose tissue. The aqueous tuber extract of *Cyperus rotundus* reduces the body weight gain, organ weight, serum triglyceride level and the total cholesterol level in obese rats and a herbal supplement containing *Cyperus rotundus* rhizome extract was suggested for controlling obesity (Athesh *et al.,* 2014). *Scirpus* species has also relevance in obesity and obesity related diseases. *Scirpus yagara* extract was reported as anti-obesity agent on HFD-induced obesity (Wang *et al*., 2015).

Anti depressant activity

Depression is a psychiatric disorder which affects more than one-fifth of the global population (Wang *et al.,* 2019). It causes considerable burden on individuals and society with its high morbidity, recurrence and mortality (Feng *et al*., 2019). Currently, a number of antidepressants are used in the clinical treatment. However, disadvantages such as delayed onset time, inadequate response rate and side effects are reported for the current drugs (Clayton *et al.*, 2018). Medicinal plants have been reported to exert antidepressant effects through synaptic regulation of serotonin, noradrenaline and dopamine, regulating activity of hypothalamic-pituitary-adrenal axis, reinforcing anti-oxidant defence system, and decreasing inflammatory mediators. Medicinal plants and their active compounds can relieve depression through different pathways and hence are considered a new source to produce antidepressants (Zahra and Sana, 2017).

Zhou *et al*. (2016) investigated the antidepressant activity of *Cyperus rotundus* and its possible mechanism of action, and found to be significantly reducing depression. Xia *et al*. (2020) showed that *Cyperus rotundus* methanol extract has therapeutic potential against depression and may be attributed to SIRT3 stimulated neuroplasticity enhancement by NLRP3 inflammasome suppression. Hot water extract of *Cyperus eleusinoides* also showed antidepressant activity (Kokate and Varma, 1982).

Anti androgenic activity

An anti-androgen is a compound that has the biological effect of blocking or suppressing the action of male sex hormones such as testosterone within the body. Androgen dysregulation can give rise to a variety of clinical disorders, including polycystic ovarian syndrome, which affects 7% of the world's population. Though several androgen antagonists are available, in recent yearsthere has been an increasing demand for complementary and alternative therapies, especially using plant derived anti-androgen agents (Grant and Ramasamy 2012).

Flavonoids from *Cyperus rotundus* possesses estrogenic property, exerting an anti-androgenic effect on androgenic hair without disturbing the testosterone level (Tang *et al.*, 2008). El-Kaream (2012) observed that the essential oils were effective against moderate hirsutism by inhibition of 5-α-reductase and 17-β-hydroxysteriod dehydrogenase without affecting the serum testosterone level. *Cyperus rotundus* essential oil is found to be effective for decreasing the growth of axillary hair.

Anti diarrheal activity

Diarrhoea is generally defined as the passage of abnormally liquid or unformed stools associated with increased frequency of defecation and abdominal pain (Guerrant *et al.*, 2001). Despite reductions in morbidity and mortality worldwide, diarrhoea still accounts for more than 2 million deaths annually and is associated with impaired physical and cognitive development in resourcelimited countries. Medicinal plants are usually preferred to treat gastrointestinal disorders such constipation and diarrhoea, because they contain multiple constituents with less side effects (Gilani *et al.*, 2005).

Cyperus rotundus tubers have been traditionally used in several Ayurvedic formulations to treat diarrhea (Shamkumar *et al.*, 2012). The aqueous extract of the plant is reported with antidiarrheal potential against castor oil induced diarrhea in mice and the pre-treatment of mice with aqueous extract decreases the purging frequency through an antisecretory mechanism. The petroleum ether and methanol extracts also showed antidiarrheal activity (Rahman *et al.*, 1986; Daswani *et al.*, 2001). A moderate dose-dependent antidiarrheal activity was exhibited by the methanol extract of *Fimbristylis aphylla* (Islam *et al.*, 2011).

The methanol extract of *Fimbristylis miliacea* also exerts strong antidiarrheal effect (Mukta *et al*., 2020).

Anti convulsant activity

Epilepsy is a serious neural disease that affects around 50 million people all over the world. Although for the majority patients with epilepsy, seizures are well controlled by currently available antiepileptic drugs (AEDs), there are still around 30% of patients suffering from medically refractory epilepsy and approximately 30-40% of all epileptic patients are affected by numerous side effects and seizure resistance to the current AEDs. Therefore, many researchers try to develop novel approaches to treat epilepsy, especially through new antiepileptic constituents from herbal medicines.

Phytochemicals present in the rhizomes of *Cyperus rotundus* are known to have anticonvulsant properties (Sonwa and Konig, 2001; Shivakumar *et al.*, 2009). The methanolic extract of rhizomes of *Cyperus articulates* showed anticonvulsant activity in mice, by protecting maximal electroshock (MES) and pentylenetetrazol (PTZ)-induced seizures (Bum *et al*., 2001). The leaves extract of the plant also showed effect on pentylenetetrazol (PTZ) induced seizures in mice (Herrera-Calderon *et al*., 2017).

Anti genotoxic activity

Genotoxicity is the ability of different agents to produce damage to genetic material (Bhattacharya, 2011). The agents capable of causing genetic toxicity are described as genotoxic. Since the genotoxic agents are involved in the initiation and promotion of several human diseases, the significance of novel bioactive phytocompounds in counteracting these mutagenic and carcinogenic effects is now gaining credence.

Flavonoids and tannins in *Cyperus rotundus* extract synergistically exhibited antigenotoxic activity. The ethyl acetate extracts were found to be effective in reducing the production of thiobarbituric acid reactive substance (TBARS) and protecting against H_2O_2/UV induced DNA damage (Kilani *et al.*, 2008). Luteolin was found to be an active ingredient in reducing TBARS production and K562 cell proliferation. The antigenotoxic potential evaluated against nifuroxazide and AFB1-induced genotoxicity showed potential activity for ethyl acetate extract of *Cyperus rotundus* (Kilani *et al.*, 2011).

Neuroprotective activity

Neuroprotection aims at preventing or slowing the loss of neurons. For neuroprotective assays, a number of neurotransmitters and signalling molecules have been identified as therapeutic targets. Conventional as well new molecules have been tried against these targets. Phytochemicals from medicinal plants play a vital role in maintaining the brain's chemical balance by influencing the function of receptors for the major inhibitory neurotransmitters (Halliwell, 1992).

Cyperus plant extracts have proven to have neuroprotective effect against damage due to reactive oxygen species (ROS). The deposition of β-amyloid in the hippocampus promotes oxidative stress, reactive oxygen formation, reduction of the antioxidant enzymes activity, and consequently, neuronal death. Previous studies have shown that the flavonoids can modulate the function of immune cells, exerting a direct effect against inflammation and oxidative stress (Dhillon *et al.,* 1993). Thus, the antioxidant activity showed by the flavonoids present in *Cyperus rotundus* extracts explains the increase in hippocampal neurogenesis of β-amyloid in rat models and consequently improves the memory (Shakerin *et al.,* 2020). The neuroprotective activity of *Cyperus rotundus* ethanol extract was assessed against sodium nitrate induced hypoxia injury and was found to be protecting rats against cognitive impairment, muscular co-ordination defects and locomotors defects. The oral administration of *Cyperus rotundus* ethanol extract prevented pyramidal cell loss in the CA1 region of hippocampus (Jebasingh *et al*., 2014). *Cyperus rotundus* extractattenuated peroxynitrite induced neurotoxicity and inhibited NO generation by downregulating i-NOS expression (Kumar *et al*., 2013).

Orientin, a flavonoid found in *Cyperus esculentus* decreased the oxidative stress, generating a neuroprotective effect against cerebral ischemia/reperfusion injury in Sprague-Dawley rats through the middle cerebral artery occlusion method (Jing *et al*., 2020). Treatment with TN extract restored Scop-induced learning and memory impairments. *Cyperus esculentus* extract lowered amyloid beta, β-secretase protein expression and acetylcholine esterase (AChE) activity in the hippocampus of rats, and also decreased malondialdehyde levels, restored antioxidant levels and reduced proinflammatory cytokines as well as the Bax/Bcl2 ratio (Saeed *et al*., 2022). *Fimbristylis ovata* extract significantly decreased the inflammatory cytokines under oxidative stress induction. The plant reported to possess protective effects in SH-SY5Y, human neuroblastoma cell line, under neurotoxicity circumstance induced by AGEs (Sirirattanakul and Santiyanont, 2021).

Nootropic activity

According to the World Health Organization, approximately 450 million people suffer from a mental or behavioural disorder. Dementia, the age-related mental disorder, is a characteristic symptom of Alzheimer's Disease (AD). It is a progressive, neurodegenerative and cerebrovascular disease, destroying cells in the brain, causing problems with memory, unusual behaviour, difficulty in thinking, personality changes and ultimately leading to death. AD is characterized by the loss of neuronal cells and is primarily linked to neurofibrillary tangles and neuritic plaques. The cholinergic system in the brain plays an important role in learning and memory, which involves acetylcholine. Dementia is produced due to reduction of Ach in the brains of patients with AD. Medicinal plants are used for memory enhancement from ancient times onwards. In rodents and human beings, drugs like scopolamine impair learning and memory (Dinesh *et al.*, 2004).

Cyperus rotundus has been traditionally used as a memory enhancer to treat memory loss and cognition, and experiments revealed that *Cyperus rotundus* significantly increased the memory (Sunil *et al.*, 2011). Treatment with total oligomeric flavonoids fraction significantly reduced the neurological deficits and reversed the anxiogenic behavior in rats (Soman *et al.*, 2013). However, the extracts and essential oils of *Cyperus rotundus* were inactive on scopolamine induced memory dysfunction in rats (Rabbani *et al.*, 2014).

Anti endometriosis and anti dysmenorrhea activities

Pain associated with menstruation is called dysmenorrhea, and medicinal plants are used for the treatment of dysmenorrhea in various traditional medicinal systems across the globe. The rhizome of *Cyperus rotundus* showed significant antidysmenorrhea effect in mice model and the compounds spathulenol and β-caryophyllene oxide were found as the active compounds (Yoon *et al.*, 2015).

Endometriosis is characterized by the presence and growth of endometrial tissue outside the uterus in the peritoneal cavity. It affects approximately 6-10% of women of reproductive age. *Cyperus rotundus* extract exerts anti-endometriotic activities by the inhibition of cell adhesion and neurotrophin expression, through the negative regulation of the Akt and NF-kB pathways in endometriotic cells (Ahn *et al*., 2022).

Anti parasitic activity

Antiparasitic drugs are a group of medications used in the management and treatment of infections by parasites including protozoa, helminths and ectoparasites. Infections by parasites are often treated by plant products or secondary metabolites isolated from medicinal plants. Malaria, caused by the parasite *Plasmodium* sp., is a life-threatening disease and a leading cause of illness and death in many developing countries. Natural products isolated from plants have been a good source of lead compounds used to treat various infectious diseases, including malaria. Two examples of phenomenal lead compounds that have greatly contributed in reducing malaria deaths worldwide are quinine isolated from the Andes tree *Cinchona officinalis* and artemisinin isolated from the Chinese medicinal plant *Artemisia annua*. However, *Plasmodium* has shown in the last few decades increasing resistance to antimalarial drugs, highlighting the need to identify novel anti-malarial compounds from plant resources (Schwikkard *et al*., 2002).

Methanol extract and essential oil of *Cyperus rotundus* rhizome inhibited the survival of *P. falciparum* (Thebtaranonth *et al*., 1995). Members of the genus *Scleria* would be worth being evaluated for their antiplasmodial properties. Efange *et al.* (2009) isolated the antiplasmodial sesquiterpene endoperoxide okundoperoxide from *Scleria striatinux* and was found active *in vitro* againstthe amoeba *Naegleria fowleria* and also against *Schistosoma japonicum, S. mansoni* and *Clonorchis sinensis* (Hien and White, 1993). *Cyperus articulatus* extract showed *in vitro* antiplasmodial activity against two strains of *P. falciparum* (Assis *et al.,* 2020). *Cyperus brevifolius* ethanol extract of aerial parts abolished the motility of *Eudrilus eugeniae* (Pucblos *et al.,* 2017).

Insecticidal activity

The major Cyperaceae member *Cyperus rotundus* is also attributed with remarkable insecticidal and larvicidal activities. Studies revealed that the tuber extracts of *Cyperus rotundus* were effective for repellency of the entire mosquito vector even at low dose (Singh *et al*., 2009). *Cyperus rotundus* was more effective insecticidal than carbamate and has almost the same efficacy as that of organophosphate against the tested ants (Solita *et al*., 2011). The ovicidal and larvicidal efficacy of essential oils of the tubers of *Cyperus rotundus* was studied on eggs and fourth instar larvae of *Aedes albopictus*. The eggs and larvae were exposed to serial concentration of the oils ranging from 5-150 ppm and observed for 24 h. Oils showed remarkable ovicidal and larvicidal activities indicated by EC_{50} value of <5 ppm and LC_{50} value of <20 ppm (Vivek *et al*., 2008).

Toxicological studies

Toxicology testingis the process of determining the degree to which a substance of interest negatively impacts the normal biological functions of an organism, given certain exposure duration, route of exposure, and substance concentration. Pharmacological activity analyses of medicinal plant extracts are associated with toxicity evaluation and need to report the feasible dosage level of various plant extracts.

A review of the pharmacological activities reported for various Cyperaceae members revealed the diverse bioactivities, as claimed by traditional herbal information, and the toxicological assays revealed the safety for human use in medicinal and food sector (**Table 1**). Different extracts of *Cyperus rotundus* in various dosages revealed no toxic effect even at higher dosages up to 4000 mg/kg, with no signs or symptoms of toxicity and recommends the rhizomes and tubers of *Cyperus rotundus* as safe for human use (Thanabhorn *et al*., 2005). Roy *et al*. (2022) studied the acute and subchronic toxicity profile of the methanol extract of the leaves of *Fimbristylis miliacea* and suggests that the plant has no toxicity.

Table 1. Pharmacological activities of Cyperaceae members

Sl. No.	Pharmacological properties	Cyperaceae species	Reference
1.	Analgesic activity	*Cyperus eleusinoides*	Kokate and Varma, 1982
		Cyperus rotundus	Imam *et al*., 2014 Chen *et al*., 2011
		Fimbristylis aestivalis	Talukder *et al*., 2022
2.	Anti androgenic activity	*Cyperus rotundus*	Tang *et al*., 2008 El-Kaream 2012

3.	Anti arthritic	*Cyperus rotundus*	Biradar *et al*., 2010
		Cyperus esculentus	Biradar *et al*., 2010
		Cyperus eleusinoides	Kokate and Varma, 1982
4.	Anti bacterial activity	*Carex humilis*	Seo, 2015
		Cyperus conglomerates	Hisham *et al*., 2012
		Cyperus esculentus	Dimayuga *et al*., 1998
		Cyperus incompletes	Dini *et al*., 1992
		Cyperus scariosus	Lahariya, 1979
		Cyperus rotundus	Buckley *et al*., 2014 Peerzada *et al*., 2015 Khojaste *et al*., 2018 Al-Hazmi *et al*., 2018 Sharma and Singh, 2011
		Cyperus sphacelatus	Mfonku *et al*., 2021
		Cyperus kyllinga	Khamsan *et al*., 2011
		Cyperus longus	Swamy *et al*., 2016
		Cyperus papyrus	Lawal *et al*., 2016
		Fimbristylis aphylla	Islam *et al*., 2011
		Rhynchospora corymbose	Pagning*et al*., 2016
		Scleria striatinux	Mbah *et al*., 2012 Nayim *et al*., 2022
		Scirpus holoschoenus	Saliha *et al*., 2017
		Carex cruciata	Bogucka-Kocka *et al*., 2011
		Carex alopecuroides	Bogucka-Kocka *et al*., 2011
		Carex baccans	Bogucka-Kocka *et al*., 2011
5.	Anti cancer activity	*Cyperus tegetum*	Chatterjee *et al*., 2022
		Cyperus exaltatus	Kim *et al*., 2022

		Cyperus rotundus	Ahn *et al.*, 2015 Bisht *et al.*, 2011 Huang, 2020 Park *et al.*, 2014 Samra *et al.*, 2021 Simorangkir *et al.*, 2019 Wang *et al.*, 2021
		Cyperus conglomerates	Al-Nuairi *et al*., 2020
		Carex folliculate	Sarrias *et al.*, 2011
		Carex gynandra	Sarrias *et al.*, 2011
		Fimbristylis aestivalis	Talukder *et al.*, 2022
		Carex cruciata	Bogucka-Kocka *et al.*, 2011
		Carex alopecuroides	Bogucka-Kocka *et al.*, 2011
		Carex baccans	Bogucka-Kocka *et al.*, 2011
6.	Anti convulsant activity	*Cyperus rotundus*	Sonwa and Konig, 2001 Shivakumar *et al.*, 2009
		Cyperus articulatus	Herrera-Calderon *et al.*, 2017
7.	Anti depressant activity	*Cyperus eleusinoides*	Kokate and Varma, 1982
		Cyperus rotundus	Zhou *et al.*, 2016 Xia *et al.*, 2020
8.	Anti diarrheal activity	*Cyperus scariosus*	Shamkumar *et al.*, 2012 Rahman *et al.*, 1986 Daswani *et al.*, 2001
		Fimbristylis aphylla	Islam *et al.*, 2011
		Fimbristylis miliaceae	Mukta *et al.*, 2020
9.	Anti dysmenorrhea activity	*Cyperus rotundus*	Yoon *et al.*, 2015
10.	Anti genotoxic activity	*Cyperus rotundus*	Kilani *et al.*, 2008 Kilani *et al.*, 2011

11.	Anti hypoxia activity	*Cyperus rotundus*	Jebasingh *et al*., 2014
12.	Anti inflammatory activity	*Cyperus iria*	Vera *et al*., 2022
		Cyperus rotundus	Jin *et al*., 2011 Mardiana *et al*., 2020 Huang *et al*., 2018 Rocha *et al*., 2020 Khan *et al*., 2011 Tsoyi *et al*., 2011 Mardiana *et al*., 2020
		Cyperus conglomeratus	El-Shamy *et al*., 2020
		Carex cruciata	Bogucka-Kocka *et al*., 2011
		Carex alopecuroides	Bogucka-Kocka *et al*., 2011
		Carex baccans	Bogucka-Kocka *et al*., 2011
		Carex humilis	Lee *et al*., 1998
		Scirpus yagara	Li *et al*., 2014
13.	Anti obesity activity	*Cyperus rotundus*	Sureshkumar and Mishra, 2005 Parvez *et al*., 2019 Yoon *et al*., 2015 Majeed *et al*., 2022 Athesh *et al*., 2014
		Cyperus alternifolius	Awaad *et al*., 2012
		Scirpus yagara	Wang *et al*., 2015
14.	Anti oxidant activity	*Cyperus alternifolius*	Ahmed, 2012
		Cyperus articulates	Rakotonirina *et al*., 2001 Kavaz *et al*., 2019
		Cyperus esculentus	Cook *et al*., 1998 Onuoha *et al*., 2017 Nwosu *et al*., 2022
		Cyperus rotundus	Kilani *et al*., 2008 Jihan *et al*., 2021
		Cyperus conglomeratus	Al-Rowaily *et al*., 2019

		Cyperus capitatus	Al-Rowaily *et al.*, 2019
		Cyperus tegetum	Chatterjee *et al.*, 2019
		Cyperus compressus	Datta *et al.*, 2018
		Cyperus odoratus	Alif *et al.*, 2018
		Scirpus holoschoneus	Saliha *et al.*, 2017
		Carex stramentitia	Shimamura *et al.*, 2007
		Carex alopecuroides	Shimamura *et al.*, 2007
		Fimbristylis miliacea	Ramli *et al.*, 2022
		Fimbristylis dichotoma	Ramli *et al.*, 2022
		Scirpus articulates	Bhardwaj *et al.*, 2014
		Scirpus articulates	Bhardwaj *et al.*, 2014
15.	Anti parasitic activity	*Cyperus brevifolius*	Pucblos*et al.*, 2017
		Cyperus rotundus	Thebtaranonth *et al.*, 1995
		Scleria striatinux	Hien and White, 1993
16.	Anti platelet activity	*Cyperus rotundus*	Seo *et al.*, 2011
17.	Anti pyretic activity	*Cyperus rotundus*	Pal *et al.*, 2009
		Fimbristylis miliacea	Roy *et al.*, 2019
18.	Anti ulcer activity	*Cyperus rotundus*	Rahman *et al.*,1986 Daswani *et al.*, 2001
		Cyperus alternifolius	Farrag *et al.*, 2019
		Cyperusconglomeratus	El Shamy *et al.*, 2020
19.	Anti uropathogenic activity	*Cyperus rotundus*	Sharma *et al.*, 2014
20.	Anti viral activity	*Cyperus niveus*	Kaij *et al.*, 1992
		Cyperus pangorei	Bhakuni *et al.*, 1988
		Cyperus rotundus	Soltan and Zaki, 2009 Parvez *et al.*, 2019 Xu *et al.*, 2020 Samra *et al.*, 2020 Vincent *et al.*,2020 Birendra Kumar *et al.*, 2021 Khuntia *et al.*, 2021
21.	Hepatoprotective activity	*Cyperus rotundus*	Sureshkumar and Mishra, 2005 Parvez *et al.*, 2019 Yoon *et al.*, 2015 Athesh *et al.*, 2014

		Cyperus alternifolius	Awaad, 2012
		Carex cruciata	Bogucka-Kocka *et al.*, 2011
		Carex alopecuroides	Bogucka-Kocka *et al.*, 2011
		Carex baccans	Bogucka-Kocka *et al.*, 2011
22.	Neuroprotective activity	*Cyperus rotundus*	Jebasingh *et al.*, 2014 Dhillon *et al.*, 1993 Shakerin *et al.*, 2020
		Cyperus esculentus	Jing *et al.*, 2020
		Fimbristylis ovata	Sirirattanakul and Santiyanont, 2021
23.	Nootropic activity	*Cyperus rotundus*	Sunil *et al.*, 2011 Rabbani *et al.*, 2014 Soman *et al.*, 2013
24.	Wound healing activity	*Cyperus articulatus*	Mongelli *et al.*, 1995
		Cyperus rotundus	Puratchikody *et al.*, 2006 Imam *et al.*, 2014

Pharmacologically active phytochemicals reported from Cyperaceae members

Cyperaceae species are reported to contain different class of compounds such as aurones, chromones, coumarins, iridoids, flavonoids, stilbenoids, lignans, benzofurans, phenolic acids, phenyl propanoids, phenolic derivatives, sesquiterpene alkaloids, diterpenoids, triterpenoids, steroids, organic acids, aliphatic ketones, aliphatic acids, amides and other nitrogenous constituents. Various phytopharmacological assays have led to the identification of potential biological activities to the isolated compounds from the plant group.

Phenolic compounds

Among the diversity of phytochemicals reported from Cyperaceae members, phenolic compounds such as aurones, chromones, coumarins, iridoids, flavonoids, stilbenoids, lignans, benzofurans, phenolic acids and phenyl propanoids are attributed with various biological activities.

Stilbenoids

Stilbenoids are phenolic compounds consisting of two differently substituted aromatic rings, which is linked by an ethylene bridge. The aromatic rings differ in the number and position of functional groups, including hydroxy, methoxy, prenyl, geranyl or farnesyl moieties. Stilbenoids can also be classified as monomers or oligomers, and are isolated as aglycones or glycosides. Stilbenoids are largely studied in the last decades because of their bioactivities such as anti-inflammatory, neuroprotective, anticancer, antimicrobial and antidiabetic effects (Akinwumi *et al.,* 2018)**.** These are important in chemotaxonomy as well and play a key role in plant defense mechanism. The most studied stilbenoid is resveratrol, which has been extensively investigated for its numerous potential health benefits including anti-oxidant, antimicrobial, anticancer, anti-inflammatory, antidiabetic, cardioprotective, anthelmintic, vasorelaxant activity and anti-aging effects. Recently, resveratrol has been identified as promising drug candidates against COVID-19 **(**Wahedi *et al*., 2021). The compound was proven to be a phytoestrogen as well (Baur and Sinclair; 2006).

More than 65 stilbenoids were isolated from 28 Cyperaceae species, while 14 stilbenoids were reported from *Cyperus rotundus* alone. Besides resveratrol, other monomeric (piceatannol and combretastatin A) and oligomeric (α-viniferin, hopeaphenol A, miyabenol C and kobophenol B) stilbenes with promising biological activities have also been isolated from Cyperaceae in recent years (**Figure 2)**.

α-Viniferin, a stilbene trimer isolated from *Carex gynandra* and *Carex folliculata* showed antiproliferative activity on HCT-116 cells with IC_{50} 6.6 µM (Gonzalez *et al*., 2011). α-Viniferin isolated from *Carex humilis* exhibited a dose dependent inhibitory activity (Lee, 1998). Among the various compounds isolated from Cyperaceae, trans-scirpusin B, a resveratrol oligomer was found to possess the most potent DPPH radical scavenging activity (SC_{50} = 2.8 µM) (Kawabata *et al*., 1991). Cyperusphenol B, a benzylidene stilbene isolated from *Cyperus rotundus* rhizome was the most effective in scavenging free radicals in DPPH assay. Resveratrol and its derivatives, piceatannol, scirpusins A and B, isolated from *Scirpus californicus*, showed xanthine oxidase inhibitory activity (IC_{50} values 3.9, 3.6 and 6.0 µM, respectively) (Kawabata *et al.,* 1991; Schmeda *et al*., 1996; González *et al.,* 2011). Piceatannol showed potent anti-inflammatory and antioxidant activity due to the ability to form semiquinone radical. Majeed *et al.* (2022) investigated the antiobesity agents in *Cyperus rotundus* rhizomes and reported piceatannol, scirpusin A and scirpusin B as the pharmacologically active molecules

Carexanes, the marker compounds in *Carex* genus are stilbenoids with a rare tetracyclic structure, originated from prenylated stilbenes by cyclization, and were able to enhance the antioxidant response of HspB transfected human gastric epithelial (AGS) cells. Among the various caraxanes, carexane I proved to be the most active (Abrosca *et al*., 2005).

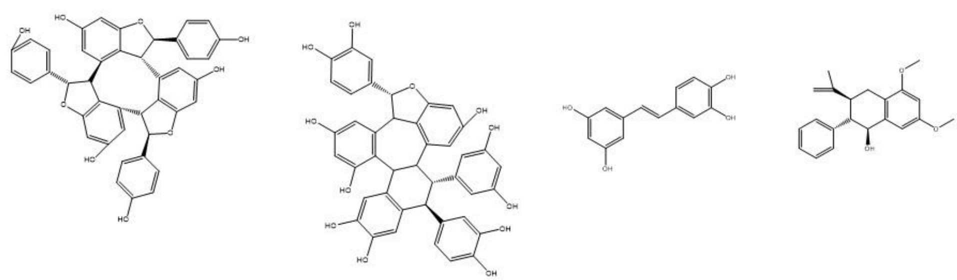

Figure 2. Major stilbenes reported from Cyperaceae members. α-Viniferin, cyperusphenol B, piceatannol and carexane I

Benzoquinones

Quinones are ubiquitous in nature, which occur predominantly in flowering plants. Benzoquinones such as 1,2-benzoquinones and 1,4-benzoquinones in plants are involved in important biological functions such as bioenergetic transport, oxidative phosphorelation and electron transport process.

Benzoquinones are important class of phytochemicals in Cyperaceae with promising pharmacological activities. Cyperaquinone, hydroxycyperaquinone, dihydrocyperaquinone, scabequinone and tetrahydrocyperaquinone are the major benzoquinones in Cyperaceae. Benzoquinones are important targets to develop new drugs that are more selective to cancer cells (Vera *et al.,* 2019). Anticancer studies showed that hydroxycyperaquinone is a novel sub-micromolar inhibitor of 20S catalytic core of the 20S proteasome, causing cell death *via*IRE1α-independent/PERK-dependent pathways. The new benzoquinone alopecuquinone isolated from the ethanol extract of the inflorescences of *Cyperus alopecuroids* by Nasser *et al.* (2002) showed moderate estrogenic activity using a strain of *Saccharomyces cerevisiae* (**Figure 3)**. It has also been reported that the compoundhas medicinal effects such as pectoral emollient, analgesic and anti-helminthic properties.

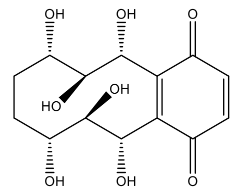

Figure 3. Thebenzoquinone alopecuquinone reported from *Cyperus alopecuroids*

Polyphenols

The polyphenols, ferulic acid, p-hydroxybenzaldehyde, p-coumaric acid, sinapinic acid, chlorogenic acid, luteolin and gallic acid reported from *Cyperus rotundus* exhibit potent antioxidant activity (Pelegrin *et al*., 2022) (**Figure 4)**.

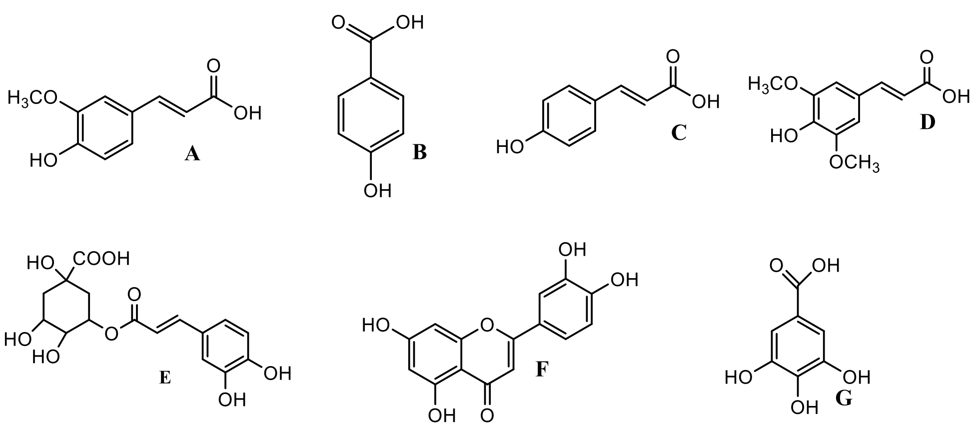

Figure 4. Major polyphenols reported from *Cyperus rotundus* **A**. Ferulic acid, **B**. p-Hydroxybenzaldehyde, **C**. p-Coumaric acid **D**. Sinapinic acid, **E.** Chlorogenic acid, **F.** Luteolin, and **G.** Gallic acid

Sesquiterpenoids

Sesquiterpenoids, made up of three isoprene units, are a class of enormously diverse natural products derived from farnesyl pyrophosphate and exist in a wide variety of forms including acyclic, monocyclic, bicyclic and tricyclic frameworks. These are important compounds in the essential oils of plants and are potent pharmaceutical agents due to the versatile biological activities. Sesquiterpenoids are the major subclass of natural products reported from the essential oils of various Cyperaceae members. Diverse structural skeletons such as patchoulane, rotundane, eudesmane, guaiane, cadinane, caryophyllane, clovane and copaene have been reported from various Cyperaceae members (Yang and Shi, 2012). In addition, sesquiterpene endoperoxides, nor-sequiterpenoids and seco-sesquiterpenoids are also reported from the plant group. Major sesquiterpenoids with potential biological activities reported from various Cyperaceae are elaborated below.

Cyperotundone

Cyperotundone is a sesquiterpene ketone with patchoulene type frame work found in many essential oils especially in *Cyperus rotundus* and *Cyperus articulates* (**Figure 5).** Pharmacological analysis revealed that the compound could be used as an anti-inflammatory and anti-viral agent, and also exhibited inhibitory activity on tumour necrosis factor-α induced activation of the NF-κB pathway, with half-maximal inhibitory concentration values ranging from 34.5 to 73.7 μmol/L (Wang *et al*.; 2021). The compound and its derivatives showed moderate anti-hepatitis B virus activity (Xu *et al*., 2015).

Rotundene

Rotundene is a characteristic sesquiterpenoid reported in *Cyperus rotundus* with azulene type frame work (**Figure 5)**. The anti-inflammatory and analgesic properties of the compound have been studied in detail. *In vitro* cytotoxicity assay with MTT indicated that rotundene is very effective against L1210 leukaemia cells line. This result correlates with significantly increased apoptotic DNA fragmentation. The oxidative effects of the compound evaluated using the 1,1-diphenyl-2-picrylhydrazyl (DPPH), xanthine/xanthine oxidase assays revealed the antioxidant potential of the compound (Kilani *et al*., 2008). The potential peripheral and central analgesic properties of the compound were also studied extensively (Rabelo *et al.*, 2014).

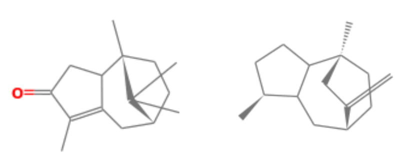

Figure 5. Cyperotundone and Rotundene

Mustakone

Mustakone is a tricyclic sesquiterpenoid and the name is derived from 'mustuka', the common name for *Cyperus rotundus* in India (**Figure 6)**. Swain *et al*. (2022) studied the inhibitory activity of *Cyperus articulates* components against *Staphylococus aureus* and proved the antibacterial activity of mustakone. Further the antifungal activity of the compound was examined against *Candida* species and showed positive response (Vaijayanthimala *et al*., 2000). The compound isolated from *Cyperus articulatus*was active against the sensitive strains of *Plasmodium falciparum* (Rukunga *et al*., 2008).

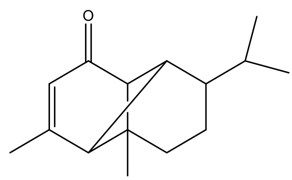

Figure 6. Mustakone

Nootkatone

Nootkatone, another potential sesquiterpenoid widely distributed in Cyperaceae members, showed insecticidal activity against *Plutella xylostella*, and also antibacterial activity and α-glucosidase inhibitory activity (Guo *et al*., 2020; Alkhaibari *et al*., 2021) (**Figure 7)**. It exhibits strong anti-inflammatory effects in LPS-stimulated RAW 264.7 cells (Park *et al*., 2021). Among the various compounds detected from *Cyperus rotundus* ethanolic extract, (+)-nootkatone was found to have the most potent inhibitory effect on collagen, thrombin and AA induced platelet aggregation, proving itsantiplatelet activity (Seo *et al*., 2011).

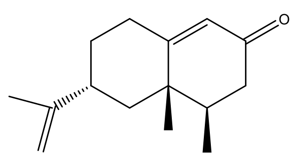

Figure 7. Nootkatone

α-Cyperone

α-Cyperone, a characteristic sesquiterpenoid isolated from *Cyperus rotundus* and other Cyperaceae members, exhibit strong anti-inflammatory effects in LPS-stimulated RAW 264.7 cells (**Figure 8)**. The compound also exerted antidepressant-like actions in a mouse depression model, and the antidepressant activity of the compound was attributed to

SIRT3/ROS pathway mediated NLRP3 inflammasome deactivation, which led to the enhancement of neuroplasticity. The findings revealed the antidepressant property of α-cyperone, and suggest targeting SIRT3/ROS signaling in depression treatment (Xia *et al.*, 2020). α-Cyperone is associated with the down-regulation of COX-2, IL-6, Nck-2, Cdc42 and Rac1, resulting in reduction of inflammation, which would be highly beneficial for treatment of inflammatory diseases such as Alzheimer's disease (Zhang *et al.*, 2022).α-Cyperone is a potential molecule for reduction of inflammation by destabilization of microtubule fibres in brain (Azimi *et al.*, 2016). The compound had a pronounced influence on the tubulin structure, decreased polymerization rate and reduced concentration of polymerized tubulin *in vitro.*

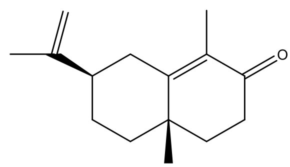

Figure 8. α-Cyperone

α-Corymbolol

The eudesmane type sesquiterpenoid α-corymbololisolated from *Cyperus rotundus* inhibited the HBV DNA replication with IC_{50} values ranging from 10.1 to 75.9 µM, and the results suggested the potential utility of the compound as an anti-HBV target **(Figure 9)** (Xu *et al*; 2015)**.**

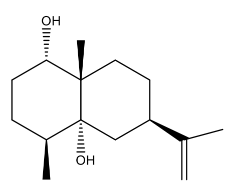

Figure 9. α-Corymbolol

Cyperene

Cyperene is one of the major constituents of various Cyperaceae species (**Figure 10)**. Molecular docking studies on selected phytochemicals in *Cyperus rotundus* with 5-α reductase enzyme revealed the sesquiterpene cyperene showing good interactions and can be used as a potential herbal medicine for Hirsutism disorders (Shirkoli *et al.*; 2018).

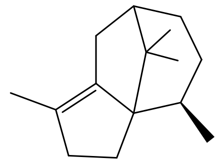

Figure 10. Cyperene

Ceramide

The amide, ceramide (2`-[2-hydroxypentacosanoylamino]-1`,3`,4`-nonadecanetriol) isolated from *Cyperus rotundus* showed promising anticancer activity and displayed inhibitory activity against HepG2 with IC_{50} values 6.81 to 8.07 µM, and PC3 with IC_{50} of 11.92 to 14.48 µM (Samra *et al*., 2021) (**Figure 11)**.

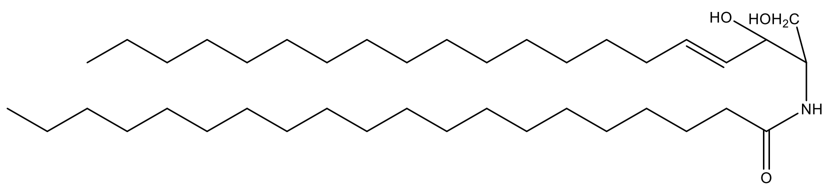

Figure 11. Ceramide

Translational research in Cyperaceae members

The pharmacological screening and phytochemical standardisation of various Cyperaceae plants, based on the traditional medicinal applications have led to the development of a wide array of products and patents out of the plant group. Various extracts as well as active compounds thereof are patented for the biological activities from different Cyperaceae members, especially on *Cyperus rotundus*. The major patents are on menopausal disorders, dental hygiene, antiseptic, cosmetic, anti-inflammatory, anti-obesity, neurodegenerative disease, stress release and antiulcer sectors.

Cyperus rotundus finds its mention in ancient ayurvedic literature as a drug capable of 'de-fatting' adipose or muscular tissues (Trivedi and Mann, 1972). The plant has been mentioned in *Charak Samhita* as lekhaniya category, indicating its anti-obesity property. Crude extract of *Cyperus rotundus* was reported to have an anti-obesity activity (Zbinden *et al*., 2007; Oh *et al*., 2016). It was demonstrated that the administration of 45 mg/kg/day of *Cyperus rotundus* tubers hexane extract for 60 days in Zucker rats induced a significant reduction in weight gain without affecting food consumption or inducing toxicity. *In vitro*, 250 µg/mL of this extract was able to stimulate lipolysis in 3T3-F442 adipocytes suggesting that this medicinal plant contains activators of β-adrenoreceptors (Bernard *et al*., 2007). The anti-adipogenic mechanism was evaluated in a diet-induced mice model of obesity and adipocytes *in vitro*. *Cyperus rotundus* hexane extract showed a dose-dependent adipogenesis reduction *in vitro* with an IC_{50} value of 9.3µg/mL. The active constituents have been identified as the stilbene derivatives piceatannol, scirpusin A and scirpusin B, and aherbal product has been developed as a health adjuvant for managing hypercholesterolemia and obesity in humans with the rhizomes of *Cyperus rotundus* as the major component (Majeed *et al*., 2022).

Another interesting application of *Cyperus rotundus* is in dental care products. The plant had been reported to be used since the pre-historic times, as evidenced from the dental plaque analysis of prehistoric skeletons. The usage of *Cyperus rotundus* explains the unexpectedly low frequency of caries among the Meroitic populations of Al Khiday, as *Cyperus rotundus* has the ability to inhibit *Streptococcus mutans* that causes dental caries (Buckley *et al*., 2014). Various pharmacological assays have further confirmed the anticariogenic properties of *Cyperus rotundus* (Yu *et al*., 2007). Based on the traditional applications as well as the pharmacological evidences, various products and patents were developed with *Cyperus rotundus* for the treatment and prevention of periodontitis and tooth decay (Khojaste *et al*., 2018).

Conclusion

An update of the progress in pharmacological properties of Cyperaceae plants reveals that though the plant group is widely distributed with extensive traditional applications in medicinal sector, and a plethora of interesting structures have been identified from the plant group, intensive explorations are needed on pharmacological activities to attain a greater clarity of the mechanism of action. Modern approaches like structure-activity relations correlating the plethora of structural features with pharmacological activities using modern computational tools will lead to a better perception of the underlying molecular mechanisms. In addition, validated clinical trials are also needed to explore as per the norms to accept the traditional claims of the Cyperaceae plants.

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Chapter 7

Phytochemical Diversity in *Cyperus rotundus* L.

Abstract

Though considered as a noxious weed, *Cyperus rotundus* is the store house of several interesting phytochemicals. The phytochemicals reported from *Cyperus rotundus* can be broadly classified into volatile compounds and non-volatile compounds, and the chapter enlists a total of 684 compounds (294 non-volatile compounds and 390 volatile compounds) reported from *Cyperus rotundus.*The volatile chemical profiles of *Cyperus rotundus* reported from 24 countries have been compared with a biogeographic perspective. Also, the chapter presents the essential oil and head space volatiles of *Cyperus rotundus* rhizomes and leaves collected from Kerala, south India. Sesquiterpenoids, especially guaiane and patchoulane type sesquiterpenoids are the major volatile compounds reported, while phenolics are the predominant non-volatile compounds in the plant. Correlation of the vast data on chemical diversity with phenology, genetics and ecology is yet to be explored.

Introduction

Among the various species coming under the Cyperaceae family, the most extensively investigated species is *Cyperus rotundus* L. The plant is a perennial sedge exhibiting erect stem with open umbel inflorescence and fibrous roots with underground, composite network of tubers, basal bulbs and rhizomes which ensure its spreading even in unfavourable conditions (**Figure 1**).

Figure 1. *Cyperus rotundus* (inset: tubers)

The plant had been used from prehistoric time onwards in food, medicinal and perfumery sectors. The wide use of the plant in traditional medicines and the potential bioactivities of the species are attributed to the characteristic chemicals present in the plant. A number of reports are available on the phytochemistry of *Cyperus rotundus* and several researchers; Singh *et al.*, (2012), Srivastava *et al.*, (2013), Imam *et al.*, (2014), Samraj *et al.*, (2014), Hemanth Kumar *et al.*, (2014), Gamal *et al.*, (2015); Pirzada *et al.*, (2015), Al-Snafi (2016), Priyanka *et al.*, (2017), Saragih *et al.*, (2019), Taheri *et al.*, (2021), Wang *et al.*, (2022), Ross (2003) and Lu *et al.*, (2022), have reviewed the literature on *Cyperus rotundus* including phytochemistry, traditional uses and pharmacological activities. Recently Babiaka *et al.* (2021) reviewed 192 compounds reported from *C. rotundus*, that includes volatile compounds as well.

It is quite interesting to note that conventional phytochemical techniques such as derivatisation, adduct formation, years long structural interpretation through decomposition and semi-synthesis along with the most modern hyphenated analytical techniques were employed in the phytochemical investigation of *Cyperus rotundus* (**Figure 2**).

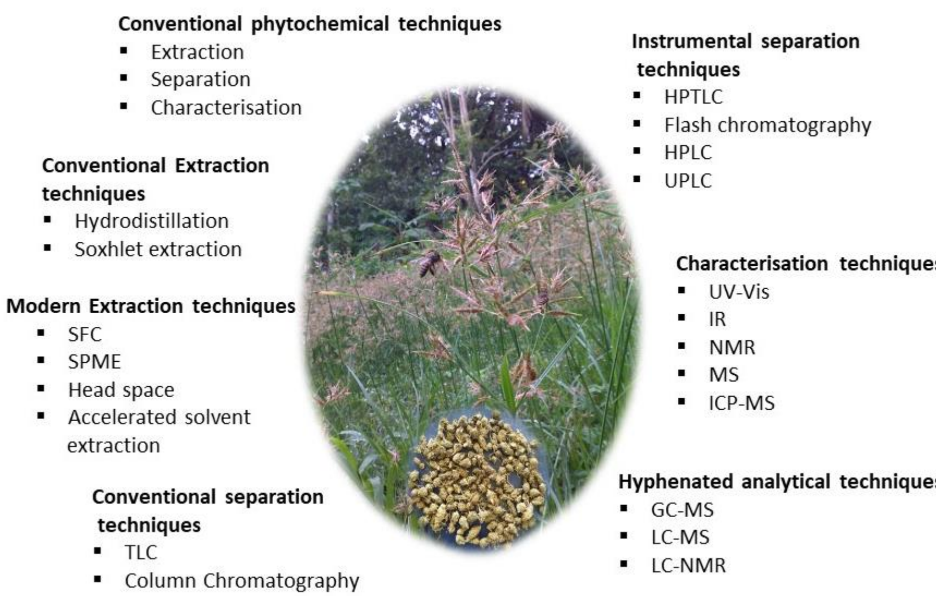

Figure 2. Major phytochemical techniques as applied in *Cyperus rotundus*

The present chapter elaborates a total of 684 compounds, with 294 non-volatile compounds reported from various solvent extracts of *C. rotundus*, and 390 volatile compounds in essential oils, head space and solvent extracts of *C. rotundus* (**Figure 3**).

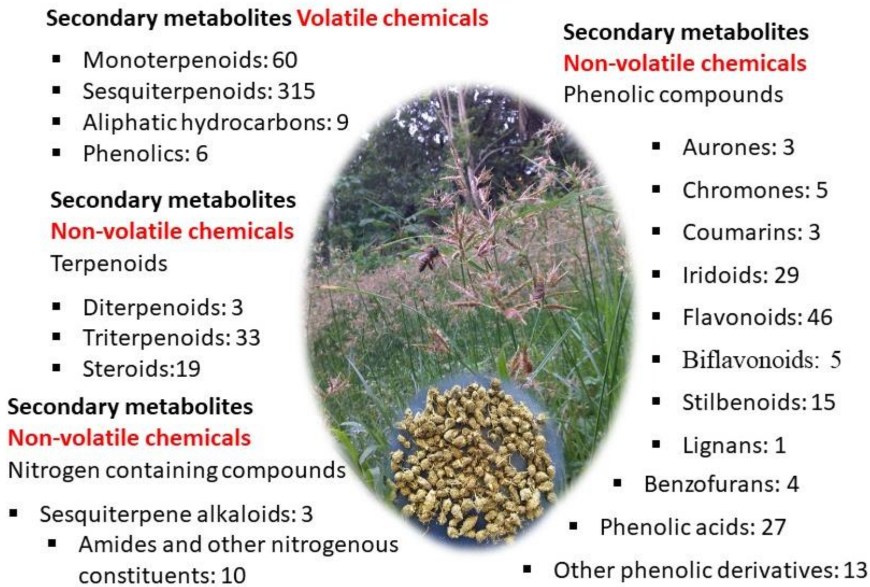

Figure 3. Phytochemical diversity in *Cyperus rotundus*

Cyperus rotundus in prehistoric times- A phytochemical exploration

Exploring the plant remaining in prehistoric skeletons using modern analytical tools reveal remarkable evidence about the herbal usage in prehistoric times (**Figure 4)**. The information hidden in the dental calculus of the skeletal remaining unearthed from the burial grounds of Motya's Phoenician community, located in Al Khidayparts of central Sudan, and lived around 7000 years before, during the pre-Mesolithic to Meroitic period, discloses the dietary ecology and phytomedicinal practices, especially the usage of *Cyperus rotundus* during that time. Samples of dental calculus taken from the burial grounds were analyzed by gas chromatography-mass spectrometry (GC-MS) and microscopy. It is interesting to note that the characteristic compounds such as rotundene, norrotundene, calamine, calamenene, cadalene and calarene present in *C. rotundus* were detected from the dental plaque of skeletal remaining. Further the starch granules extracted from dental calculus was superficially similar to that of *C. rotundus*. The finding revealed that the plant had been used either as medicinal or food material from ancient time (Buckley *et al.*, 2014). Also, the usage of *C. rotundus* explains the unexpectedly low frequency of caries among the Meroitic populations of Al Khiday, as *C. rotundus* has the ability to inhibit *Streptococcus mutans* that causes dental caries.

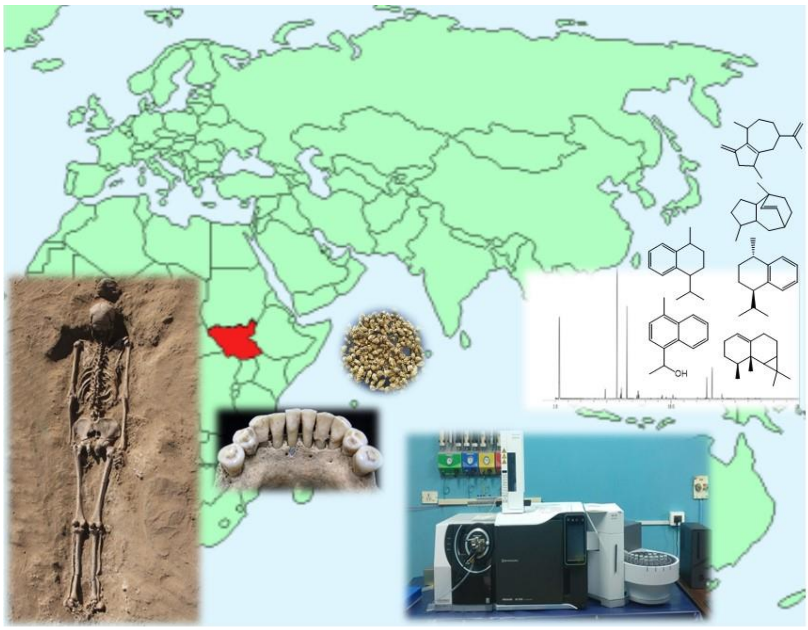

Figure 4. Schematic diagram of the discovery of *Cyperus rotundus* used in prehistoric time based on phytochemical tracing

The species has been a source of interesting structural skeletons in the history of phytochemistry. Doyens in the field of phytochemistry in India and abroad such as Sukh Dev *et al*., Nigam *et al*. andHarborne *et al*. had contributed significantly in understanding the complex structural features of phytochemicals in *C. rotundus* (Kapadia *et al.*, 1963; Kapadia *et al.*, 1967; Harborne *et al.*, 1982). Several interesting structures have been reported for the first time from the species, and several phytochemicals were named after the plant.

The plant still remains to be source of novel phytochemicals and biological activities, and 3,9-peroxy sesquiterpene-15-O-glucoside, a new sesquiterpene with fungicidal, bactericidal and cytotoxic properties has been reported from *C. rotundus* recently (Sabir *et al.*, 2020). In the COVID-19 pandemic period, the phytochemicals from the plant have been found promising. Kumar *et al*. (2021) reported sugetriol-3,9-diacetate from *C. rotundus* as one among the active phytochemicals, screened for binding affinity to PL^{pro} protein of SARS-CoV-2. Recently Majeed *et al.* (2022) has reported the stilbene derivatives piceatannol, scirpusin A and scirpusin B as the pharmacologically active molecules from the ethyl acetate extract of *C. rotundus* rhizomes. The present chapter elaborates the phytochemicals reported from the species.

Physicochemical profile and proximate composition of *Cyperus rotundus*

The phytochemicals reported from *Cyperus rotundus* can be broadly classified into proximate components, volatile compounds and non-volatile compounds from solvent extracts. Proximate analysis is used to estimate the relative amounts of protein, lipid, water, ash, carbohydrate *etc* in any sample, and are the first and foremost step to determine the identity and to assess the quality of plant material. The proximate analysis of *C. rotundus* gain much attention since the rhizomes are edible as a staple carbohydrate and is a famine food in some agrarian cultures (Farre, 2003; Prakash *et al.*, 2019; Ibrahim and Abdullahi, 2013; Umerie and Ezeuzo, 2000).

Physicochemical properties and extractive values of *Cyperus rotundus* rhizome such as total ash, acid-insoluble ash, water-soluble ash, loss on drying, sulfated ash, water-soluble extractive, alcohol-soluble extractive were determined along with successive extractive values with different solvent systems including petroleum ether, *n*-hexane, benzene, acetone, chloroform, ethyl acetate, alcohol, methanol and water (Sri Ranjani, 2017; Surendra Kumar and Ajay Pal, 2011;Emelugo *et al.*, 2011; WHO, 1998).

Various physicochemical parameters were determined for Cyperus *rotundus* and the tuber has been found to be good source of carbohydrates, minerals and fibre (Nalini *et al.*, 2014). Emelugo *et al.* (2011) reported 9.0% moisture, 1.75% crude protein, 9.50% oil, 7.87% ash, 17.48% crude fibre and 63.60% carbohydrate in *Cyperus rotundus* tubers. The high content of crude fibre in the rhizome helps to increase the bioavailability of nutrients in human diet (Sivapalan, 2013). The carbohydrate content in *Cyperus rotundus* is comparable with that of peanut, suggesting the rhizomes as a healthy component in human diet. The starch extracted from tuberous part of the plant has various applications in food and confectionary industries. The starch yield was 24.1% (on a dry weight basis) by wet-milling process

(Umerie and Ezeuzo, 2000).The large sized starch granules were comparable to the potato starch and with high amylose content (26.7%).

Mineral composition of *Cyperus rotundus*

The mineral content of plants has an important role in human conception since these are necessary vital elements for metabolic processes. Both the micro and macro elements in the *Cyperus rotundus* tubers were critically analysed, since the tubers of the plant were included in diet since ancient times (**Table 1)** (Oladunni *et al.*, 2011).

Table 1. Mineral composition of *Cyperus rotundus* (Ref. Oladunni *et al.*, 2011)

Sl. No.	Mineral	Content
1.	Phosphorus (mg/100ml)	0.52
2.	Zinc (ppm)	0.79
3.	Copper (ppm)	0.065
4.	Cadmium (ppm)	0.002
5.	Cobalt (ppm)	< 0.03
6.	Sodium (mg/g)	119.29
7.	Potassium (mg/g)	110.11
8.	Magnesium (mg/g)	50.76
9.	Calcium (mg/g)	16.40

The mineral analysis revealed the presence of sufficient amounts of macro (magnesium, phosphorus, potassium, calcium) as well as micro (sodium, copper, zinc) elements in *C. rotundus* rhizomes. The mineral concentration showed that sodium was found to be most abundant followed by potassium and also significant quantity of magnesiumand calcium while manganese and iron were not detected. The determination of heavy metals has drawn a significant attention due to the toxic and nutritional effects of these elements.

Phytoremediation potential of *Cyperus rotundus*

Phytoremediation refers to the use of plants to reduce the concentrations of contaminants in the environment. Heavy metal contamination is a major threat to the environment and human health, and phytoremediation is widely accepted as a cost-effective environmental restoration technology and considered as an alternative to industrial process for removing heavy metals from the surroundings (Onakpa *et al*. 2018; Das and Maiti 2007; Pinto *et al*.; 2014). Phytoremediation use a variety of mechanisms such asphytoextraction, phytostabilization, phytodegradation, phytovolatilization and phytofilteration (Dary *et al.*, 2010; Kumar and Maiti, 2015; Saran *et al*., 2020).

Cyperus rotundus is a hyper tolerant plant with high ability to take up heavy metals from soil, accumulate it in its underground tissues. Jahan-Nejati *et al*. (2021) reported that *Cyperus rotundus* is a safe forge or phytostabilizer species in copper contaminated soils. The plant is suggested as safe for grazing and forage production in copper contaminated environments as the translocation factor of copper is very low. Sultana *et al*. (2018) studied the interaction of *Cyperus rotundus* in nickel contaminated water, and found the Ni phytoremediation potential of *Cyperus rotundus* at 14mg/L. The plant showed remarkable metal uptake which remain accumulated near the root tips in contact with the medium. The plant is considered as a good accumulator of cadmium and chromium as well, and was recommended for remediation of cadmium and chromium contaminated soils (Subhashini and Swamy, 2014). Phytoremediation potential of *Cyperus rotundus* against Pb contamination revealed that the Pb concentrations were maximum in roots in comparison to shoots and the plant reduced more than 90% of lead in 30 days (Sunil Kumar *et al*., 2020). Hence, *Cyperus rotundus* could be used in natural treatment of polluted soil and in the rehabilitation programmes as a safe tool and treatment of polluted soil on road side (Elsayed Nafea and Šera, 2020).

Secondary metabolite diversity in *Cyperus rotundus*

The structural features of secondary metabolites in *Cyperus rotundus* is astonishingly diverse, and in addition to the proximate composition, the general secondary metabolites reported from *Cyperus rotundus* can be broadly classified into volatile compounds and non-volatile compounds.

Volatile chemical composition of *Cyperus rotundus*

Cyperus rotundus was used in ancient India, Egypt, Greece and elsewhere as an aromatic and perfume agent. Ancient Egypt and Greece literature reveals the use of *Cyperus rotundus* for aromatic purposes, and the plant had reputation as a source of perfume during the time of Greek physicians Hippocrates (5^{th} century BC), Theophrastus, Pliny and Dioscorides (1^{st} century AD). Dioscorides highlights the use of *Cyperus rotundus* tubers as an ingredient of ancient Egypt's best-known perfume, kuphi or kyphi, an incense that also had medicinal properties. The perfume as described by Dioscorides, is similar to the one in the *Ebers Papyri*, demonstrating its continuity over 1600 years (Negbi,1992). The plant is known in Ayurveda as *sugandhamusthaka* (aromatic *Cyperus*) and also being suggested as substitute for *karpura* (*Cinnamomum camphora*) based on the concept of drug substitution (*AbhavaPratinidhi Dravya*) (Venkatasubramanian *et al.*, 2010).

The aromatic nature of *Cyperus rotundus* is due to the presence of volatile compounds. Volatile compounds are typically small molecules with low boiling points and high vapour pressure at ambient temperature. Plant volatiles are generally made up of terpenoids, phenylpropanoids, benzenoid compounds, amino acid derivatives and fatty acid derivatives. Unconjugated volatiles can cross the cell membranes freely to be released from flowers, fruits and vegetative tissues into the atmosphere and from roots into the soil. The array of volatile compounds, released into the atmosphere by plants are responsible for attracting pollinators and other beneficial insects, providing a means of inter-plant communication, and directly repelling or intoxicating attacking herbivores. The plant volatiles have been investigated intensively with respect to integrated pest management (Ahuja *et al.*, 2010), defence against herbivores (Mithöfer and Boland, 2012; Das *et al.*, 2013), below-ground emissions (Ali *et al.*, 2012; Ghimire *et al.*, 2013), detection of disease infestation (Sankaran *et al.*, 2010; Cevallos-Cevallos *et al.*, 2011), food quality (Oms-Oliu *et al.*, 2013), chemotaxonomy (Sajewicz *et al.*, 2009; Liu *et al.*, 2013), biological control mechanisms (Smith and Beck, 2013; Wheeler and Schaffner, 2013) and metabolomics (Roze *et al.*, 2010; Cevallos-Cevallos *et al.*, 2011). The essential oils and volatile organic compounds are also found to be responsible for a variety of biological and pharmacological activities of *C. rotundus* (Sonwa and Konig, 2001; Jirovetz *et al.*, 2004; Kilani *et al.*, 2005).

The volatile aroma chemicals in plants are generally investigated through essential oils (EO) and recently head space (HS) analysis has received much attention as a rapid tool for volatile aroma chemical analysis.

Essential oil volatiles: Essential oils are steam volatile components of plants responsible for the aroma of the plant and mainly constitute terpenes, some phenolics, and aliphatic derivatives. Essential oils, as the name implies, bears the essence of the plant. Essential oils are not directly involved in growth and reproduction, but rather in fitness of plant life. Essential oils act as a safe guard against pathogens and insects, attractant for pollinator and fruit dispersers, and as deterrents to the growth of competing plants, and thus have a major role in chemical ecology.

Essential oils have important role in various industrial sectors such as perfumery, aromatherapy, insect control, flavor, medicines and preservatives**.** The distribution of the volatile chemicals can be utilized forchemotaxonomic purpose, to subgroup the species and also for phylogenic evaluation.The distribution of some of the essential oil constituents can be used as chemotaxonomical markers that aid in the identification of taxonomically closely related plants. Further, standardization with respect to the volatile chemicals will help authenticate marketsamples of the economically important species.

Essential oils are seen in specialized plant cells, glands or vessels and are isolated by different methods, of which distillation, especially hydro distillation is the most widely used technique. Gas Liquid Chromatography (GLC) coupled with Mass Spectrometry (MS) is used for the qualitative and quantitative analysis of mixtures of volatile compounds. Gas chromatography is the ideal separator, whereas mass spectrometry is excellent for identification. The GC-MS with computerized library search facility can be regarded as the best single tool for plant volatile chemical analysis.

Head space volatiles: Headspace refers to the gas phase above a solid or liquid sample. Headspace analysis is a simple, non-destructive and solvent-free technique used to analyse the volatile compounds from both liquid and solid samples. The technique has been widely used in food, cosmetic, flavour, perfume and forensic sectors. Headspace is an equilibrium state, depending on the partition coefficient of the analytes, and not all of the volatile analytes of the solid or liquid sample will evolve into the headspace gas volume.

The sample is placed into a sealed headspace vial of 10 to 20 ml capacity, and generally the sample is heated to a predetermined temperature for an incubation time. During this time, volatile compounds travel between the matrix and the headspace, and reach an equilibrium where the rate of migration from the matrix into the headspace equals the rate of migration from the headspace back to the matrix. The equilibrium condition does not mean that the concentration of the analyte is equal between the headspace and the matrix. The concentration is determined by partition coefficient (K) of the analyte.

Two types of sampling, static and dynamic, are widely used for headspace volatile investigation. Static headspace encloses the sample for a set period of time, and volatiles collected at the end of the period are analysed. Generally, in static HS analysis, the volatile analytes present above the solid or liquid sample are evolved into the headspace by heating the sample at a fixed temperature and for a fixed length of time in a vial of known volume. The volatiles are then adsorbed on solid-phase microextraction (SPME) unit. Dynamic headspace essentially moves the volatile chemicals continuously from the sample directly to the collecting matrix. In dynamic HS, the sample is heated and agitated in a sealed vial and the headspace above the sample is purged onto a solid sorbent tube. This is also known as purge and trap technique, where volatile organic compounds are purged out of the sample matrix by an inert gas and carried onto a sorbent trap, where they are concentrated and later introduced into an analytical instrument such as GC-MS.

The head space volatiles of *Cyperus rotundus* have seldom been analysed. α-Copaene, cyperene, valerenal, caryophyllene oxide, trans-pinocarveol and valencene have been identified as the head space volatiles through SPME-headspace analysis by Jirovetz *et al.* (2004), while Ilham *et al*. (2018) reported cyperene, α-copaene and α-ylangene as the major volatiles through headspace SPME analysis of *Cyperus rotundus* rhizomes. The study has reported variation in percentage composition of the identified components depending on the temperature of SPME exposure.

Essential oil, generally isolated through steam/hydro distillation process, represent a comprehensive volatile chemical profile. However, during the distillation process of essential oil isolation, the exact nature of the oil may be destructed as the compounds may change by oxidation, hydrolysis, decompose by heat, may polymerize or resinify or some of the delicate constituents may escape the process. While head space profile depicts the fine aroma of the plant material without any extraction process. However, HS has only the most volatile chemicals, while EO has a wide representation of the whole volatile chemicals, both low volatile and high volatile compounds.

The hyphenated analytical technique GC-MS is perhaps the most widely used analytical technique for *Cyperus rotundus* phytochemical evaluation, especially the volatile chemical profile. However, as several complex sesquiterpenoid structures such as endoperoxides, norsequiterpenoids, secosesquiterpenoids, hydroazulene, eudesmane, elemene, aristolane, eremophilane and aromadendrene are present in *Cyperus rotundus*, it is difficult to identify the constituents by GC-MS alone. Researchers have used both electron impact (EI) and chemical ionization (CI) detection modes on nonpolar and polar stationary phases in GC-MS. In addition to essential oils, volatile compounds were isolated from different solvent extracts, including supercritical fluid extracts (Wang *et al.,* 2012). Several investigators have tried separation of the volatile components through ordinary column chromatography (CC), CC at low temperature, CC over silver nitrate precoated silica, and preparative TLC and other techniques such as high-speed counter-current chromatography. Further characterization of the isolated compounds was done by various spectroscopic techniques such as high-resolution electrospray ionization mass spectrometry, and 1D and 2D nuclear magnetic resonance spectroscopy to establish the structures of the compounds from *C. rotundus* essential oils (Thebtaranonth *et al.,* 1995; Ohira *et al.,* 1998; Sonwa and Konig, 2001; Shi *et al.,* 2009; Tsoyi *et al.,* 2011; Zhou and Yin, 2012; Sultana *et al.,* 2019; Wang *et al.,* 2021; Xu *et al.,* 2009).

Cyperus rotundus contains essential oil in its roots, rhizomes, tubers and leaves, of which the rhizomes are rich in essential oils and the oil content varied in rhizomes from 0.5 to 1.0 % v/w, depending on the geographical origin (Ohira *et al.,* 1998). Among the various components present in the essential oil of *Cyperus rotundus* rhizomes, sesquiterpenoids, especially oxygenated sesquiterpenoids, are the most important category. Wang *et al*. (2022) has reviewed around 100 volatile chemicals from *Cyperus rotundus*, and α-cyperone and cyperenonewere the main components of volatile oil of *Cyperus rotundus.*

Table 2 enlists a total of 390 volatile chemicals reported from *Cyperus rotundus* essential oils, head space as well as in solvent extracts, belonging to sesquiterpene- oxygenated (208 numbers), sesquiterpene- hydrocarbons (107 numbers), monoterpene- oxygenated (46 numbers), monoterpene- hydrocarbons (14 numbers), aliphatic hydrocarbons (9 numbers) and phenolic derivatives (6 numbers).

Table 2: Volatile phytochemicals reported from *Cyperus rotundus* tubers

Sl. No.	Class of compounds	Phytochemicals	Reference
1.	Monoterpene hydrocarbons	1. Camphene 2. Limonene 3. Myrcene 4. o-Cymene 5. p-Cymene 6. Sabinene 7. Terpinolene 8. Verbenene 9. α-Pinene 10. β-Phellandrene 11. β-Pinene 12. β-Thujene 13. γ-Terpinene 14. α-Phellandrene	Bisht *et al.*,2011 Chang *et al.*, 2012 El-Gohary, 2004 Essaidi *et al.*, 2014 Ghannadi *et al.*, 2012 He *et al.*, 2018 Hu *et al.*, 2017 İlham *et al.*, 2018 Janaki *et al.*, 2018 Jin *et al.*, 2011 Kapadia *et al.*, 1967 Richa and Suneet, 2014 Xu *et al*. 2010 Yagi *et al.*, 2016 Zoghbi *et al.*, 2008 Fenanir *et al.*, 2021 Samra *et al.*, 2020
2.	Monoterpene oxygenated	1. (-)-Dihydrocarveol 2. (+)-Dihydrocarvone 3. 1,8-Cineole 4. 6-Camphenol 5. Borneol 6. Bornyl acetate 7. Camphene hydrate 8. Camphor 9. Carvacrol 10. Carvenone 11. Carvone 12. cis-Carveol 13. cis-Dihydrocarvone 14. cis-Verbenol 15. Citronellal 16. Cuminaldehyde 17. Dihydrocarvone 18. Dihydro carvylacetate 19. Geraniol 20. iso-Pinocamphone 21. Linalool	Bisht *et al.*,2011 El-Gohary, 2004 İlham *et al.*, 2018 Jin *et al.*, 2011 Chang *et al.*, 2012 Yagi *et al.*, 2016 Janaki *et al.*, 2018 Al-Snafi 2016 Liu *et al.*, 2016 Hu *et al.*, 2017 Fenanir *et al.*, 2021 Eltayeib and Ismaeel, 2014 Ghannadi *et al.*, 2012 Eröz Poyraz *et al.*, 2018 Yagi *et al.*, 2016 Hu *et al.*, 2017 Janaki *et al.*, 2018

		22. Myrtenal 23. Myrtenol 24. Myrtenyl acetate 25. Nerol 26. Nopinone 27. p-Cymen-8-ol 28. p-Cymol 29. Perilla alcohol 30. Pinocamphone 31. Pinocarvone 32. Piperitone 33. p-Menth-2-en-1-ol 34. p-Mentha-1,5-diene-8-ol 35. Terpinen-4-ol 36. Thymol 37. trans-Carveol 38. trans-Pinocarveol 39. trans-Verbenol 40. Verbenone 41. α-Campholenal 42. α-Fenchol 43. α-Ionone 44. α-Terpineol 45. α-Terpineol 46. β-Citronellol	He *et al.*, 2018 Zhang *et al.*, 2017 Kilani *et al.*, 2008 Lawal and Oyedeji 2009 Ohira *et al.*, 1998 Fang *et al.*, 2004 Chang *et al.*, 2012 Zoghbi *et al.*, 2008 Richa and Suneet 2014
3.	Sesquiterpene hydrocarbons	1. (-) Cypera-2,4-diene 2. (-)-Cypera-2,4(15)-diene 3. (-)-Eudesma-2,4(15),11-triene 4. (-)-iso-Rotundene 5. (-)-iso-Sativene 6. (-)-Norrotundene 7. (+)-Calarene 8. (+)-Ylanga-2,4(15)-diene 9. δ-Cadinene 10. (E,E)-α-Farnesene 11. 1-Isopropyl 2,7 dimethyl naphthalene 12. 1-Isopropyl-2,7 dimethylnaphthalene 13. 4,5-Secoeudesmane 14. 5,10-Cycloaromadendrane 15. 8,8-Dimethyl-9-methylene-1,5-cycloundecadiene 16. 8,9-Dehydrocycloisolongifolene 17. 8,9-Dehydro neoisolongifolene 18. 9,10-Dehydro isolongifolene	Bisht *et al.*, 2011 Chen *et al.*, 2011 El-Gohary, 2004; He *et al.*, 2018 Jirovetz *et al.*, 2004 Eröz Poyraz *et al.*, 2018 Essaidi *et al.*, 2014 Fenanir *et al.*, 2021 Ghannadi *et al.*, 2012 Ilham *et al.*, 2018 Janaki *et al.*, 2018 Qu *et al.*, 2021; Fenanir *et al.*, 2021 Jirovetz *et al.*, 2004

		19. allo-Aromadendrene 20. Aromadendrene 21. Cadalene 22. Cadina-1,4-diene 23. Calarene 24. cis-Calamenene 25. cis-α-Bisabolene 26. cis-γ-Bisabolene 27. Copadiene 28. Cyclosativene 29. Cypera-2,4-diene 30. Cyperene 31. Cyprotene 32. Dehydrocostuslactone 33. Dihydro aromadendrene 34. E-Caryophyllene 35. epi-α-Selinene 36. Eudesma-1,4(15),11-triene 37. Eudesma-2,4(15)-11-triene 38. Eudesma-2,4,11-triene 39. Germacrene B 40. Germacrene D 41. Gurjunene 42. iso-Aromadendrene 43. iso-Germacrene D 44. iso-Ledene 45. iso-Longifolene 46. iso-Patchoula-3,5-diene 47. iso-Rotundene 48. Longifolene 49. Longipinene 50. Nootkatene 51. Norrotundene 52. Patchoula-2-4-diene 53. Rotundene 54. Selina-4,11-diene 55. Selinatriene 56. trans-Calamenene 57. trans-β-Bergamotene 58. trans-γ-Bisabolene 59. Valencene 60. Ylanga-2,4-diene 61. α-Amorphene 62. α-Aromadendrene 63. α-Bergamotene 64. α-Bulnesene	Kandikattu *et al.*, 2015 Kilani *et al.*, 2008 Lawal and Oyedeji 2009 Li, 2013 Liu *et al.*, 2016 Narasimhan and Senich, 1956; Trivedi *et al.*, 1964 Ohira *et al.*, 1998; Lu *et al.*, 2022 Ohira *et al.*, 1998 Richa and Suneet, 2014 Sonwa and König, 2001 Wang *et al.*, 2021 Xu *et al.*, 2015 Yagi *et al.*, 2016; Hu *et al.*, 2017 Yang and Shi, 2012 Zhou and Yin, 2012 Zoghbi *et al.*, 2008

		65. α-Cadinene 66. α-Calacorene 67. α-Caryophyllene 68. α-Copaene 69. α-Cubebene 70. α-Elemene 71. α-Farnesene 72. α-Guaiene 73. α-Gurjunene 74. α-Himachalene 75. α-Humulene 76. α-Longipinane 77. α-Maaliene 78. α-Muurolene 79. α-Selinene 80. α-Ylangene 81. β-Acoradiene 82. β-Bourbonene 83. β-Calacorene 84. β-Caryophyllene 85. β-Cedrene 86. β-Copaene 87. β-Cubebene 88. β-Elemene 89. β-Farnesene 90. β-Guaiene 91. β-Gurjunene 92. β-Humulene 93. β-Selinene 94. β-Vatirenene 95. γ-Cadinene 96. γ-Calacorene 97. γ-Elemene 98. γ-Gurjunene 99. γ-Muurolene 100. γ-Selinene 101. γ-Vetivenene 102. δ-Cadinene 103. β-Calacorene 104. β-Elemene 105. β-Gurjunene 106. δ-Copadiene	
4.	Sesquiterpene oxygenated	1. (-)-10-epi-α-Cyperone 2. (-)-Clovane-2,9-diol 3. (-)-Eudesma-3,11-diene-5-ol 4. (-)-Isobicyclogermacrenal	Ahmed *et al.*, 1998 Ahn *et al.*, 2015 Al-Massarani *et*

		5. (+) Oxo-α-ylangene 6. (+) α-Cyperone 7. (+)-Alismoxide 8. (+)-Cyperadione 9. (4S, 5E, 10R)-7-Oxo-trinoreudesm-5-en-4β-ol 10. (4αS, 7S), -7-Hydroxy-1,4a-dimethyl-7-(prop-1-en-2-yl)-4,4α,5,6,7,8-hexahydronaphthalen-2 (3H)-one 11. (4αS,7S, 8R)-8-Hydroxy-1,4a-dimethyl-7-(prop-1-en-2-yl)-4,4α,5,6,7,8-hexahydronaphthalen-2(3H),-one 12. (6S)-Patchoulan-4-ene-6-ol 13. (E, E)-Farnesol 14. 1,4-Epoxy-4-hydroxy-4,5-seco-guain-11-en-5-one 15. 10,12-Peroxycalamenene 16. 10-Epieudesm-11-ene-3β, 5α-diol 17. 10-epi-α-Cyperone 18. 10-Hydroxy amorph-4-en-3-one 19. 11(13)-Eudesmene-3,4,12-triol 20. 11,12 Dihydroxy eudesm-4en,3-one 21. 12-Hydroxy nootkatone 22. 12-Methyl cyprot-3-en-2-one-13-oic acid 23. 14-Acetoxy cyperotundone 24. 14-Hydroxy cyperotundone 25. 14-Hydroxy-α-cyperone 26. 1β,4α-Dihydroxyeudesm -11-ene 27. 1β-Hydroxy-α-cyperone 28. 2-(4α,8-Dimethyl-1,2,3,4,4α,5,6,7-octahydro-naphthalen-2-yl)-prop-2-en-1-ol 29. 2-Hydroxy-14-calamenenone 30. 2-Methyl cyprot-3-en-2-one-13-oic acid 31. 2-Oxo-α-cyperone 32. 2α-(5-Oxypentyl)-2β-methyl-5β-isopropenyl cyclohexanone 33. 2β-Hydroxy-α-cyperone 34. 3,5,6,7,8,8α-Hexahydro-4,8α-dimethyl-6-(1-methyl	*al.*, 2016 Bisht *et al.*, 2011 Carvalho *et al.*, 2003 Chang and Lee, 2016 Chiu *et al.*, 2001 Dhillon *et al.*, 1993 El-Gohary, 2004; Fang *et al.*, 2004 El-Gohary, 2004 Eltayeib and Ismaeel, 2014 Eneh *et al.*, 2016 Fenanir *et al.*, 2021 Fraga *et al.*, 1995 Fu *et al.*, 2010 Ghannadi *et al.*, 2012 Gliszczyńska *et al.*, 2011 He *et al.*, 2018 Hikino *et al.*, 1971 Hikino *et al.*, 1975 Hu *et al.*, 2017 Huffman *et al.*, 1980 Ibrahim *et al.*, 2007 İlham *et al.*, 2018 Jiang *et al.*, 2011 Jirovetz*et al.*, 2004 Kandikattu *et al.*, 2015 Kapadia *et al.*, 1967 Khan *et al.*, 2011 Tsoyi *et al.*, 2011 Priya Rani and Padmakumari 2012 Kim *et al.*, 2013 Lawal and

		ethenyl)2(1H) naphthalenone 35. 3β, 4α-Dihydroxy-7-epieudesm-11 (13)-ene 36. 3β, 4α-Dihydroxy-7-epi-eudesm-11(13)-ene 37. 3β-Hydroxy cyperenoic acid 38. 3β-Hydroxy ilicic alcohol [11(13)-eudesmene-3,4,12-triol] 39. 4,5-Secoeudesmane epimer/2β-(5-oxopentyl)-2β-methyl- 5β-isopropenylcyclohexanone 40. 4,5-Secoeudesmane/2α-(5-oxopentyl)-2β-methyl-5β-isopropenylcyclohexanone 41. 4,5-seco-Eudesmanolide 42. 4,5-seco-Guaia-1(10) ,11- diene-4,5-dioxo 43. 4-Oxo-α-ylangene 44. 4α,5α-Oxido eudesm-11-en-3-one 45. 4α,5α-Oxido eudesm-11-en-3α-ol 46. 5-Hydroxy lucinone 47. 6,9-Diacetoxy cyperene 48. 6-Acetoxy cyperene 49. 6-Acetoxypatchoul-4-en-3-one 50. 6-Acetyl sugebiol 51. 7-epi-Teucrenone 52. 7α (H), 10β-Eudesm-4-en-3-one-11,12-diol 53. 8-Oxo-9H-cycloisolongifolene 54. 9-Methoxycalamenene 55. Agarospirol 56. Alismoxide 57. Argutosine D 58. Aristol-9-en-3-one 59. Aristolene epoxide 60. Aristolone 61. Aromadendrene epoxide 62. Britanlin E 63. Carophylla-6-one 64. Carotol 65. Caryophylla-2(12), 6(13) dien-5-one 66. Caryophylladienol 67. Caryophyllane-2-6-β-oxide	Oyedeji, 2009 Luo *et al.*, 2014 Morikawa *et al.*, 2002 Morimoto *et al.*, 2009 Nyasse *et al.*, 1988 Ohira *et al.*, 1998 Qin *et al.*, 2006 Rani *et al.*, 2012 Rukachaisirikul *et al.*, 2005 Ryu *et al.*, 2015 Wang *et al.*, 2021b Sabrin *et al.*, 2018 Sanz and Marco, 1990 Sun *et al.*, 2000 Wang *et al.*, 2021 Wu *et al.*, 2007 Xu *et al.*, 2004 Xu *et al.*, 2008 Xu *et al.*, 2009 Xu *et al.*, 2013 Xu *et al.*, 2015 Xu *et al.*, 2016 Yagi *et al*. 2016 Yang and Shi, 2012 Yang, 2012 Zhang *et al.*, 2007 Zhou and Yin, 2012 Zoghbi *et al.*, 2008

		68. Caryophyllene acetate 69. Caryophyllene alcohol 70. Caryophyllene ketone 71. Caryophyllene oxide 72. Caryophyllenol-I 73. Caryophyllenol-II 74. Cedrol 75. cis-12-Caryophyll-5-en-2-one 76. cis-Nerolidol 77. cis-Valerenol 78. cis-Valerenyl acetate 79. cis-α-Bisabolene epoxide 80. Clovane-2,9-diol 81. Cubebol 82. Cyclic acetal 83. Cyper-11-ene-3,4-dione 84. Cyperadione 85. Cyperenal 86. Cyperene epoxide 87. Cyperene-3,6-diol 6-acetate 88. Cyperene-3,8-dione 89. Cyperene-3,8-dione, 14-hydroxy 90. Cyperenoic acid 91. Cyperenol 92. Cyperenone 93. Cyperensol A 94. Cyperol 95. Cyperolone 96. Cyperotundic acid 97. Cyperotundol 98. Cyperotundone 99. Cyperusol 100. Cyperusol A1 101. Cyperusol A2 102. Cyperusol A3 103. Cyperusol C 104. Cyperusol D 105. Cyprotene 106. Dehydrocostuslactone 107. diepi-α-Cedrenepoxide 108. Elema-1,3,11 (13)-trien-12-ol 109. Elemol 110. epi-Cubebol 111. epi-Cubenol 112. epi-Guaidiol A 113. epi-α-Cadinol	

		114. epi-α-Muurolol 115. Epoxy caryophyllane-5α,15-diol 116. Epoxyguaiene 117. Eudesm-7(11)-en-4-ol 118. Eudesma-4(14),11(13)-diene-7α,8α,12-triol 119. Eudesma-4(14),11-dien-3β-ol 120. Eudesmene-3, 4, 12-triol 121. Globulol 122. Guaidiol 123. Guaidiol A 124. Guaiol 125. Humulene epoxide II 126. Humulene oxide 127. iso-Aromadendrene epoxide 128. iso-Corymbolone 129. iso-Curcumenol 130. iso-Cyperol 131. iso-Cyperotundone 132. Isokobusone 133. iso-Longifolen-5-one 134. iso-Longifolenone 135. iso-Mustakone 136. iso-Patchoul-4-en-3-on-8α-ol 137. iso-Patchoulenone 138. iso-Rotundenol 139. iso-Spathulenol 140. Khusinol 141. Kobusone 142. Ledene alcohol 143. Ledene oxide 144. Ledol 145. Ligucyperonol 146. Longifolinaldehyde 147. Longipinocarvone 148. Longiverbenone 149. Mandassidione 150. Methoxy cyperotundol 151. Mustakone 152. Nardol 153. Nootkatone 154. Norcyperone 155. Oplopanone 156. Oxyphyllenone C 157. Oxyphyllenones B 158. Oxyphyllol C	

		159. Palustrol 160. Patchoulenone 161. Patchoulenyl acetate 162. Perilla alcohol 163. Rhombitriol 164. Rotundene 165. Rotundenol 166. Rotundone 167. Rotundusolide A 168. Rotundusolide B 169. Santalol 170. Scariodione 171. Solavetivone 172. Spathulenol 173. Sugebiol 174. Sugebiol 6-acetate 175. Sugeonol 176. Sugeonyl acetate 177. Sugetriol 178. Sugetriol triacetate 179. Sugetriol-3,9-diacetate 180. Sugetriol-6,9-diacetate 181. Torreyol 182. Valeranone 183. Valerenal 184. Valerianol 185. Vellerdiol 186. Viridiflorol 187. Vulgarol A 188. Vulgarol B 189. Widdrol 190. Zerumbone 191. Zierone 192. α-Cadinol 193. α-Calacorene 194. α-Cedrene epoxide 195. α-Corymbolol 196. α-Cyperol 197. α-Cyperolone 198. α-Cyperone 199. α-Muurolol 200. α-Rotunol 201. β-Bisabolol 202. β-Cyperone 203. β-Eudesmol 204. β-Hydroxycyperone	

		205.β-Rotunol 206.γ-Eudesmol 207.γ-Gurjunene epoxide 208.δ-Epoxyguaiene	
5.	Phenolic derivatives	1. Carvacrol 2. Cinnamaldehyde 3. Cuminaldehyde 4. Eugenol 5. Thymol 6. trans-Anethole	Chang *et al.*, 2012 Eltayeib and Ismaeel, 2014 Ghannadi *et al.*, 2012 Hu *et al.*, 2017 Janaki *et al.*, 2018 Yagi *et al.*, 2016 Zhang *et al.*, 2017
6.	Aliphatic hydrocarbons	1. 3-Methyl heneicosane 2. Eicosane 3. Hentriacontane 4. Hexadecane 5. Nonacosane 6. Octacosane 7. Octadecane 8. Pentatriacontane 9. Triacontane	Nidugala *et al.*, 2015

Sesquiterpenoids reported from *Cyperus rotundus*

Terpenoids are the major class of compounds reported from *Cyperus rotundus* essential oils (**Table 2**). A characteristic of naturally occurring terpenes is the bewildering array of structures, varying from acyclic chains to cyclic ring systems with ring sizes ranging from three to eleven carbons, with an obvious prevalence for five and six membered rings. The sesquiterpenoids form a major group of natural products with extraordinary structural variety, and different polycyclic carbon skeletons were elaborated for sesquiterpenoids that are derived biosynthetically from farnesyl pyrophosphate.

Sesquiterpenoids are the major subclass of natural products reported from *Cyperus rotundus*, and sesquiterpenoids possessing diverse skeletons such as eudesmane, patchoulane, cadinane, rotundane, guaiane, caryophyllane, clovane, copaene anderemophilanehave been reported from *Cyperus rotundus* (Yang and Shi, 2012).In addition, sesquiterpene endoperoxides, norsequiterpenoids and secosesquiterpenoids are also reported from *Cyperus rotundus*.It is interesting to note that several sesquiterpenoids were isolated for the first time from *Cyperus* species, and the compounds names are thus associated with *Cyperus* (Nigam, 1965; Hikino *et al.*, 1967; Hikino *et al.*, 1968; Neville *et al.*, 1968; Hikino *et al.*, 1971). Even recently, new sesquiterpenoids were reported from *C. rotundus* (Wang *et al.*, 2021). **Table 2** enlists 315 sesquiterpenoids reported from *C. rotundus,* of which 107 are sesquiterpene hydrocarbons, while 208 are oxygenated sesquiterpenoids.

Guaiane and patchoulane type sesquiterpenes

Among the various sesquiterpenoids reported from *Cyperus rotundus,* guaiane and patchoulane sesquiterpenes, with a characteristic fused structure of five and seven membered rings, are peculiar to the plant group (Sonwa and Konig, 2001; Kim *et al.,* 2012; Yang and Shi, 2012). Rotundone, (6S)-6-acetoxy cyperene, (6S)-cyperene-6-ol, sugetriol triacetate, (6S,9S)-6,9-diacetoxy cyperene, 14-acetoxy cyperotundone, 14-hydroxy cyperotundone, 3β-hydroxy cyperenoic acid, 6,12 cyperotunone, cyperene-3,8-dione, cyperenoic acid and sugetriol-3, 9-diacetate are few examples of guaiane/ patchoulane type sesquiterpenoids reported from *Cyperus rotundus* (Xu *et al.*, 2015). Guaiane/patchoulanetype sesquiterpenoids were found to act as allelochemicals and growth inhibitors on the surrounding plants (Morimoto and Komai, 2005; Yang and Shi, 2012).

Sugetriol triacetate

The patchoulane type sesquiterpenoid sugetriol triacetate and analogues sugetriol-3,9-diacetate and sugetriol-6,9-diacetate areimportant secondary metabolites reported from *Cyperus rotundus* (**Figure 5**) (Kim *et al*., 2012; Kim *et al*., 2013; Wang *et al*., 2021). Sugetriol triacetate has been attributed with tumour necrosis factor-alpha (TNF-α)-induced NF-κB activation inhibition with IC_{50} value of 72.6 ± 3.0 μM (Wang *et al*., 2021).Sugetriol-3,9-diacetate exhibited remarkable binding affinity to PL^{pro} of SARS CoV-2(Wu *et al*., 2020; Birendra Kumar *et al*., 2021).

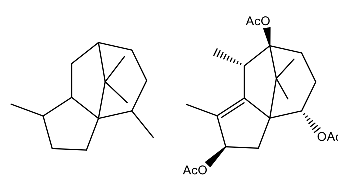

Figure 5. Patchoulane skeleton and sugetriol triacetate

Rotundone: The guaiane sesquiterpene rotundone is so called because it was originally isolated and characterised from the rhizomes of *Cyperus rotundus* (**Figure 6**) (Kapadia *et al.,* 1967). Rotundone is also present in several aromatic plants, including black pepper, marjoram, oregano, rosemary, basil, thyme, boswelia and geranium (Johannes *et al.*, 2016). However, till the discovery of the odour impact of the compound by Siebert *et al*.(2008), the compound was relatively unknown. Rotundone is an important component of agarwood scent and patchouli scent, and recently cypriol oil (*Cyperus scariosus*) with rotundol is emerging as an alternative to the costly agarwood oil.

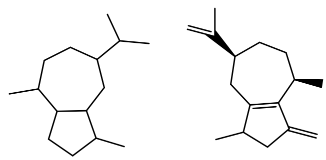

Figure 6. Guaiane skeleton and rotundone

Rotundone, the stealthy structure behind the peppery note for Australian Shiraz wines: The popular Australian Shiraz wines have the characteristic spicy black pepper aroma, and rotundone was identified as the major contributor to peppery characters in Shiraz grapes and wine, with an odor threshold of 8 ng/L in water and 16 ng/L in red wine (**Figure 7)** (Siebert *et al.*, 2008; Wood *et al.*, 2008). In addition to the peppery note, rotundone is responsible for spicy and woody odors of several aromatic plants. Rotundone was found to have the highest odor activity value among the measured compounds, and together with the other ketones, contributes to the woody amber character of cypriol oil (Clery *et al.*, 2016). An investigation of the aromas of grapefruit, orange, apple and mango revealed the presence of rotundone as the odor-active compound that gave off a strong woody odor (Akira *et al.*, 2017).

Figure 7. Rotundone, the peppery odour compound in Australian Shiraz wines

Cyperenone (Cyperotundone, isopatchoulenone): The sesquiterpene was isolated for the first time from the essential oil of *Cyperus scariosus* by Nigam (1965), and the structure was characterised by hydrogenation and deoxidation **(Figure 8)**. The compound was synthesized from cyperene by chromic acid oxidation, and named cyperenone in view of its relationship to cyperene.

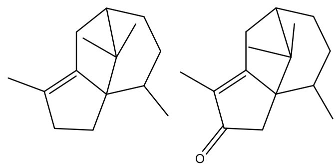

Figure 8. Cyperene and cyperenone

Mustakone: The tricyliccadinane sesquiterpenoid mustakone has its name derived from the common name in *Sanskrit* for *Cyperus rotundus* 'mustuka'. The compound was first isolated from *Cyperus rotundus* by Kapadia *et al.* (1963) (**Figure 9**). Mustakone is an important odour component of *Cyperus rotundus.*

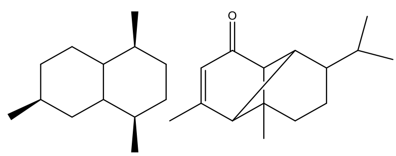

Figure 9. Cadinane skeleton and the structure of mustakone

Eudesmane type sesquiterpenoids

Eudesmane type sesquiterpenes are another important class of volatile compounds reported from *C. rotundus* essential oil. α-Cyperone, isocyperol, cyperol, 1β-hydroxy-α-cyperone, 10-epieudesm-11-ene-3β, 5α-diol, 3β-hydroxyilicic alcohol, eudesmene-3, 4, 12-triol, cyperusol C, α-corymbolol, 3β, 4α-dihydroxy-7-epieudesm-11 (13)-ene, 7α (H), 10β-eudesm-4-en-3-one-11,12-diol and rhombitriolare few examples of eudesmane type sesquiterpenoids reported from *C. rotundus* (Kim *et al.*, 2012).

α-Cyperone: The sesquiterpene ketone α-cyperone is the most important eudesmane sesquiterpenoid reported from *Cyperus rotundus* **(Figure 10)**. The compound exhibits insecticidal properties against diamondback moth larvae (Dadang *et al.,* 1996).

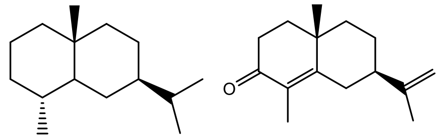

Figure 10. Eudesmane skeleton and the structure of α-cyperone

Rotundusolide A is a rare, rearranged secoeudesmane sesquiterpenoid skeleton reported from *Cyperus rotundus* (**Figure 11)** (Yang and Shi, 2012). Eudesmane type sesquiterpenes and their glycosides show broad bioactivities, including anti-inflammatory, anticancer, anti-angiogenic, antifungal, and anti-hepatitis B virus activities (Yang *et al.*, 2018).

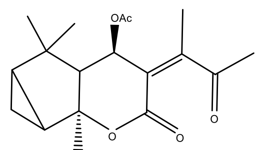

Figure 11. Rotundusolide A

Norsesquiterpenes

Norsesquiterpenes are compounds formally derived from a sesquiterpene by the removal of a methylene or methyl group. Several norsesquiterpenes have been reported from *Cyperus* species, and it seems to be a peculiarity of *Cyperus* species to produce norsesquiterpenes (Sonwa and Konig, 2001). A novel norsesquiterpene, named norcyperone was reported from *Cyperus rotundus* by Xu *et al.* in 2008 (**Figure 12)**.

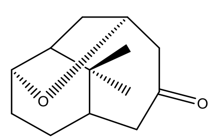

Figure 12. Structure of norcyperone

Volatile aroma profiles of *Cyperus rotundus* tubers and leaves collected from Kerala, south India

The volatile chemicals of *Cyperus rotundus* tubers and leaves collected from Kerala, south India were analysed through essential oil and head space GC-MS.

Headspace volatile chemical analysis of *Cyperus rotundus*

The head space volatile chemical profiles of *Cyperus rotundus* rhizomes and leaves, collected from south India were analysed through Shimadzu Gas Chromatograph- Mass

Spectrometer, model QP2020C NX attached to Shimadzu Head Space Sampler (HS 20), by static method.

Plant sample preparation: The plant samples, 1.0 g of the fresh leaves and rhizomes, cut into fine pieces of 2 x 2 mm, were taken in 20 ml headspace vials and introduced into the Shimadzu Head Space Auto-Sampler (HS 20 with 90 vials capacity).

Head space volatile extraction and transfer to GC: The sealed vial containing the plant sample were kept at 60° C for 10 minutes equilibrating time at shaking level 3 and after equilibration, a sampling needle is inserted into the vial through the vial septum to pressurize the sample vapor using He gas.The head space volatiles were introduced to GC inlet through valve loop injection, where the pressurized vapor is allowed to escape to a sampling loop of 1mL capacity and held at sample line temperature of 150℃, instead of being directly diverted into the GC column. From the sampling loop, the sample vapor is mixed with carrier gas and moved to a transfer line connected to the GC, at transfer line temperature of 150℃.

GC analysis: The column used was SH-Rxi-5ms capillary column (30m, 0.25mm ID, 0.25um). GC oven temperature was from 50ºC (2 min. hold) to 200ºC (3 min. hold), at the rate of 10° C/ min., and the analysis time was 20 minutes. The carrier gas (Helium) flow rate was 1.5 mL/min, at split ratio 20.0.

MS analysis: The ionization mode was electron impact ionization (EI); 70 eV with source temperature 200°C and interface temperature 220 °C. The mass analysis was done with Shimadzu single quadrupole 8030 series mass selective detector. The MS was done at full scan mode, at the range 45.0 m/z to 300.0 m/z.

Data processing: The data was processed using the software GC-MS solution Ver. 4.

Compound identification: The constituents were identified by MS library search (NIIST 17, Wiley 275), comparison of the relative retention indices (RRI) calculated with respect to homologous of n-alkanes, mass fragmentation analysis, and compared with literature data and published Mass spectra (Adams, 2017). Relative retention indices (RRI) of essential oil constituents were calculated on the same column using C_8-C_{30} straight chain alkanes as standards (Aldrich Chemical Company, USA).

$$RRI=100[(RT-H_n)/(H_{n+1}-H_n)]+100n$$

Where RT is the retention time of the compound (oil constituents), H_n and H_{n+1} are retention times of reference hydrocarbons with n and n+1 carbon respectively.

Essential oil analysis of Cyperaceae members

The plant material (fresh leaves 300 g; fresh rhizomes 200 g) were hydrodistilled using a Clevenger type apparatus for 3 hr. The oil obtained was dried over anhydrous sodium sulphate and stored in 4° C prior to further analysis. The essential oils were analyzed by injecting 1 µL of the diluted essential oil in diethyl ether (1:10 dilution) to Shimadzu Gas Chromatograph Mass Spectrometer (QP2020C NX), fitted with a cross bond 1,4-bis (dimethylsiloxy) phenylene dimethyl polysiloxane Rxi-5 Sil MS capillary column (30 m x 0.32 mm, film thickness 0.25 µm) coupled with Shimadzu single quadrupole 8030 series mass selective detector. The injector temperature was 240°C, and the oven temperature was 60-250°C at the rate 3°C/minute. The ionization mode was electron impact ionization (EI); 70 eV. The ion source temperature of the mass detector was 240°C, and the interphase temperature was 260°C.

The tuber essential oils of *Cyperus rotundus* were yellow in colour and the yield was 0.6% v/w. Patchoulane, copaene and eudesmane type skeletons were predominated in the essential oil samples of the tuber and leaf essential oils of *Cyperus rotundus* collected from Kerala, south India.

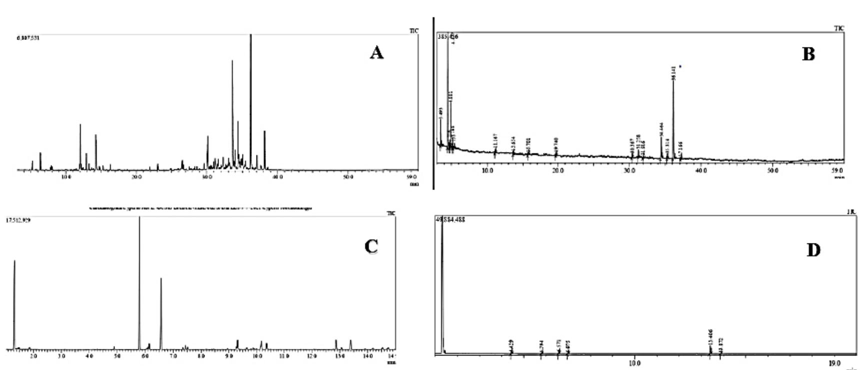

Figure 13. Essential oil and head space GC-MS TICs of *Cyperus rotundus.* **A.** Rhizome essential oil, **B.** Leaves essential oil, **C.** Rhizome head space and **D.** Leaves head space

The major compounds in rhizome essential oil were identified as α-cyperone (18.0%), mustakone (14.0%) and caryophyllene oxide (5.7%), while the leaf oil had γ-himachalene (13.1%), α-humulene (12.3%), cyperene (8.8%), β-caryophyllene (7.8%), δ-amorphene (7.6%), humulene epoxide II (6.6%) and longipinanol (6.2%) as the major compounds (**Table 3**, **Figure 14**).

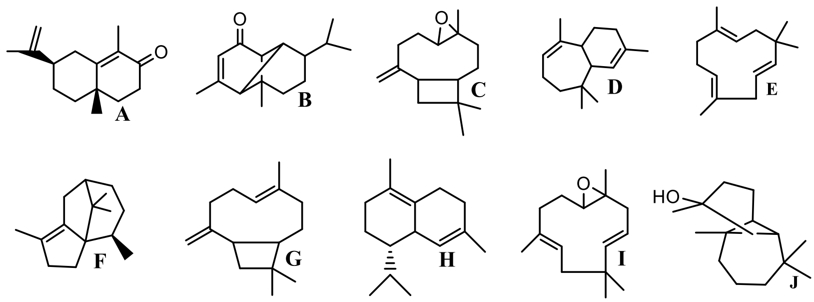

Figure 14. Major essential oil volatile chemicals of *Cyperus rotundus.*Rhizome, **A-** α-Cyperone, **B-** Mustakone, **C-** Caryophyllene oxide. Leaves, **D-** γ-Himachalene, **E-** α-Humulene, **F-** Cyperene, **G-** β-Caryophyllene, **H-** δ-Amorphene, **I-** Humulene epoxide II, **J-** Longipinanol

The major head space volatiles of the rhizome were α-pinene (43.1%) and β-pinene (25.7%) while the leaves HS showed β-caryophyllene (70.7%) and β-pinene (11.3%) as the major constituents (**Figure 15)**.

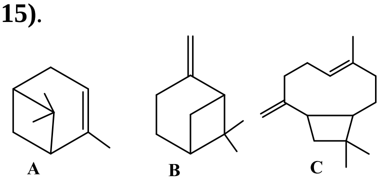

Figure 15. Major head space volatile chemicals of *Cyperus rotundus.*
A- α-Pinene, **B-** β-Pinene and **C-** β-Caryophyllene

Table 3. Essential oil and head space composition of *Cyperus rotundus*

Sl. No.	RRI $_{cal}$	RRI $_{lit}$	Compound	Essential oil Area %		Head space Area %	
				Rhizome	Leaf	Rhizome	Leaf
1	842	844	3-Hexenol	-	-	-	4.4
2	932	932	α-Pinene	1.2	-	43.1	3.3
3	950	946	Camphene	-	-	0.4	-
4	955	952	α-Fenchene	-	-	3.0	-
5	957	953	Thuja-2,4(10)-diene	-	-	1.2	-
6	974	977	β-Pinene	2.2	-	25.7	11.3
7	988	988	Myrcene	-	1.4	-	-

8	1021	1022	o-Cymene	-	-	0.9	-
9	1023	1026	1,8-Cineole	-	-	1.1	-
10	1024	1028	Limonene	0.6	4.1	2.0	-
11	1043	1032	β-Ocimene	-	0.6	-	-
12	1135	1139	trans-Pinocarveol	3.4	-	-	-
13	1143	1135	Nopinone	-	-	0.4	-
14	1160	1159	Pinocarvone	1.5	-	0.5	-
15	1193	1192	neo-Dihydro carveol	3.1	-	-	-
16	1194	1193	Myrtenol	1.8	-	-	-
17	1199	1195	Myrtenal	-	-	1.3	-
18	1204	1203	Verbenone	0.3	-	0.4	-
19	1215	1216	trans-Carveol	0.3	-	-	-
20	1239	1240	Carvone	0.4	-	-	-
21	1371	1369	Cyclosativene	-	1.3	0.2	-
22	1389	1389	β-Elemene	-	1.8	0.2	-
23	1398	1398	Cyperene	0.7	8.8	8.8	-
24	1414	1408	β-Caryophyllene	-	7.8	-	70.7
25	1443	1437	α-Guaiene	-	2.0	-	-
26	1454	1452	α-Humulene	-	12.3	-	3.7
27	1455	1457	Rotundene	-	1.3	-	-
28	1469	1458	Aromadendrene	-	2.0	-	-
29	1472	1480	Germacrene D	-	1.4	-	-
30	1475	1475	δ-Gurjunene	-	1.0	-	-
31	1478	1478	γ-Muurolene	-	9.6	-	-
32	1487	1481	γ-Himachalene	1.5	13.1	-	-
33	1489	1493	β-Selinene	0.9	-	-	-
34	1492	1471	4,5-di-epi-Aristolochene	-	-	1.3	-
35	1501	1496	Viridiflorene	-	3.0	-	-
36	1513	1511	δ-Amorphene	-	7.6	-	-
37	1517	1509	Nootkatene	0.3	-	-	-
38	1582	1575	Caryophyllene oxide	5.7	-	-	-
39	1590	1584	β-Copaen-4-α-ol	1.1	-	-	-
40	1574	1562	Longipinanol	-	6.2	-	-
41	1607	1597	β-Oplopenone	1.2	-	-	-
42	1608	1602	Humulene epoxide II	2.2	-	-	-
43	1609	1608	Humulene epoxide II	-	6.6	-	-
44	1616	1613	Patchoulenone	1.1	-	-	-
45	1655	1651	Pogostol	-	1.3	-	-

46	1676	1667	Mustakone	14.0	-	-	-
47	1695	1687	Cyperotundone	4.3	-	-	-
48	1770	1767	13-Hydroxyvalencene	-	3.0	-	-
49	1727	1735	α-Cyperone	18.0	2.0	-	-
50	1755	1759	Cyclocolorenone	4.2	-	-	-
51	1806	1792	Nootkatone	4.2	-	-	-

Notes: RRI[a]: Relative retention index from literature (Adams, 2017). RRI[b]: Relative retention index calculated on SH-Rxi-5Sil column with respect to homologous of n-alkanes (C7-C30, Aldrich Chem. Co. Inc.).

Isolation and characterisation of components from the essential oil of *C. rotundus*

The major compounds from the tuber essential oil were isolated by column chromatography, using hexane: ethyl acetate gradient elution and characterized by EI-MS analysis. The major compounds identified were; trans-pinocarveol (100% hexane), caryophyllene oxide (100% hexane), pathchoulenone (100% hexane), α-cyperone (1% ethyl acetate) and mustakone (1% ethyl acetate) (**Figure 16)**.

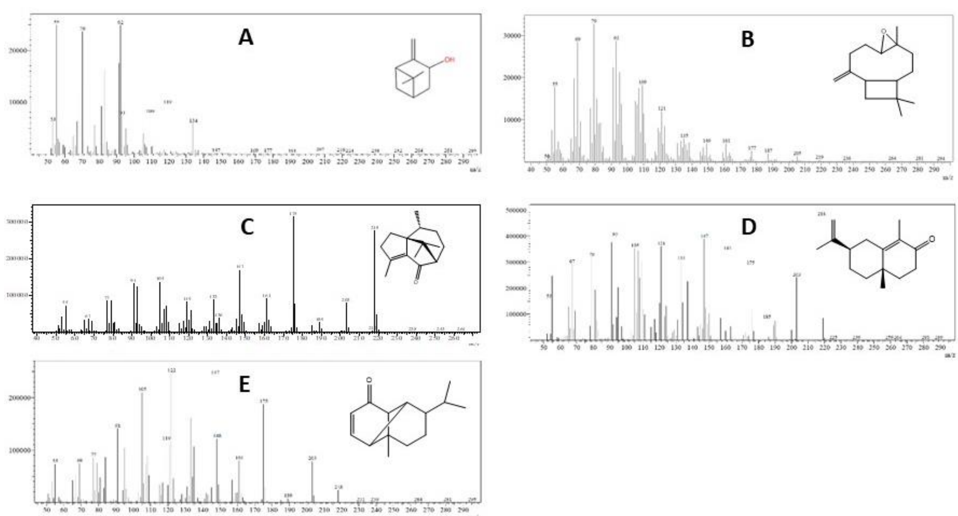

Figure 16. Electron Impact Mass Spectrum (EI-MS) and structure of major compounds isolated from *Cyperus rotundus* rhizome essential oil by column chromatography. **A-** trans-Pinocarveol, **B-** Caryophyllene oxide, **C-** Pathchoulenone, **D-** α-Cyperone and **E-** Mustakone

Chemical profiling of solvent extract of *Cyperus rotundus*

Solvent extraction: About 50g of dried rhizomes of *Cyperus rotundus* were extracted using hexane by Soxhlet apparatus. The hexane extract was submitted to column chromatography on silica gel (60-120 mesh size) by gradient elution of hexane: ethyl acetate. Fractions eluted at 5% ethyl acetate yielded the pure compounds. The compounds were characterized through ^{13}C NMR and GC-MS analysis as α-cyperone and cyperotundone. Quantification of the isolated pure compounds was done through HPTLC.

α-Cyperone: ^{13}C NMR showed that the compound has 15 carbon signals with chemical shifts at δ (ppm); 198.9, 162.0, 147.7, 130.3, 110.6, 43.5, 39.0, 37.4, 36, 33.9, 31.4, 26.6, 22.5, 21.5 and 10.3 (**Figure 17)**.

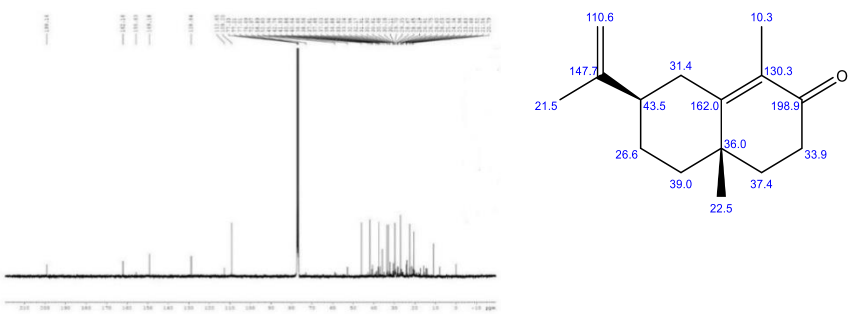

Figure 17. ^{13}CNMR of α-cyperone

Cyperotundone: ^{13}C NMR showed that the compound has 15 carbon signals with chemical shifts at δ (ppm); 207.6, 166.4, 137.9, 57.2, 49.0, 41.2, 40.5, 33.0, 37.8, 28.2, 28.0, 10.0, 20.5, 20.5 and 17.0 (**Figure 18)**.

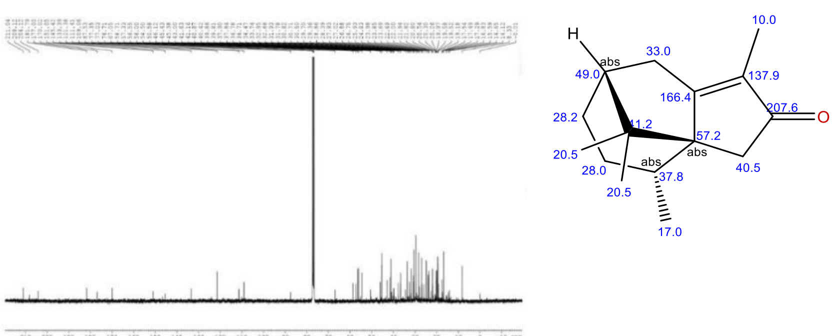

Figure 18. ^{13}CNMR of cyperotundone

HPTLC profiling

The isolated compounds α-cyperone and cyperotundone were profiled in the hexane extracts of different assessions of *Cyperus rotundus* rhizomes using HPTLC (**Figure 19)**. The HPTLC chromatogram gave a better resolution in the solvent system, chloroform: methanol (9.5:0.5 v/v) with R_f value 0.58 and 0.49 respectively, and was recorded at 366 nm. Linear regression analysis was performed with peak area and concentration to calculate the calibration equation and correlation coefficients. α-Cyperone in the range of 0.4 to 3 µg per band gave linear response with regression equation$y = 5825x + 0.694$. The correlation coefficient 0.995, indicated good linear relationship of peak area with concentration of the standard. Cyperotundonein the range of 0.6 to 5 µg per band gave linear response with regression equation$y = 5965x + 0.694$ with the correlation coefficient 0.984, indicating good linear relationship of peak area with concentration of the standard.

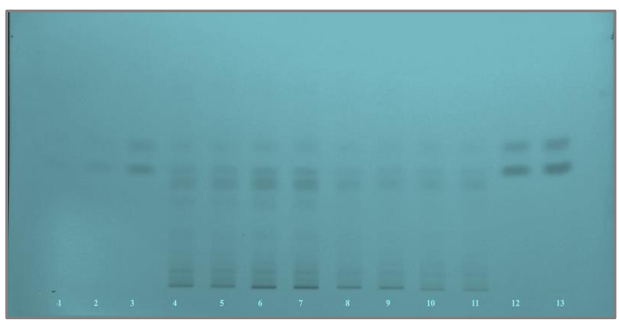

Figure 19. HPTLC profile (366 nm) of standard α-cyperone and cyperotundone (1,3 and 5 µg of std 1 and 2 in tracks 1-3), hexane extracts of different accessions of *Cyperus rotundus* rhizomes (15µg in track 4 and 5, 3µg in track 6 and 7, 8µg in track 8 and 9, 3µg in track 10 and 11 respectively of *Cyperus rotundus*Vaikom, Kannur, Thiruvananthapuram and Karunagappally accessions) 5,7µg of standard 1 and 2 in track 12-13.

Biogeographic variation and chemotaxonomy

The constitution of *Cyperus rotundus* essential oils from different parts of the world has been studied, and literature review revealed the report of essential oils from 24 different countries across the world (**Table 4, Figure 20**).

Several attempts have been made to utilize the diversity of volatile chemicals in *Cyperus rotundus* for chemosystematic purpose, and various chemotypes of *Cyperus rotundus* were expected, and variations were observed in the phytochemical composition. Based on the volatile chemicals, four chemotypes (H, K, M and O) were reported for *C. rotundus* from different parts of Asia (Komai and Tang, 1989; Komai *et al.*, 1994).

H-type (Japan): α-Cyperone, β-selinene, cyperol and caryophyllene.

M-type (China, Hong Kong, Japan, Taiwan and Vietnam): α-Cyperone, cyperotundone, β-selinene, cyperene and cyperol.

O-type (Japan, Taiwan, Thailand, Hawaii and the Philippines): Cyperene, cyperotundone and β-elemene.

K-type (Hawaii): Cyperene, cyperotundone, patchoulenyl acetate and sugeonyl acetate.

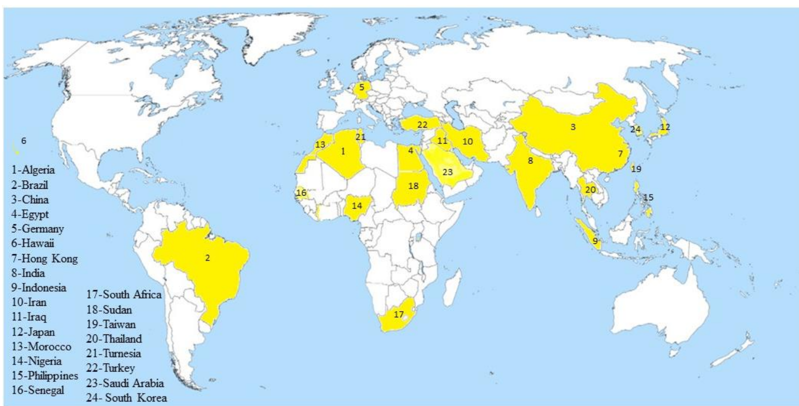

Figure 20. *Cyperus rotundus* essential oil composition reported from the world

Table 4. Country wise distribution of volatile phytochemicals in *Cyperus rotundus*

Sl. No.	*Cyperus rotundus* origin	Major compounds	References
1.	Algeria	Humulene oxide-II, caryophyllene oxide, khusinol, agarospirol, spathulinol, trans-pinocarveol	Fenanir *et al.*, 2022
2.	Brazil	α-Cyperone, cyperotundone	Zoghbi *et al.*, 2008
3.	China	α-Cyperone, cyperol, α-copaene, cyperene	Komai *et al.* 1994
		Cyperene, b-caryophyllene oxide, a-selinene, a-copaene,	Chen *et al.*, 2011
		α-Cyperone, cyperene, caryophyllene oxide, β-selinene	Xin *et al.*, 2016
		α-Cyperone, cyperene, α-selinene	Hu *et al.*, 2017

		α-Cyperone, cyperene, caryophyllene oxide, β-selinene, trans-pinocarveol, aristolone, α-copaene	Liu *et al.*, 2016
		Cyperone, cyperene, α-selinene	Zhang *et al.*, 2017
		Cyperenone, α-cyperone, cyperene	Qu *et al.*,2021
		α-cyperone, aristolone	Wu, 2007
		Cyperene, α-cyperone, β-selinene, aristolone	Feng *et al.*, 2006
		Caryophyllene oxide, cyperene, α-cyperone, β-selinene, aristolone, α-copaene, longiverbenone, isolongifolen-5-one	Li, 2013
		Cyperene, α-cyperone,	Jin *et al.*, 2006
		Cyperene, α-cyperone, β-selinene	Lin *et al.*, 2006
		α-Cyperone, aristolone	Xu *et al.*, 2006
		Isolongifolen -5-one	He *et al.*, 2015
4.	Egypt	(+) Oxo-α-ylangene, α-cyperone, trans-pinocarviol, cyperene	Gohary *et al*., 2004
		Humulene epoxide, caryophyllene oxide	Samra *et al.*, 2020
5.	Germany	Cyprotene, α-copaene, cyperene, α-selinene, rotundene	Sonwa and Konig, 2001
6.	Hawaii	Cyperotundone, cyperene	Komai *et al*., 1989
		Cyperene, α-cyperone	Komai *et al*., 1994
		Cyperone, patchoulenyl acetate, sugeonyl acetate, β-elemene	Komai *et al*., 1994
		Caryophyllene	Komai *et al*., 2005
7.	Hong Kong	Cyperotundone	Komai *et al*., 1994
8.	India	α-Copaene, cyperene, valerenal, caryophyllene oxide	Jirovetz *et al*., 2004
		Cyperene, humulene, α-selinene	Tiwari *et al*., 2014
		Caryophyllene alcohol	Dhillon *et al.*, 1993
		β-Selinene, α-cyperone, anethole	Singh *et al.*, 2018
		Cyperene	Richa and Suneet, 2014
		Caryophyllene oxide	Gupta *et al.*, 2016
9.	Indonesia	Longiverbenone, β-silinene, 3,4-isopropylidene, caryophyllene oxide	Busman *et al.*, 2018

10.	Iran	Cyperene, caryophyllene oxide, α-longipinane	Ghannadi *et al.*, 2012
		Cyperene, cyperotundone	Ali *et al.*, 2013
		Elemenone, αcyperone, and caryophyllene oxide	Janaki *et al.*, 2018
		α-Cyperone	Mojab *et al.*,2009
11.	Iraq	Cyperol, caryophyllene, cyperene	Nima *et al.*, 2008
12.	Japan	α-Cyperone, β-selinene, cyperene	Komai *et al.*, 1991
		Cyperol	Komai *et al.*, 1994
13.	Morocca	Longiverbenone, cyperotundone, (-) eudesma-1,4(15),11-triene, β-copaen-4α-ol, humulene epoxide-2	Karima *et al.*, 2022
14.	Nigeria	Cyperene, α-cyperone	Kilani *et al.*, 2008
		Cyperene, α-cyperone	Ekundayo *et al.*, 1991
15.	Philippines	Cyperotundone, β-selinene	Komai *et al.*, 1991
16.	Saudi Arabia	α-Cyperone, 4-oxo-α-ylangene	Al-Massarani *et al.*, 2016
17.	Senegal	Caryophyllene oxide, humulene oxide II, longiverbenone	Thiam *et al.*,2022
18.	South Africa	α-Cyperone, myrtenol, caryophyllene oxide, β-pinene	Lawal and Oyedeji, 2009
		β-Pinene, α-pinene, α-cyperone, myrtenol, α-selinene	Lawal *et al.*, 2009
19.	South Korea	α-Cyperone, β-selinene, cyperene, aristolone, caryophyllene oxide	Chang *et al.*, 2012
20.	Sudan	Humulene epoxide 2, allo-aromadendrene, cyperene, α-calacorene, 3,7-guaiadiene, humulene epoxide-II	Eltayeb *et al.*, 2016
		Longiverbenone	Yagi *et al.*, 2016
		Longiverbenone	Eltayeib and Ismaeel, 2014
		Isolongifolen -5-one	Eltayeib and Ismaeel, 2014
		Isolongifolen -5-one	Eltayeib and Ismaeel, 2014
21.	Taiwan	Cyperene	Kilani *et al.*, 2008
22.	Thailand	Cyperene, cyperotundone	Ohira *et al.*, 1998
23.	Tunesia	Cyperene, α-cyperone	Kilani *et al.*, 2005
		Cyperene, α-cyperone, isolongifolen-5-one, rotundene, cyperorotundene	Kilani *et al.*, 2008
		Cyperotundone, cyperene	Essaidi *et al.*, 2014
24.	Turkey	Cyperene, α-copaene, α-ylangene	Ilham *et al.*, 2018

A systematic investigation of the *Cyperus rotundus* volatile chemicals reported from different regions of the world reveals that the essential oil composition varied considerably. However, few characteristic compounds such as α-cyperone, cyperene and cyperotundone can be considered as the major compounds in most of the accessions (**Figure 21)** (Komai *et al.,* 1994; Lawal *et al.,* 2009).

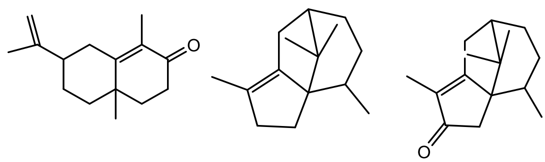

Figure 21. Major volatile compounds reported from the essential oils of *Cyperus rotundus*- Cyperone, Cyperene and Cyperotundone

Several factors such as time of the day, temperature, diurnal/nocturnal nature, soil, nutrient levels, water availability, fungal or endophyte presence, systemic pathogens, and mechanical or herbivore damage need to be considered for getting consistent volatile chemical profiles (Holopainen and Gershn-hexaneenzon, 2010; Kusari *et al.*, 2013). It is always advisable to mention the exact plant parts, phytogeographical location of plant collection, season of collection, extraction technique and analytical technique.

The constituents of volatile compounds of *C. rotundus* obtained by hydrodistillation, supercritical fluid extraction, pressurized liquid extraction and headspace techniques vary considerably (Jirovetz *et al.,* 2004). Tam *et al.* (2007) tried three methods; hydrodistillation (HD), pressurized liquid extraction (PLE) and supercritical fluid extraction (SFE) for extraction of volatile compounds from *C. rotundus* and found that the contents varysignificantly with HD, PLE and SFE. PLE had the highest extraction efficiency for α-copaene, cyperene, β-selinene, β-cyperone and α-cyperone, while SFE had the best selectivity for extraction of β-cyperone and α-cyperone.

Non-volatile chemical composition of *Cyperus rotundus*

In addition to the wide array of volatile constituents, the relevance of the plant also depends on different classes of non-volatile compounds as well. Phenolic acids, flavonoids, iridoids, furochromons, stilbenoids, triterpenoids, steroids, alkaloids and fatty acids are the major class of non-volatile compounds reported from *C. rotundus* (Babiaka *et al.,* 2021).

The non-volatile phytochemicals from various solvent extracts are generally analysed through conventional techniques such as extraction, separation and characterisation, while phytochemical screening through LC-MS is another approach. The reports of phytochemicals through the conventional techniques are much less, while the hyphenated techniques such as LC-MS/MS predominates.

In the beginning, conventional phytochemical techniques such as solvent extraction and column chromatographic separation were used for isolating the phytochemicals from *C. rotundus*, and spectroscopic and synthetic methods were adopted for structure elucidation. Currently several novel techniques such as supercritical fluid extraction, solid phase micro extraction, high-speed counter current chromatography, reverse phase chromatography, supercritical fluid chromatography (SFC), ultraperformance convergence chromatography (UPCC), high resolution mass spectrometry (HRMS), inductively coupled plasma mass spectrometry (ICPMS), 1D and 2D nuclear magnetic resonance spectroscopy, and various hyphenated analytical techniques such as GC-MS, GC-MS/MS, LC-MS, LC-MS/MS and LC-NMR are used for the phytochemical investigation of *Cyperus rotundus*.

Liquid Chromatography- Mass Spectrometry (LC-MS) analysis: While GC-MS is the apt technique for analysing volatile components, LC-MS is the preferred analytical technique for non-volatile components such as flavonoids, triterpenoids, iridoid glycosides and alkaloids (Kilani *et al.*, 2005; Chen *et al.*, 2011; Madhulika and Varsha, 2015). Recent technological developments and methodological advances of both liquid chromatography (LC) and mass spectrometry (MS) have allowed LC-MS based plant metabolomics to become a common tool for qualitative and quantitative investigation of plant metabolites. Tandem mass spectrometry (LC-MS/MS), especially triple quadrupole mass spectrometers and quadrupole time of flight (QToF) are the most commonly used hyphenated analytical technique for solvent extracts. Different solvent extracts of *C. rotundus* rhizomes were analysed by various LC-MS/MS techniques, yielding elaborate chemical profiles (Singh and Singh, 1980; Jeong *et al.*, 2000; Kilani *et al.*, 2005; Sayed *et al.*, 2008; Kilani *et al.*, 2009; Chen *et al.*, 2011; Zhou and Yin, 2012; Zhang *et al.*, 2014; Madhulika and Varsha, 2015; Kakarla *et al.*, 2015; Hemanth Kumar *et al.*, 2015; Singh and Sharma, 2015; Gamal *et al.*, 2015; Zhou *et al.*, 2016; Kakarla *et al.*, 2016; Sultana *et al.*, 2017; Sabrin *et al.*, 2018; Kamala *et al.*, 2018; Majeed *et al.*, 2022; Xu *et al.*, 2015).

The non-volatile phytochemicals reported from *Cyperus rotundus* are tabulated in **Table 5**. A total of 294compounds comprising aurones (3), chromones (5), coumarins (3), quinanoids (2), iridoids (29), flavonoids (46), biflavonoids(5), stilbenoids (15), lignans (1), benzofurans (4), phenolic acids and derivatives(27), phenolic derivatives (13), sesquiterpene alkaloids (3), diterpenoids (3), triterpenoids (33), steroids (19), organic acids (8), aliphatic acids and derivatives(28), amides and other nitrogenous constituents(10) and miscellaneous compounds (37) were reported from *Cyperus rotundus* (**Table 5)**.

Table 5. Non-volatile phytochemicals reported from *Cyperus rotundus*

Sl. No.	Class of compounds	Phytochemicals	Reference
1.	Aurones	1. Aureusidin 2. 4,6,3,4-Tetramethoxy aurone 3. 6,3,4-Trihydroxy-4-methoxy-5-methylaurone	Harborne *et al.*, 1982
2.	Chromones	1. Ammiol 2. Isorhamnetin 3. Khellin 4. Khellol-β-D-glucopyranoside 5. Visnagin	Sayed *et al.*, 2007
3.	Coumarins	1. 6,7-Dimethoxy coumarin 2. 6-O-p-Coumaroyl genipingentiobioside 3. Coumarin	Sayed *et al.*, 2008
4.	Quinanoids	1. Catenarin 2. Physcion	Wu *et al*., 2008
5.	Iridoids	1. 10-Hydroxyoleuropein 2. 10-O-p-Hydroxybenzoyl theviridoside 3. 10-O-Vanilloyl theviridoside 4. 6″-O-(trans-p-Coumaroyl)-procumbide 5. 6-Hydroxy ipolamiide 6. 6'-O-p-Coumaroylgenipin gentiobioside 7. 6-O-p-Hydroxybenzoyl-6-epi-monomelittoside 8. 6-O-p-Hydroxybenzoyl-6-epi-aucubin	Sayed *et al*. 2008 Zhou and Yin, 2012 Zhou *et al*., 2013 Zhou and Zhang, 2013 Zhang *et al*., 2014 Gamal, 2015 Jeong *et al.*, 2017 Zhang *et al*.; 2016 Cheng *et al.*, 2014 Lin *et al*., 2015

		9. 7-O-p-Hydroxybenzoyl-8-epi-loganic acid 10. Ipolamiide 11. Isooleuropein 12. Loganic acid 13. Negundoside 14. Neonuezhenide 15. Nishindaside 16. Oleuropeinic acid 17. Oleuroside 18. Rotunduside A 19. Rotunduside B 20. Rotunduside C 21. Rotunduside D 22. Rotunduside E 23. Rotunduside F 24. Rotunduside G 25. Rotunduside H 26. Senburiside I 27. Syringopicroside B 28. Syringopicroside C 29. Verproside	
6.	Flavonoids	1. (2RS,3SR)-3,4′,5,6,7,8-Hexahydroxyflavane 2. 5,7,4'-Trihydroxy-2'-methoxy-3'-prenylisoflavone 3. 5,7-dihydroxy-4'-methoxy-8-C-[2''-(2''-methylbutyryl)]-β-D-glucopyranosyl flavone 4. 5-Hydroxy-4'methoxy-7-[(3-methyl-2-buthenyl) oxy]-isoflavone 5. 7,8-Dihydroxy-5,6-methylenedioxyflavone 6. 7-Methoxy-isoflavone 7. Afzelechin 8. Apigenin 9. Biochanin 10. Biochanin A 11. Catechin 12. Chrysoeriol 13. Cinaroside 14. Cyperaflavoside 15. Epiorientin 16. Isorhamnetin 17. Isovitexin	Harborne *et al.*, 1982 Kilani-Jaziri *et al.*, 2009 Zhou *et al.*, 2012 Sayed *et al.*, 2008 Sayed *et al.*, 2008 Ibrahim *et al.*, 2007 Sayed *et al.*, 2001 Sayed *et al.*, 2007 Sayed *et al.*, 2008 Krishna and Renu, 2013 El-Habashy *et al.*, 1989 Singh and Singh, 1986 Kasala *et al.*, 2016 Cheng *et al.*, 2014 Gamal *et al.*, 2015 Xu *et al.*, 2016

		18. Kaempferol 19. Leucocyanidin 20. Licoricone 21. Luteolin 22. Luteolin 3`-methyl ether 23. Luteolin 4′-glucoside 24. Luteolin 5,3'-dimethyl ether 25. Luteolin 5'-methyl ether 26. Luteolin 5-methyl ether 27. Luteolin 7,3′-dimethyl ether 28. Luteolin 7-diglucoside 29. Luteolin 7-O-glucoside 30. Luteolin 7-O-β-D-glucuronopyranoside-6"-methyl ester 31. Myricetin 32. Myricetin 3-O-β-D-galactopyranoside 33. Myricetin 3-O-β-D-glucopyranoside 34. Orientin 35. Pinoquercetin 36. Pongamone A 37. Pongamone A/4'-Methoxyl-8-methoxyl-7-γ, γ-dimethylallyloxy isoflavone 38. Quercetin 39. Quercetin 3-O-β-D-glucopyranoside 40. Quercitrin 41. Rhamnetin 3-O-rhamnosyl (1→4) rhamno-pyranoside 42. Rutin 43. Scaberin 44. Tricin 45. Tricin 5-glucoside 46. Vitexin	
7.	Biflavonoids	1. Amentoflavone 2. Bilobetin 3. Ginkgetin 4. Isoginkgetin 5. Sciadopitysin	
8.	Stilbenoids	1. (–)-(Z)-Cyperusphenol A 2. (+)-(Z)-Cyperusphenol A 3. (E)-Cyperusphenol C 4. (E)-Mesocyperusphenol A	Ito *et al*., 2012 Tran *et al*., 2014 Majeed *et al*., 2022

		5. (Z)-Mesocyperusphenol A 6. Cassigarol E 7. Cyperusphenol A 8. Cyperusphenol B 9. Cyperusphenol C 10. Cyperusphenol D 11. Mesocyperusphenol 12. Piceatannol 13. Piceid 14. Scirpusin A 15. Scirpusin B	
16.	Lignans	1. Liriodendrin	Xu *et al*., 2016
17.	Benzofurans	1. 1-[2,3-Dihydro-6- hydroxy-4,7-dimethoxy2S-(prop-1-en-2-yl)benzofuran-5-yl]ethenone 2. 2S-Isopropenyl-4,8- dimethoxy-5-hydroxy-6- methyl-2,3-dihydrobenzo[1,2-b;5,4-b`]difuran 3. 2S-Isopropenyl-4,8- dimethoxy-5-methyl-2,3- dihydrobenzo-[1,2-b;5,4- b`]difuran 4. Sulfuretin	Amesty *et al.*, 2011
18.	Phenolic acids and derivatives	1. (-)-(E)-Caffeoylmalic acid 2. 1-[2,3-Dihydro-6-hydroxy-4,7-dimethoxy-2S-(prop-1-en-2yl) benzofuran-5-yl] ethanone 3. 3-Hydroxy,4-methoxybenzoicacid 4. 4',6'-Diacetyl-3,6-diferuloylsucrose 5. 4-Hydroxy benzoic acid 6. 4-Hydroxy butyl cinnamate 7. 4-Hydroxy cinnamic acid 8. 6'-Acetyl-3,6-diferuloylsucrose 9. Benzoic acid 10. Caffeic acid 11. Caffeoylmalic acid 12. Chlorogenic acid 13. Cinnamic acid 14. Ellagic acid 15. Ferulic acid 16. Gallic acid 17. Galloyl quinic acid 18. Hydroxybenzoic acid 19. Methyl 3,4-dihydroxy benzoate 20. Methyl ferulate	Sayed *et al*., 2008 Jahan *et al*., 2013, Samariya and Sarin, 2013 Zhou *et al*., 2013, Li, 2014 Amestry *et al.*, 2011 Zhou and Yin, 2012 Zhou and Zhang, 2013 Zhang *et al.*, 2014, Gamal, 2015 Komai and Kunikazu, 1981 Kowthar *et al.*, 2010 Chen *et al.*, 2011 Zhou and Zhang, 2013 Komai and Kunikazu, 1981

		21. p-Coumaric acid 22. p-Hydroxybenzoic acid 23. Propyl gallate 24. Protocatechuic acid 25. Salicylic acid 26. Vanillic acid 27. Vanillin lactoside	
19.	Other phenolic derivatives	1. 1-(3, 4-Methylenedioxyphenyl)-1E-tetradecene 2. 1-(3,4-Methylenedioxyphenyl)-1E-tetradecene 3. 1α,3β-Dihydroxy-4α-(3′,4′-dihydroxyphenyl) -1,2,3,4-tetrahydronaphthalene 4. 1α-Methoxy-3βhydroxy-4α-(3′,4′- dihydroxyphenyl)-1, 2,3,4-tetrahydro naphthalin 5. 3-(4-Hydroxy-3-methoxy phenyl)-methyl ester 6. 3-Hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-2-[4-(3-hydroxy-1-(E)-propenyl)-2,6-dimethoxy phenoxy] propyl-β-D-glucopyranoside 7. Catechol 8. Chionoside A 9. Cyperine 10. Helioside C 11. Isoaragoside 12. Pungenin 13. Salidroside	Zhou and Yin, 2012 Zhou and Zhang, 2013
20.	Sesquiterpene alkaloids	1. Rotundine A 2. Rotundine B 3. Rotundine C	Jeong *et al.*, 2017 Jeong *et al.*, 2000
21.	Diterpenoids	1. Dolabella-3,7,18-triene 2. Phytol 3. Rosenonolactone	Xu *et al*., 2008
22.	Triterpenoids	1. 18-epi-α-Amyrin glucuronoside 2. 3,4-seco-Mansumbinoic acid 3. 3β-Hydroxyolean-12-en-28-oic acid α-D-arabinofuranoside 4. 5α,8α-epidioxy-(20S,22E,24R)-Ergosta-6,22-dien-3β-ol/ergosterol peroxide 5. 9,10-seco-Cycloartane 6. 9,10-seco-Cycloartane α-D-	Singh *et al.*, 1980 Alam *et al.*, 2012 Sultana *et al.*, 2017 Singh and Sharma, 2015 Yang *et al.*, 2010 Zhou *et al.*, 2012 Lin *et al.*, 2018 Zhou *et al.*, 2016

		arabinofuranoside 7. Cyperalin A 8. Cyprotuside A 9. Cyprotuside B 10. Cyprotuside C 11. Cyprotuside D 12. Dammaradienyl acetate 13. Dammaradienyl acetate 14. Daucosterol 15. epi-α-Amyrin glucuronoside 16. Lup-12, 20 (29)-dien-3β-ol-3-α-L-arabinopyranosyl-2'-oleate 17. Lupenyl 3β-O-arabinpyranosyl 2'-Oleate /Lupenylarabinopyranosyl oleate 18. Lupenylarabinosyl oleate 19. Lupeol 20. Oleanolic acid 21. Oleanolic acid 3-O-(2-rhamnosylglucosyl) 22. Oleanolic acid arabinoside 23. Oleanolic acid-3-O-neohesperidoside 24. Oleanolic acid-3-O-neohesperidoside/3-O-(2-rhamnosylglucosyl)-oleanolic acid 25. Rotundusolide C 26. Secomacrogenin A 27. Secomacrogenin B 28. Taraxerone 29. Zeorin 30. α-Amyrin glucopyranoside 31. β-Amyrin 32. β-Amyrin acetate 33. β-Amyrin glucopyranoside	Sabrin *et al.*, 2018 Yang and Shi, 2012
23.	Steroids	1. 4,4-Dimethylandrost-5-en-3-one 2. 5,16-Pregnadiene 3. 5α,8α-Epidioxy-(20S,22E,24R)-ergosta-6,22-dien-3β-ol 4. Daucosterol 5. Sitosteryl (6`-hentriacontanoyl)-β-D-galactopyranoside 6. Stigmast-5,22-dien-3β-olyldodecanoate 7. Stigmast-5,22-dien-3β-olyltetradecanoate	Singh *et al.*, 1980 Sultana *et al.*, 2017 Gamal, 2015 Samra *et al.*, 2021 Xu *et al.*, 2008 Singh *et al.*, 2017 Luo*et al.*, 2014 Abo-Altemen *et al.*, 2019

		8. Stigmast-5-ene 9. Stigmasterol 10. Stigmasterol laurate 11. Stigmasterol laurate 12. Stigmasterol myristate 13. Stigmasterol myristate 14. Stigmasterol-n-dodecanoate 15. Stigmasterol-n-tetradecanoate 16. Taraxerone 17. β-Sitosterol 18. β-Sitosterol-3β-O-glucoside 19. β-Stigmasterolglucoside	
24.	Organic acids	1. (-)-(E)-Caffeoylmalic acid 2. 2-Hydroxy-2-methylmalonic acid 3. 2-Hydroxypropanoic acid 4. 2-Propenoic acid 5. 3,4-O-Isopropylidene shikimic acid 6. Lactic acid 7. Methyl tartronic acid 8. Propanoic acid	Sayed *et al.*, 2008 Zhou and Yin, 2012
25.	Aliphatic acids and derivatives	1. (9Z,12Z,15Z)-Octadecatrienoic acid methyl ester 2. 12-Dienoate n-pentadecanyl linoleate 3. 22-Dien-3β-olyl n-dodecanoate 4. 5-Hydroxy-4-oxo-10-pentadecenoic acid lactone 5. 9,12,15-Octadeca trienoic acid 6. Behenic acid 7. Behenic acid monoglyceride 8. Fulgidic acid 9. Linoleic acid 10. Linolenic acid 11. Methyl (Z)-5,11,14,17-eicosatetraenoate 12. Methyl linoleate 13. Myristic acid 14. n-Hexadecanoic acid 15. n-Hexadecanyl linoleate 16. n-Hexadecanyl oleate 17. n-Pentacos-13′-enyl octadec-9-enoate 18. n-Pentacos-13'-enyl oleate 19. n-Pentadecanyl linoleate 20. n-Pentadecanyl octadec-9, 12-	Jin *et al.*, 2015 Sultana *et al.*, 2017 Singh and Sharma, 2015 Samra *et al.*, 2021 Sim *et al.*, 2016 Shin *et al.*, 2015

		dienoate 21. n-Pentadecanyl-9-octadecenoate 22. n-Tetradecanyl-n-octadec-9, 12-dienoate 23. Oleanolic acid 24. Oleic acid 25. Palmitic acid 26. Pinellic acid 27. Stearic acid 28. Tetradecanyl linoleate	
26.	Amides and other nitrogenous constituents	1. 6,7-Dihydro-2,3-dimethyl-5-cyclopentapyrazine 2. Adenosine 3. Aristolochic acid 4. Caprolactam 5. Cerebroside 6. Guineensine 7. Octopamine 8. Pellitorine 9. Sarmentine 10. Uridine	Xu *et al*., 2016 Smith, 1977 Cantalejo, 1997 Wu, 2009 Chen *et al*., 2017
27.	Miscellaneous compounds	1. 1(2)-Acetyl-3(5)-styryl-5(3)-methylthiopyrazole 2. 1-(3,4-Methylenedioxyphenyl)-1E-tetradecene 3. 1,4,4-Trimethyl bicyclo [3.2.0] hept-6-en-2-ol 4. 1-[2,3-Dihydro-6-hydroxy 4,7-dimethoxy-2S-(prop-1-en-2yl)benzofuran-5-yl] ethenone 5. 1-Isopropyl-2,7 dimethylnaphthalene 6. 2,4-Decadienal 7. 2-Furfural 8. 2S-Isopropenyl-4,8-dimethoxy-5-hydroxy-6-methyl-2,3-dihydrobenzo[1,2-b;5,4b’] difuran 9. 2S-Isopropenyl-4,8-dimethoxy-5-methyl-2,3-dihydrobenzo-[1,2-b;5,4b'] difuran 10. 3`, 4`-Nonadecanetriol 11. 3-Furfural 12. 4',6' Diacetyl-3,6-diferuloylsucrose 13. 4,7-Dimethyl-1-tetralone	Sonwa *et al.*, 2001 Ohira *et al.*, 1998 Gamal, 2015 Syed *et al.*, 2008 Thebtaranonth *et al.*, 1995 Smith,1977 Chen *et al.*, 2011 Sim *et al.*, 2016 Kamala *et al.*,2018 Luo *et al*., 2014

		14. 4-Hydroxy-4,7-dimethyl-1-tetralone 15. 5-Hydroxymethyl furfural 16. 6,7-Dihydro-2,3-dimethyl,5-cyclopentapyrazine 17. 6'-Acetyl-3,6-diferuloylsucrose 18. 7-Hydroxy-1,4α-dimethyl-7-(prop-1-en-2-yl),-4,4α,5,6,7,8-hexahydronaphthalen-2 (3H),-one 19. 8-Hydroxy-1, 4α-dimethyl- 7-(prop-1-en-2-yl),-4,4a,5,6,7,8-hexahydronaphthalen-2 (3H)-one 20. Ascorbic acid 21. Cyclohexane,1,1,2-trimethyl,3,5 bis-(1-methyl ethyl) 22. Cyclopentene-3-ethylidene-1-methyl 23. Ethyl acetate 24. Ethyl ethanoate 25. Ethyl-α-D-glucopyranoside 26. Glycerol 27. N-(1-Deoxy-D-fructos-1-yl)-L-tryptophan 28. Naphthalene 29. n-Butyl, β-D-fructopyranoside 30. n-Dodecanol 31. n-Dotriacontan-15-one 32. n-Dotriacontan-16-one 33. n-Tetracontan-7-one 34. n-Tricont-1-ol-21-one 35. n-Tritriacontan-16-one 36. o-Methylacetophenone 37. Tryptophan α-D fructofuranoside	

Phenolic derivatives in *C. rotundus*

The major class of non-volatilecompounds are phenolic derivatives (total 140 compounds), belonging to aurones (3), chromones (5), coumarins (3), quinanoids(2), iridoids (29), flavonoids (46), biflavonoids(5), stilbenoids (15), lignans (1), benzofurans (4), phenolic acids and derivatives (27) and phenolic derivatives (13). Phenolic compounds such as flavonoids are the key ingredients in natural products, purported to have several health benefits. However, most of the phenolic compounds are detectedthrough various LC-MS analyses, rather than conventional phytochemical analytical techniques. Out of the 40 flavonoid derivatives reported in *C. rotundus*, luteolin and derivatives, quercetin and derivatives, and myricetin glycosides are the major flavonoids (**Table 5, Figure 22**).

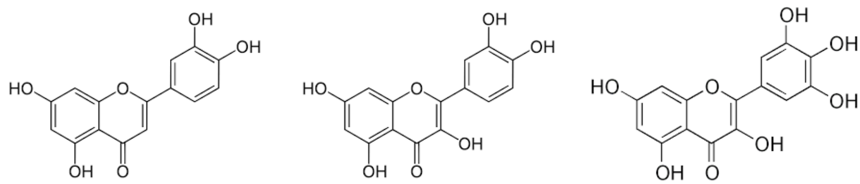

Figure 22. The common flavonoid skeletons in *Cyperus rotundus*- Luteolin, quercetin and myricetin

Biflavonoids

Biflavonoidsare characteristic class of phenolics with diverse biological activities and has significance in chemotaxonomy as well. Amentoflavone, bilobetin, Ginkgetin, isoginkgetinand sciadopitysin are the bioflavonoids reported from *Cyperus rotundus.* Amentoflavone, isolated from *C. rotundus* showed a significant inhibitory effect on uterine tumours in rats (**Figure 23**) (Ying and Bing, 2016). The mechanism of action has been suggested as elevating Bax protein expression, down-regulating Bcl-2 expression, forming homodimers Bax/Bax, and reducing plasmaestradiol and progesterone to promote apoptosis of uterine fibroid cells. Amentoflavone has previously been reported as bioactive constituent from several medicinal plants including *Ginkgo biloba, Biophytum sensitivum, Selaginella tamariscina* and *Hypericum perforatum.*

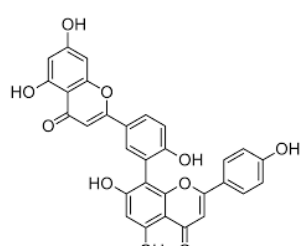

Figure 23. Amentoflavone, the bioactive biflavonoid in *Cyperus rotundus*

Stilbenes

Cyperaceae family is known for the presence of bioactive stilbenes, that possess cardioprotective, anticancer, anti-inflammatory, anti-obesity, chemopreventive, antioxidative and antimicrobial activities (Arraki *et al.*, 2017; Majeed *et al.*, 2022). Fifteen stilbenoidswere reported from *Cyperus rotundus* (**Table 5, Figure 24**). Ito *et al.* (2012) isolated enantiomeric and meso-stilbene trimers (+)- and (−)-(E)-cyperusphenol A, (E)-mesocyperusphenol A, a trimer bearing a novel hexacyclic ring system, cyperusphenol B, together with the known stilbenoids, cyperusphenol C, cyperusphenol D, trans-scirpusin A and scirpusin B from the rhizomes of *C. rotundus*. Tran *et al.* (2014) isolated the stilbene dimers cassigarol E, scirpusin A and B from *C. rotundus* rhizomes. Majeed *et al.* (2022) investigated the components in ethyl acetate extract of *Cyperus rotundus* rhizomes and reported piceatannol, scirpusin A and scirpusin B as the pharmacologically active molecules responsible for the antiobesity properties.

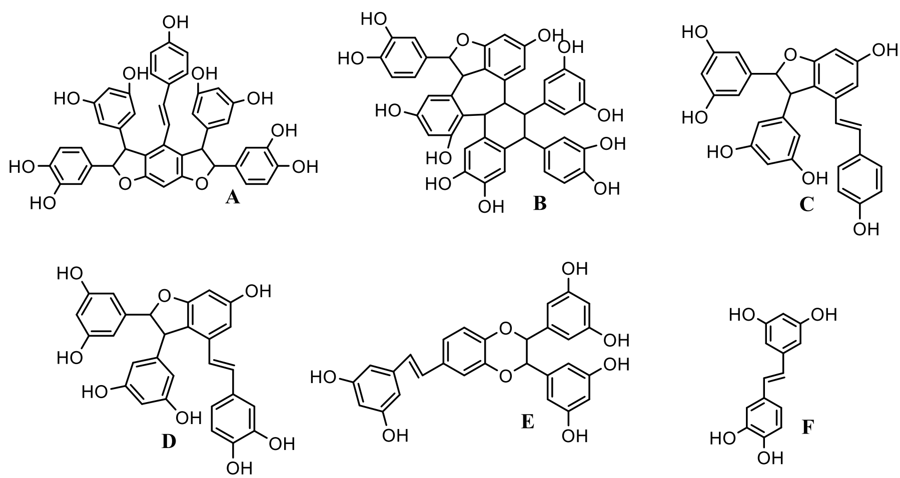

Figure 24. Major stilbenes reported from *Cyperus rotundus*; **A-** (E)-Cyperusphenol, **B-** Cyperusphenol B, **C-** Scirpusin A, **D-** Scirpusin B, **E-** Cassigarol E and **F-** Piceatannol

Iridoids

Iridoids are derivatives of monoterpenes and occur usually as glycosides, and provide a biogenetic and chemotaxonomic link between terpenes and alkaloids. Twentynine iridoids were reported from *Cyperus rotundus* (**Table 5, Figure 25**). The cleavage of the cyclopentane ring of iridoids produces secoiridoids. Iridoids have bitter taste and have antifeedant and growth inhibitory activities against insects, and have been regarded as defense chemicals against herbivores and pathogens. Iridoid glycosides exert inhibitory effects in numerous cancers. *C. rotundus* rhizome is reported to possess several iridoid glycosides (Zhou and Zhang, 2013; Gamal, 2015).

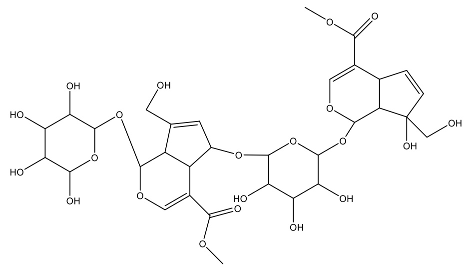

Figure 25. The iridoid glycoside rotunduside A reported from *Cyperus rotundus*

Triterpenoids and steroids

Triterpenoids and steroids are common secondary metabolites among plants, and around 33 terpenoids and 19 steroids were reported from *C. rotundus* (**Table 5, Figure 26**). The major triterpenoids are oleanolic acid and glycosides, amyrin and glycosides. Cycloartane terpenoid glycosides such as cyprotusides are characteristiccompounds reported from *C. rotundus* (Zhou *et al.,* 2016). Rotundusolide C is a triterpenoid with rare 9,10-seco-cycloartane skeleton, reported from *C. rotundus* (Yang and Shi, 2012; Lin *et al.*, 2018). β-Sitosterol and stigmasterol glycosides and esters are the major steroids reported from *C. rotundus* (Singh *et al.*, 2017).

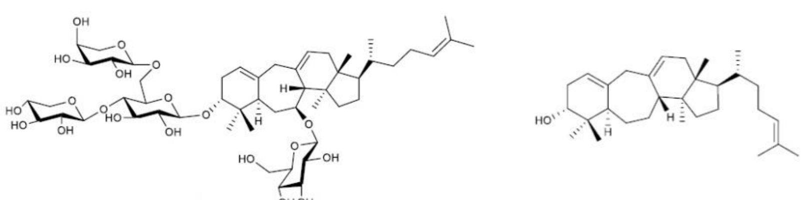

Figure 26. The cycloartane terpenoid glycoside cyprotuside A and the 9,10-seco-cycloartane triterpenoid rotundusolide C

Sesquiterpene alkaloids

Sesquiterpenes with nitrogen atom within the basic carbon skeleton of the sesquiterpenoid structure are reported from *Cyperus rotundus*. Three novel sesquiterpene alkaloids rotundines A, B, and C, with an unprecedented carbon skeleton of cyclopentane ring attached to the pyridine ring, were isolated from the methanol extract of *C. rotundus* (**Figure 27)** (Jeong *et al*., 2000).

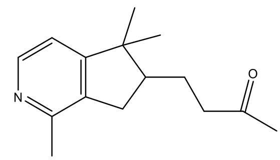

Figure 27. The sesquiterpene alkaloid rotundine A

Fatty acids

Table 5 shows 28 long chain aliphatic acids and derivatives reported from *Cyperus rotundus*. The fatty acids are generally identified through GC-MS method, after making the volatile Fatty Acid Methyl Esters (FAME). In addition to the common fatty acids, the species has been reported as source of characteristic fatty acids as well. Ceramides are a family of lipid molecules, composed of sphingosine and a fatty acid, and are found in the cell membrane (**Figure 28)**. The new ceramide, 2`-[2-hydroxypentacosanoylamino]-1`,3`,4`-nonadecanetriol reported from *Cyperus rotundus* has displayed inhibitory activity against HepG2 with IC_{50} value 6.81 to 8.075 µM, and PC3 with IC_{50} of 11.92 to 14.48 µM (Samra *et al*., 2021).

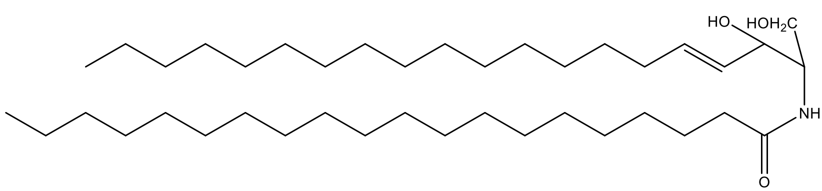

Figure 28. Ceramide derivative, a new cytotoxic lipid from *Cyperus rotundus*

Two unsaturated trihydroxy C_{18} fatty acids fulgidic acid and pinellic acid were isolated from *Cyperus rotundus* rhizomes, of which fulgidic acid possess anti-inflammatory activity (**Figure 29)** (Shin *et al*., 2015).

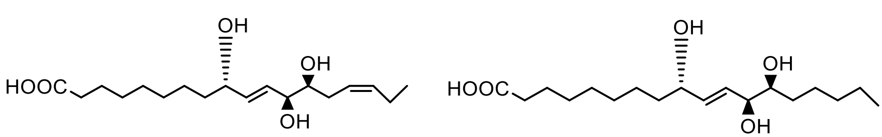

Figure 29. Fulgidic acid and pinellic acid reported from *Cyperus rotundus*

It is interesting to note that in Ayurveda, the rhizomes of *Cyperus rotundus* has been recommended as substitute for tubers of *Aconitum heterophyllum* (Family: Ranunculaceae), and *karpura* (*Cinnamomum camphora*), based on the concept of drug substitution (*Abhava Pratinidhi Dravya*). A comparative HPLC profile of *Aconitum heterophyllum* and *Cyperus rotundus* revealed the same pattern for HPLC peaks, however, there is scope for detailed phytochemical investigation using modern hyphenated analytical techniques such as LC-MS/MS and LC-MS/NMR (Venkatasubramanian *et al.*, 2010; Nagarajan *et al*., 2015).

Conclusion

Though the plant *Cyperus rotundus* is considered as a problematic weed all over the world, a review of the phytochemistry of the plant suggested the species as a store house of exiting structural features, with 294 non-volatile organic compounds, and 390 volatile organic compounds reported so far in the species. Though the phytochemistry of the species has been explored extensively, systematic studies are yet to be done to correlate the chemical diversity with phenology, genetics and ecology. Also, the seasonal, geographical and climatic effects need to be studied in detail in correlation with chemical diversity. More effective statistical approaches such as chemometry can also be employed in *Cyperus rotundus* metabolomics. Recently, ethno-botanical and traditional uses of natural compounds, especially of plant origin, received much attention as they are well tested for their efficacy and generally safe for human use, and *Cyperus rotundus* isone of the oldest herbs being used by mankind. Being a noxious weed widely distributed globally, *C. rotundus* rhizomes can be collected in huge quantity, and a systematic approach employing the recent developments in science and technology tools can yield value added herbal products from the weed.

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Chapter 8

Phytochemical Diversity in Cyperaceae Members

Abstract

The phytochemistry of Cyperaceae members is generally restricted to the most common member, *Cyperus rotundus,* while there are 5687 species reported globally. A review of the phytochemistry of other Cyperaceae members revealed that only 180 species have been studied, and among the various Cyperaceae groups, *Cyperus* (97species), *Carex* (53 species) and *Scirpus* (19 species) are the major genera studied for their phytochemicals. Out of the 274 Cyperaceae members reported from south India, only 39 species have been investigated for their phytochemicals, and many of them are preliminary screening only. GC-MS studies on essential oils and LC-MS studies on solvent extracts are the most explored, while conventional phytochemical studies through extraction, chromatographic separation and spectroscopic characterization are comparatively less. In addition to volatile sesquiterpnoids, phenolic compounds are reported in plenty in the Cyperaceae species. Presence of characteristic compounds such as stilbenes and quinones warrants further studies on Cyperaceae members.

Introduction

Traditionally, the phytochemical investigation of Cyperaceae members is restricted to the most widely used *Cyperus rotundus* and few related *Cyperus* species like *Cyperus scariosus,Cyperus conglomeratus*, *Cyperus esculentus*, *Cyperus distans*, *Cyperus articulatus* and *Cyperus longus,* which are being used in traditional medicinal systems in different parts of the world. Though several other Cyperaceae members are important region wise, they are least investigated with respect to their constitution or potential biological activities, and though the phytochemistry of *Cyperus rotundus* has been reviewed extensively, compilation of the phytochemistry of Cyperaceae members is rare (Taheri *et al.*, 2021).

The conventional analytical techniques, as well as the modern hyphenated analytical techniques have been used for the investigation of Cyperaceae phytochemistry. Harborne and team in their classical works employed traditional phytochemical techniques skilfully in elaborating the flavonoid profile of Cyperaceae members (Clifford and Harborne, 1969; Harborne, 1971; Harborne *et al.*, 1985). Noori *et al.* (2012) investigated the root flavonoids of 5 *Scirpus* species using 2-dimentional paper chromatography and thin layer chromatography. By employing the recent developments in phytochemical analytical techniques, Elshamy *et al.* (2020) performed a comprehensive metabolite profiling of *Cyperus conglomeratus* using UPLC-qTOF-MS, and 70 compounds including organic acids, phenolic acids, cinnamic acid derivatives, flavonoids, stilbenes, aurones, quinones, terpenes and steroids were identified by comparing retention times and MS data, through accurate mass, isotopic distribution, and fragmentation pattern in both negative and positive ionization modes. Though widely distributed with remarkable traditional uses, the Indian Cyperaceae plants are generally least investigated (Rajak and Ghosh, 2022).

Phytochemistry of Cyperaceae members can be broadly divided into proximate composition reporting mainly the primary metabolites, volatile composition and non-volatile composition. Proximate analysis is used to estimate the relative amounts of protein, lipid, water, ash, carbohydrate *etc* in any sample, and is the first and foremost step to determine the identity and to assess the quality of plant material. Most of the Cyperaceae members are aromatic and the volatile chemicals have significance, while the characteristic phenolic, terpene and nitrogenous compounds are of non-volatile, and extractable with organic solvents.

Proximate analysis of Cyperaceae members

Geophytes, plants with underground storage organs, are important forage for animals, and the proximate analysis of the arial parts of geophytes has relevance with respect to the nutritional aspects of the forage plants (Al-Rowaily *et al.*, 2019; Mashaly *et al.*, 2007). Cyperaceae plants that grow naturally in sandy habitats with low content of water has high dry matter content, usually around 90%. The less moisture content (generally less than 10%) makes them more stable for storage. The ash content is around 10% for *Cyperus capitatus*, while the crude fiber content is around 12% for *Cyperus conglomeratus*. The total protein content is considered as an indicator of the nutritional value and is relatively high (>10%) for Cyperaceae tubers. The dry matter of forage crops contains about 50-80% carbohydrates, and the energy level for *Cyperus capitatus* was 311.62 kcal 100 g^{-1}.

Although fats are a concentrated source of energy, for Cyperaceae forage the fat content is significantly less, around 3%. However, few species such as *Cyperus esculentus* are reputed as rich in fatty acids. *Cyperus esculentus* tubers, commonly known as Chufa tubers contain high amount of dietary fiberthat consists of insoluble carbohydrates, mainly cellulose and lignin. Chufa is potentially a commercial source of higholeic acid vegetable oil and highcarbohydrate tuber cakes. The proximate analyses reveal fats (30.2%), starch (35.0%), protein (12.0%), ash 1.2 %), dietary fibre (9.8%) and sucrose 11.8% in *Cyperus esculentus* tubers (Coşkuner *et al.,* 2002). Mineral composition of forage has essential physiological roles in animals, in maintaining the livestock health, and Cyperaceae forage is reported to have both macro (K, Ca, Mg, and Na) and micro elements (Fe, Mn, Zn, and Cu), and have comparatively higher contents of Na, Fe and Mn.

Comparative nutritional analysis of *Cyperus rotundus* and *Cyperus esculentus*

The nutritional analysis of Cyperaceae members needs much attention since several Cyperaceae species are used as food from ancient times onwards. Studies revealed that, among the various Cyperaceae members, *Cyperus rotundus* and *Cyperus esculentus* were highly nutritional**.** Musa *et al*. (2020) had done a comparative proximate analysis of *Cyperus rotundus* and *Cyperus esculentus. Cyperus rotundus* had a higher moisture content than *Cyperus esculentus* which could mean that the *Cyperus esculentus* variety can be stored longer than the *Cyperus rotundus*variety. Total ash content is a rough indicator of the mineral content of a food sample. *Cyperus rotundus* had higher ash content than *Cyperus esculentus* suggesting higher mineral content than *Cyperus esculentus*. The presence of zinc, copper, cobalt, calcium and phosphorus in both species suggest that regular consumption could help mitigate the diseases resulting from these mineral deficiencies. *Cyperus rotundus* and *Cyperus esculentus* consist of some trace elements also. Ekeanyanwu and Ononogbu (2010) reported that the lipid found in *Cyperus rotundus* and *Cyperus esculentus* is edible. Carbohydrate is abundant in both the species. The free carbohydrates D-saccharose, D-glucose, D-mannitol and D-fructose were determined in *Cyperus esculents*. The total content of fructans was determined by the spectrophotometric method at13.5% and in tubers the fructans content was 8.8% (Marchyshyn *et al*., 2021). Adejuyitan (2011) also reported relatively low protein content for both *Cyperus rotundus* and *Cyperus esculentus*. The low protein content suggests that although both the species have rich energy content and high satiety values, they cannot be used as complete or whole diet because of the low protein content.

Phytochemicals reported from Cyperaceae members

Literature review on the phytochemicals reported from Cyperaceae members revealed that out of the 5687 Cyperaceae members, only 180 species have been investigated for the constituents (**Table 1).** Out of the 274 Cyperaceae members reported from south India, only 39 species have been investigated for their phytochemicals, and many of them are preliminary screening only. Only the major components of the essential oils are included in the table. In addition to *Cyperus* (97 species), the major genera investigated for the phytochemicals are *Carex* (53 species) and *Scirpus* (19 species). Out of the 274 Cyperaceae members reported from south India, only 39 species have been investigated for their phytochemicals, of which *Cyperus* is the major genus with 31 species, followed by *Carex* (3 species), *Kyllinga* (3 species), *Rhynchospora* (1 species) and *Scleria* (1 species). Volatile chemical studies through GC-MS and LC-MS studies of solvent extracts are the most explored, while the number of species investigated through conventional phytochemical steps such extraction, chromatographic separation and spectroscopic characterization are much less.

Table 1. Phytochemicals reported from Cyperaceae members

Sl. No.	*Cyperaceae* species	Phytochemicals reported	Reference
1.	*Carex acuta*	Linoleic acid, α-linolenic acid, oleic acid, palmitic acid	Bogucka-Kocka and Janyszek, 2010
2.	*Carex acutiformis*	Tricin 5-glucoside, iso orientin	Harborne, 1971
3.	*Carex albicans*	Apigenin 7-glucoside, luteolin 7-xyloside, luteolin 7-methyl ether 4'-diglucoside, chrysoeriol 7-glucoside, chrysoeriol 7-xyloside, chrysoeriol 7,4'-diglucoside, chrysoeriol 7,4'-dixyloside, luteolin 7-methyl ether, iso-orientin	Rettig and Giannasi, 1990
	Carex albicans var. *emmonsii*	Apigenin 7-glucoside, luteolin 7-xyloside, luteolin 7-methyl ether	Rettig and Giannasi, 1990

		4'-diglucoside, chrysoeriol 7-glucoside, chrysoeriol 7-xyloside, chrysoeriol 7,4'-diglucoside, chrysoeriol 7,4'-dixyloside, luteolin 5-glycoside, luteolin 7-methyl ether, iso-orientin	
	Carex albicans var. *australis*	Apigenin 7-glucoside, luteolin 7-xyloside, chrysoeriol 7-glucoside, chrysoeriol 7-xyloside, chrysoeriol 7,4'-diglucoside, chrysoeriol7,4'-dixyloside, luteolin 7-methyl ether, luteolin 5-substituted aglycone, luteolin 7-methyl ether, iso-orientin	Rettig and Giannasi, 1990
4.	*Carex alopecuroides*	Catechin, caffeic acid, ferulic acid, biochanin A	Rajak and Ghosh, 2022
5.	*Carex appropinquata*	Linoleic acid, α-linolenic acid, oleic acid, palmitic acid	
6.	*Carex appressa* var. *virgata*	Piceatannol, ε-viniferin, virgatanol	Arraki *et al*., 2017
7.	*Carex arenaria*	Caffeic acid, p-coumaric acid, vanillic acid, synapic acid	Bogucka-Kocka *et al*., 2011
	Carex arenaria (Leaves)	Tricin	Van de Staaij *et al.* 2002
8.	*Carex baccans*	trans-Resveratrol, α-viniferin, smiglasid A, B	Kumar *et al*., 2013 Giri *et al*., 2015
		Phloroglucinol, caffeic acid, ferulic acid	Rajak and Ghosh, 2022
9.	*Carex buchananii*	Kobophenol A	Arraki *et al*., 2013
10.	*Carex capillacea*	Longusol B, (E)-miyabenol A	Arraki *et al*., 2013
11.	*Carex contigua*	Linoleic acid, α-linolenic acid, oleic acid, palmitic acid, stearic acid	Bogucka-Kocka and Janyszek, 2010
12.	*Carex cruciata*	Caffeic acid, rosmarinic acid	Rajak and Ghosh, 2022
13.	*Carex cuprina*	Carexinol A, kobophenol A	Arraki *et al*., 2017 Arraki *et al*., 2013
14.	*Carex curta*	Caffeic acid, p-coumaric acid, vanillic acid, ferulic acid	Bogucka-Kocka *et al*., 2011
15.	*Carex diandra*	Caffeic acid, p-coumaric acid, ferulic acid	Bogucka-Kocka *et al*., 2011
		Linoleic acid, α-linolenic acid, oleic acid, palmitic acid	Bogucka-Kocka and Janyszek, 2010
16.	*Carex dimorpholepis*	trans-Resveratrol	Lee *et al*., 2013 Buommino *et al*.,

			2017 Fiorentino *et al.*, 2008 D'Abrosca *et al.*, 2005 Fiorentino *et al.*, 2006
17.	*Carex distachya*	Carexane A-P, pallidol	Fiorentino *et al.*, 2008 Buommino *et al.*, 2017 D'Abrosca *et al.*, 2005 Fiorentino *et al.*, 2006
		Caffeic acid, p-coumaric acid	Bogucka-Kocka *et al.*, 2011
		Distachyasin	Fiorentino *et al.*, 2006
	Carex distachya (Leaves)	Feruloyl monoglyceride macrocycles, dibenzoxazepinones	Fiorentino *et al.*, 2007
		(+)-Pinoresinol 4-O-β-D-glucopyranoside, (+)-phylliroside, (+)-8-hydroxypinoresinol 4-Oβ-D-glucopyranoside, (+)-8-hydroxypinoresinol 8-O-β-D-glucopyranoside	Ricci *et al*., 2008
		5′-O-β-D-Glucopyranosyloxy-3,3′-dimethoxy-7,9′-epoxylignan-4,8′,9-triol, 3,5-bis-O-β-D-glucopyranosyloxy-3′-methoxy-trans-stilben-4′-ol, synapic alcohol 4-O-β-D-glucopyranoside, (+)-pinoresinol 4-O-β-D-glucopyranoside, phylliroside, (+)-1-hydroxy pinoresinol 4′-O-β-D-glucopyranoside, tanegosides A, 3-(4-O-β-D-glucopyranosyloxy-3,5-dimethoxy) phenyl-2E-propenol, phenylethanoid glycosides, decaffeoylverbascoside, isoverbascoside, verbascoside,	Fiorentino *et al.*, 2008

		teucrioside, pallidoldiglucoside, 10-hydroxyligustroside, tricin, tricin 4’-O-(erythro-β-guaiacylglyceryl)ether, apigenin-6-C-β-D-xylopyranosyl-8-C-β-D-glucopyranoside, apigenin-6-C-β-D-glucopyranosyl-8-C-β-D-xylopyranoside, luteolin-6-β-D-glucopyranosyl-8-C-β-D-xylopyranoside	
		13-Hydroxy-clerodane-7,4-diene, 15-hydroxy-clerodane-7,13-diene	Fiorentino *et al.*, 2010
18.	*Carex divulsa*	Caffeic acid, p-coumaric acid, vanillic acid, ferulic acid	Bogucka-Kocka *et al.*, 2011
19.	*Carex elata*	Caffeic acid, p-coumaric acid, synapic acid	Bogucka-Kocka *et al.*, 2011
		Linoleic acid, α-linolenic acid, oleic acid, palmitic acid	Bogucka-Kocka and Janyszek, 2010
20.	*Carex fedia* var. *miyabei*	ε-Viniferin, trans-miyabenol C, (E)-miyabenol A, miyabenol B	Suzuki *et al.*, 1987
21.	*Carex flava*	Linoleic acid, oleic acid, palmitic acid, stearic acid	Bogucka-Kocka and Janyszek, 2010
22.	*Carex floridana*	Chrysoeriol 7-glucoside, chrysoeriol 7,4'-diglucoside, chrysoeriol 7,4'-dixyloside, tricin 7-xyloside, luteolin 5-glycoside, luteolin 7-methyl ether, iso-orientin	Rettig and Giannasi, 1990
23.	*Carex folliculata*	Pallidol, kobophenol A, iso-orientin, luteolin, quercetin, 3-O-methylquercetin, rutin	González-Sarrías *et al.*, 2011 Li *et al.*, 2009
24.	*Carex glauca*	Pallidol, α-viniferin, cis-miyabenol C	Arraki *et al.*, 2013 Fiorentino *et al.*, 2008
25.	*Carex gynandra*	Pallidol, α-viniferin, trans-miyabenol C, kobophenol B	González-Sarrías *et al.*, 2011
26.	*Carex hirta*	(E)-Miyabenol A	Arraki *et al.*, 2013
27.	*Carex humilis*	α-Viniferin	Lee *et al.*, 1998 Seo *et al.*, 2017
28.	*Carex insignis*	Phloroglucinol, quercetin, phloroglucinol	Rajak and Ghosh, 2022
29.	*Carex kobomugi*	ε-Viniferin, trans-miyabenol C, kobophenol A	Kawabata *et al.*, 1989 Kurihara *et al.*, 1991

30.	*Carex leporina*	Linoleic acid, α-linolenic acid, oleic acid, palmitic acid, stearic acid	Bogucka-Kocka and Janyszek, 2010
31.	*Carex montana*	Caffeic acid, p-coumaric acid	Bogucka-Kocka *et al.*, 2011
32.	*Carex muricata*	Caffeic acid, p-coumaric acid, vanillic acid	Bogucka-Kocka *et al.*, 2011
33.	*Carex nigra*	Caffeic acid, p-coumaric acid, vanillic acid, ferulic acid	Bogucka-Kocka *et al.*, 2011
		Linoleic acid, α-linolenic acid, oleic acid, palmitic acid, stearic acid	Bogucka-Kocka and Janyszek, 2010
34.	*Carex nigromarginata*	Apigenin 7-glucoside, luteolin 7-xyloside, chrysoeriol 7-glucoside, chrysoeriol 7-xyloside, chrysoeriol 7,4'-diglucoside, chrysoeriol 7,4'-dixyloside, tricin 7-xyloside, luteolin 5-glycoside, iso orientin, luteolin C-glycoside	Rettig and Giannasi, 1990
35.	*Carex ornithopoda*	Caffeic acid, p-coumaric acid	Bogucka-Kocka *et al.*, 2011
36.	*Carex otrubae*	Caffeic acid, p-coumaric acid, vanillic acid	Bogucka-Kocka *et al.*, 2011
		Linoleic acid, α-linolenic acid, oleic acid, palmitic acid	Bogucka-Kocka and Janyszek, 2010
37.	*Carex ovalis*	Caffeic acid, p-coumaric acid, synapic acid, ferulic acid	Bogucka-Kocka *et al.*, 2011
38.	*Carex panicea*	Caffeic acid, ferulic acid	Bogucka-Kocka *et al.*, 2011
39.	*Carex paniculata*	Linoleic acid, α-linolenic acid, oleic acid, palmitic acid	Bogucka-Kocka and Janyszek, 2010
40.	*Carex peckii*	Luteolin 7-xyloside, chrysoeriol 7-glucoside, chrysoeriol 7-xyloside, luteolin 7-methyl ether, iso-orientin, luteolin C-glycoside	Rettig and Giannasi, 1990
41.	*Carex pendula*	cis-Miyabenol C, (E)-miyabenol A, kobophenol B	Meng *et al.*, 2001 Kurihara *et al.*, 1990 Kawabata *et al.*, 1991 Cho *et al.*, 2013
42.	*Carex praecox*	Vannilin, benzaldehyde, p-cresol, dehydrovomifoliol	David *et al*., 2021
43.	*Carex pseudocyperus*	Linoleic acid, oleic acid, palmitic acid	Bogucka-Kocka and Janyszek, 2010

44.	*Carex pumila*	Trans-Resveratrol, ε-viniferin, trans-miyabenol C, kobophenol B, (E)-miyabenol A	Kurihara *et al.*,1990 Cho *et al.*, 2013 Kawabata *et al.*, 1991
45.	*Carex remota*	Ferulic acid, rosmarinic acid	Rajak and Ghosh, 2022
		Caffeic acid, p-coumaric acid	Bogucka-Kocka *et al.*, 2011
46.	*Carex riparia*	Tricin 5-glucoside, iso-orientin	Harborne, 1971
47.	*Carex rostrata*	Caffeic acid, p-coumaric acid, vanillic acid	Bogucka-Kocka *et al.*, 2011
		Linoleic acid, oleic acid, palmitic acid	Bogucka-Kocka and Janyszek, 2010
48.	*Carex stramentitia*	Gallic acid, catechin, rosmarinic acid, quercetin	Rajak and Ghosh, 2022
49.	*Carex strigose*	Caffeic acid, p-coumaric acid	Bogucka-Kocka *et al.*, 2011
50.	*Carex sylvatica*	Caffeic acid, p-coumaric acid, vanillic acid, protocatechuic acid	Bogucka-Kocka *et al.*, 2011
51.	*Carex teres*	Gallic acid, phloroglucinol, quercetin	Rajak and Ghosh, 2022
52.	*Carex vulpina*	Caffeic acid, p-coumaric acid	Bogucka-Kocka *et al.*, 2011
		Linoleic acid, α-linolenic acid, oleic acid, palmitic acid, stearic acid	Bogucka-Kocka and Janyszek, 2010
53.	*Carex vulpinoidea*	Vulpinoideol A, vulpinoideol B, hopeaphenol, α-hydroxychalcone, grandiphenol A, 3,5,5′,7′-tetrahydroxyflavone, benzofuran, butein, luteolin, bavachalcone	Niesen *et al.*, 2011
54.	*Carpha glomerata*	Carphaben	Cho *et al.*, 2018
55.	*Cymophyllus fraseri* (Leaves)	Swertisin, iso-orientin, swertiajaponin, isovitexin, luteolin 7-O-glycoside, tricin 7-O-glucoside, apigenin 7-O-xylosylglucoside, luteolin 7-O-rutinoside, tricin 7-O-diglucoside, apigenin 7-O-glucoside, tricin 7-methyl ether 4'-O-glucoside, vicenin 1, vicenin 2, luteolin 7-O-diglucoside, luteolin 7,4'-O-diglucoside, 6-C-glycosyl apigenin, C-glycosyl luteolin,	Robert and James, 1988

		luteolin 7-methyl ether-O-glucoside	
	Cymophyllus fraseri (Flowers)	Luteolin 7-O-glucoside, apigenin 7-O-diglucoside, apigenin 7-O-glucoside, apigenin, luteolin, tricin, tricin 7-O-glucoside, iso-vitexin	Robert and James, 1988
56.	*Cyperus alopecuroides*	Caryophellene oxide, α-cyperone, 1,8-cineole, β-pinene, trans-pinocarveol, α-copaene, caryophyllene, α-humulene	El-Gohary, 2004
		α-Cubebene, trans-calamenene, δ-cadinene, iso-cyperol, trans-calamenene, β-caryophyllene, α-copaene, eudesma-2-4-11-triene, eudesma-3-11-dien-2-one, imperatorin	Sonwa and Konig, 2001
		2,4,11-Eudesmatriene, 3,5,11-eudesmatriene, cyperene, 2,4-patchouladiene, rotundene, cyprenal, cyprotene, cypera-2,4-diene, δ-cadinene, epoxy cyperene	Sonwa and Konig, 1997 Guenther, 1952 Hikino and Aota, 1976
		Luteolin 5-methyl ether, luteolin 7-glucoside, luteolin 7-diglucoside, tricin 5-glucoside, tricin 7-glucoside, sulphuretin, quercetin 3,4´-dimethyl ether	El- Habashi *et al*., 1989
		Luteolin 4´-methyl ether, vicenin 2, quercetin 3,3’-dimethyl ether, rengasin, kaempferol 3-O-β-D-(glucosylrutinoside), kaempferol 3-O-β-D-(xylosylrutinoside)	Sayed *et al*., 2006
		Orientin	Singh *et al*., 1986
		Imperatorin, bergapten, xanthotoxin, xanthotoxol, iso-scopoletin, esculetin	Awaad, 1999
		Dihydro cyperaquinone	Allan *et al*., 1978
		Aesculetin, bergapten	Awaad *et al*., 2001
		Alopecuquinone, diosmetin, dolabella-3-7-18-triene, orientin, patchoula-2-4-diene, quercetin 3,3'-dimethyl ether, diosmetin	Nassar *et al*., 2002
		Quercetin-3-rutinoside	El-Habashy *et al*.,1989

		α-Cyperone, cyperol	El-Gohary, 2004
		Dolabella-3,7,18-triene, α-pinene, β-selinene, benzaldehyde, p-cymene, limonene, 1,8-cineole, p-cymenene, α-terpineol, myrtenal, myrtenol, trans-carveol, isocitronellol, carvone, trans-caryophyllene, patchoulane	Sonwa *et al.*, 2001
57.	*Cyperus alternifolius*	Esculetin, umbelliferon, imperatorin, xanthotoxin, psoralen, quercetin, quercetin-3-O-rutinoside, gallic acid	Amani *et al.*, 2018
		6-Octadecenoic acid, 1-dodecanol, hexadecanoic acid, octadecanoic acid, 2,3-dihydroxypropyl ester, 9,12-octadecadienoic acid, 2,6-dihexadecanoate, 2-methyl-Z-4-tetradecene, hexadecyl neopentyl ester, 2-pentadecanone, campesterol, stigmasterol, γ-sitosterol, phytol, squalene, 6,10,14- trimethyl, 9,19-cyclolanost-24-en-3-ol, (3β)-2H-1-benzopyran-6-ol, 3,4-dihydro-2,8-dimethyl-2-(4,8,12-trimethyltridecyl), [2R-[2,α-tocopherol-β-D-mannoside,(Z)-,4,8,12,16-tetramethylheptadecan4-olide, 2-hydroxy-1-(hydroxymethyl)ethyl ester, (+)-ascorbic acid, sucrose	Taiba *et al.*, 2022
		Dimethyl cyperaquinone, dihydro cyperaquinone, tetrahydro cyperaquinone	Allan *et al.*, 1978
		Luteolin 5-methyl ether	Harbone *et al.*, 1982
		Luteolin 7-glucuronide	El-Habashy *et al.*, 1989
		Caryophyllene, caryophyllene oxide, farnesyl acetone	Elshrif *et al.*, 2017
	Cyperus alternifolius (Aerial part)	D-limonene, γ-terpinene, theaspirane A-B	Elshrif *et al.*, 2017
	Cyperus alternifolius	α-Cyperone, β-selinene, caryophyllene oxide, cyperene	Ahmed, 2012

	(Flower)		
58.	*Cyperus aquatilis*	Quercetin, luteolin 5-methyl ether	Harborne *et al.*, 1982
59.	*Cyperus arenarius*	Cyperene, cyperotundone	Feizbakhsh *et al.*, 2012
60.	*Cyperus aristatus*	Cyperaquinone, dimethyl cyperaquinone	Allan *et al.*,1978
61.	*Cyperus articulatus*	Corymbolol, α-corymbolone, mandassidione, patchoul-4(5)-en-3-one	Nyasse *et al.*, 1988
		Myrtenol, myrtenal, trans-pinocarveol	Bakaly, 2001
		Cyperotundone, 1,2-dehydro-α-cyperone,sesquichamaenol,mustakone	Brillatz *et al*., 2020
		Myrtenal, myrtenol, copaene, articulone	Couchman *et al.*, 1964
		Mandassidione, mustakone, isopatchoul-4(5) en-3-one	Nyasse, 1988
		α-Campholenal, α-corymbolol, α-cyperone, α-pinene, cyperol, cyclocolorenone, β-copaen-4-α-ol, p-cymene, caryophyllene oxide, corybolane, mustakone, cyperotundone, limonene, thuja-2,4(10)-diene, trans-pinocarveol, p-mentha-1,5-dien-8-ol, myrtenal, mustakone	Dikwa *et al*., 2019 Silva *et al*., 2019
		α-Thujene, α-pinene, camphene, sabinene, β-pinene, p-cymene, limonene, m-cymene, eucalyptol	Heba *et al*., 2014
		Luteolin 5-methyl ether	Harborne *et al.*, 1982
		Luteolin 7-glucoside, luteolin 7-rutinoside	El-Habashy *et al.*, 1989
		Copa-3-en-2α-ol, caryophyllene oxide, humulene epoxide-II, mustakone, kobusone, cyperotundone, humulene dioxide, (-)-guaia-1(10),11-dien-9-one, muurolane-2β,9β-diol-3-ene, corymbolone, p-hydroxybenzoic acid, trans-p-hydroxycinnamic acid, 2*R*/2*S* dihydroluteolin, 4R/4S-4-	Mittas *et al.*, 2022

		hydroxy-1,10-seco-muurol-5-ene-1,10-dione, trans-sobrerol, piceatannol, trans-scirpusin B, cyperusphenol B	
		Pinene, eucalyptol, myrtenol, copaene, cyperene, caryophyllene, patchoulene, caryophyllene oxide	Heba *et al*., 2014
		α-Campholenal, α-corymbolol, α-cyperone, α-pinene, cyperol, cyclocolorenone, β-copaen-4-α-ol, p-cymene, caryophyllene oxide, corybolane, cyperotundone, limonene, thuja-2,4(10)-diene, trans-pinocarveol, p-mentha-1,5-dien-8-ol, myrtenal, mustakone	Silva *et al*., 2019
	Cyperus articulates var. *articulates*	Mustakone, caryophyllene oxide	Zoghbi *et al*., 2006
	Cyperus articulates var. *nodosus*	Mustakone, caryophyllene oxide	Zoghbi *et al*., 2006
	Cyperus articulates Red type	Cyperotundone, piperitone, β-maaliene, germacrone	Nureni *et al*., 2006
	Cyperus articulates Black type	Cedrol, guaia-5-en-11-ol, cyperotundone	Nureni *et al*., 2006
62.	*Cyperus asiatica*	Asiatic acid	
63.	*Cyperus baoulensis*	Cyperotundone	Hikino *et al*., 1976
64.	*Cyperus bowmanii*	Apigenin, tricin, luteolin	Harborne *et al*.,1982
65.	*Cyperus brevibracteatus*	Breverin, breviquinone, hydroxy breviquinone	Allan *et al*.,1973
66.	*Cyperus brevifolius*	Quercetin, tricin	Harborne *et al*., 1982
		α-Cyperone, β-selinene, α-humulene	Komai *et al*., 1989
67.	*Cyperus bulbosus*	δ-Cadinene, calamenene, β-caryophyllene, α-copaene, cyperene, α-cyperone, β-elemene, cyperotundone, humulene oxide, α-humulene, luteolin, apigenin, patchoulenol acetate, β-selinene, sugeonol acetate	Harborne *et al*., 1982
		Luteolin 7-glucuronide, luteolin 7-diglucoside, tricin 7-diglucoside	El-Habashy *et al*., 1989
		Caryophyllene oxide, humulene oxide	Komai *et al*., 1994

68.	*Cyperus capitatus*	Aureusidin	Seabra *et al*., 1995
		4,6,3′,4′-Tetrahydroxy-5-methylaurone, 4,6,3′,4′-tetrahydroxy-7-methylaurone, 6,3′,4′-trihydroxy-4-methoxy-5-methylaurone, 6,3`-dihydroxy-4,4`-dimethoxy-5-methylaurone	Seabra *et al*., 1998
		Capiquinone A-K	Alves *et al*., 1992
		Flavan,3'-5-dihydroxy-4'-6-dimethoxy	Mogib *et al*., 2001
		Oleanolic acid, β-sitosterol, tocopherol	
		Cyprene, cyperotundone	El Gendy *et al*., 2017
		Sulphuretin	El-Habashy *et al*., 1989
		3,5, 3´,4´-Tetramethoxy stilbene	Abdel-Razik *et al*., 2005
69.	*Cyperus castaneus*	Apigenin	Harborne *et al*., 1982
70.	*Cyperus clarke*	Quercetin 3-methyl ether, kaempferol 3-methyl ether	Harborne *et al*., 1982
71.	*Cyperus compressus*	Apigenin, luteolin, luteolin-5-methyl ether, tricin	Harborne *et al*., 1982
		Cyperaquinone	Allan *et al*., 1978
		Vannilic acid, ferulic acid, rutin, myricetin, quercetin, apigenin	Datta *et al*., 2018
		Luteolin 7-glucuronide	El-Habashy *et al*., 1989
72.	*Cyperus congestus*	Aureusidin, cyanidin, luteolin, tricin	Harborne *et al*.,1985
73.	*Cyperus conglomerates*	Luteolin, luteolin 7-methyl ether, luteolin 7-glucuronide, 7,3'-dihydroxy-5,5'-dimethoxy-8-prenylflavan, 5,7,3'-trihydroxy-5'-methoxy-8-prenylflavan, 5-hydroxy-7,3',5'-trimethoxyflavan, 5,7-dihydroxy-3',5'-dimethoxy-6-prenylflavan, 2-prenyl-3,4'-dihydroxy-5-methoxystilbene, 5,7,4'-trimethoxy-6-prenylflavanan, 4-hydroxyallylbenzene, 3-ethoxy-4-hydroxyallylbenzene	Abdel-Razik *et al*., 2005 Nassar *et al*., 2005 Basaif, 2003 Abdel-Mogib *et al*., 2001 Nassar *et al*., 1998 El-Habashy *et al*., 1989
		Eugenol, α-cyperone,	Hisham *et al*., 2012

		cyperotundone	
		7,3′-Dihydroxy-8,4′-dimethoxy flavan, 7,4′-dihydroxy-5,3′-dimethoxy-8-methyl flavan, 7,4′-dihydroxy-5,3′-dimethoxy-8-prenyl flavan, 4-hydroxy-5′-methoxy-6″,6″-dimethylpyran [2″,3″: 3′, 2′] stilbene, 4′-hydroxy-3,5-dimethoxy-2-prenyl stilbene, 5,4′-dihydroxy-7,3′-dimethoxy flavan, 3′,4′-dimethoxy luteolin, 3′,4-dihydroxy-5′-methoxy-2′-prenyl stilbene, 4,4′-dihydroxy-3,3′-dimethoxy-2′-prenyl stilbene	Ahmed *et al*., 2018
		Palmitic acid, oleic acid, heptadecanoic acid, linoleic acid, arachidonic acid, lignoceric acid, stearic acid, myristic acid, α-amyrin, β-sitosterol	Ghaferah *et al*., 2018
		Quinic acid, malic acid, tetrahydroxypentanoic acid, citric acid, isocitric acid, malic acid, fumaric acid, leucine-hexose, homocitric acid, dihydroxybenzoic acid, dihydroxybenzoic acid methyl ester, dihydroxy benzoic acid-O-hexoside, hexahydroxyflavan, dihydroxy benzoic acid methyl ester hexoside, O-hexosyl-O-methyl-myo-inositol-dihydroxy benzoic acid, salicylic acid, p-hydroxybenzoyl tartaric acid, benzoyl tartaric acid, procyanidin B dimer, hexahydroxyflavan, C-hexosylprocyanidin B dimer, epi-catechin, caffeic acid, hydroxymethoxy cinnamaldehyde, O-caffeoylquinic acid, O-syringoylquinic acid, caffeoquinone, procyanidin B dimer, syringoylmalic acid, syringic acid, dihydroxyhomophthalic acid	Elshamy *et al*., 2020

		dimethyl ester, hydroxycinnamic acid, epi-catechin, eriodictyol, scopoletin, hydroxydimethoxy cinnamic acid, erulic acid, dihydrocyperaquinone, caffeoquinone isomer, trihydroxycoumestan, trihydroxyflavanone, tetrahydroxyflavanone, longusol C, hydroxymethoxycoumarin, trihydroxycinnamic acid dimethyl ether, luteolin, dimethoxy luteolin, hesperitin, tetrahydroxyflavanone, tetrahydroxymethyl aurone, trihydroxyflavanone, hydroxymethoxycinnamaldehyde, trihydroxyoctadecadienoic acid, trihydroxymethoxy methyl aurone, trihydroxyoctadecenoic acid, tetrahydroxymethyl aurone isomer, trihydroxymethoxyprenyl isoflavone, tetrahydroxyflavanone methyl ether, trihydroxy-prenylflavan, trihydroxymethoxyprenylflavan	
		β-Elemene, flavan,3'-5'-dihydroxy-6-7-dimethoxy-4'-prenyl	Mogib *et al*., 2000
		4'-5-7-Trimethoxy-6-prenyl flavanan	Nassar *et al*., 1998
		Luteolin 5-methyl ether, luteolin 7-glucuronide, tricin 7-glucuronide	El-Habashy *et al*., 1989
		7,3'-Dihydroxy-5,5'-dimethoxy-8-prenylflavan, 5,7,3'-trihydroxy-5'-methoxy-8-prenylflavan	Razik *et al*., 2005
		α-Amyrin, β-sitosterol, palmitic acid, oleic acid, heptadecanoic acid, linoleic acid, arachidonic acid, lignoceric acid, stearic acid, myristic acid	Al-Hazmi *et al*., 2018
		5-Hydroxy-7,3',5'-trimethoxyflavan,7-dihydroxy-3',5'-dimethoxy-6-prenylflavan	Mogib *et al*., 2000

74.	*Cyperus conicus*	Conicaquinone, hydroxy cyperaquinone	Allan *et al.*, 1978
75.	*Cyperus corymbosus*	Corymbolone, iso-corymbolone, α-cyperone	Garbarino *et al.*, 1985
76.	*Cyperus cunninghamii*	Jaranol, isokaempferide, quercetin 3-methyl ether, kaempferol 3-methyl ether, kaempferol 3,7-dimethylether	Harborne *et al.*, 1982
77.	*Cyperus cuspidatus*	Apigenin, luteolin	Harbone *et al.*, 1982
78.	*Cyperus cyperoides*	Hydroxy cyperaquinone	Allen *et al.*, 1978
79.	*Cyperus cyperinus*	Luteolin 5-methyl ether	Harbone *et al.*, 1982
80.	*Cyperus dactylotes*	Quercetin 3-methyl ether, quercetin 3,7-dimethyl ether	Allen *et al.*, 1978
		Kaempferol 3-methyl ether, kaempferol 3,7-dimethylether	Harborne *et al.*, 1982
81.	*Cyperus decompositus*	Cyperaquinone, hydroxy cyperaquinone	Allen *et al.*, 1978
82.	*Cyperus dietricheae* var. *brevibracteatus*	Breviquinone, hydroxy breviquinone	Allen *et al.*, 1978
83.	*Cyperus difformis*	α-Cadinol, β-caryophyllene, cyperotundone, α-humulene	Iwamura *et al.*, 1979
		Cyperene, cyperotundone, isorotundene	Feizbakhsh *et al.*, 2012.
		3,7,11,15 Tetramethyl-2-hexadecen-1-ol, phytol, 2-furancarboxaldehyde,5-(hydroxymethyl), acetic acid, 2-(2,2,6-trimethyl-7- oxa-bicyclo[4.1.0]hept-1-yl)- propenyl ester, α-tocopherol-β-D-mannoside, phenol, 2,3,5,6-tetramethyl-)- 7, cholestan-3-one, 4,4-dimethyl-(5α)-, γ-sitosterol, ascorbic acid 2,6-dihexadecanoate, butyl 9,12,15-octadecatrienoate, hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester, octadecanoic acid, 2,3-dihydroxypropyl ester, 9,12-octadecadienoic acid (Z,Z)-, butanamide, N-(4-methoxyphenyl)-, hydrazinecarboxamide, 2-(2-	Taiba *et al.*, 2022

		methylcyclohexylidene, dichloroacetic acid, tridec-2-ynyl ester, 3-acetoxy-3-hydroxypropionic acid, methyl ester, norvaline, n-methoxycarbonylbutyl ester	
		Luteolin 7-glucuronide, luteolin 7-diglucoside, tricin 5-glucoside	El-Habashy *et al*., 1989
		Cyprene, cyperotundone	El Gendy *et al*., 2017
84.	*Cyperus digitatus*	Luteolin 7-glucuronide, tricin 5-glucoside, tricin 7-diglucoside	El-Habashy *et al*., 1989
85.	*Cyperus disjunctus*	Luteolin 5-methyl ether	Harbone *et al*., 1982
86.	*Cyperus distans*	Cyperene, α-pinene, 1,8-cineole, caryophyllene oxide	Oladipupo and Adebola, 2009
		α-Cyperone, cyperotundone, scabequinone	Vilhena *et al*., 2014
		Zierone, caryophyllene oxide, α-cyperone	Lawal *et al*., 2016
		Scabequinol, dihydro scabequinone	Allan *et al*., 1973
		Cyperene, α-pinene, 1,8-cineole, caryophyllene oxide	Lawal and Oyedeji, 2009
		Zierone, caryophyllene oxide, α-cyperone	Oladipupo *et al*., 2009
		Scabequinone	Morimoto *et al*., 1999
87.	*Cyperus dubius*	1,4,8-Cycloundecatriene, 2,6,6,9-tetramethyl-, (E,E,E), 6-(1-hydroxy-1-methylethyl)-3-methyl-2-cyclohexen-1-yl acetate, guanosine, 1,3,4,5-tetrahydroxy-cyclohexanecarboxylic acid,1-octadecyne, hexahydrofarnesyl acetone, naphthalene, 1,2,3,5,6,7,8,8α-octahydro-1,8α-dimethyl-7-(1-methylethenyl)-, [1R- (1-α,7-β,8-α, 9-eicosyne, 5,9,13-pentadecatrien-2-one, 6,10,14-trimethyl-, (E,E)-, hexadecanoic acid, methyl ester, phenanthrene, 7-ethenyl-1,2,3,4,4a,4b,5,6,7,9,10,10a-dodecahydro-1,1,4a,7-	Srinivasan and Priya, 2015

		tetramethyl-, [4as-(4a.alpha.,4b.beta.,7.beta.,10a.beta, 9-octadecenoic acid (Z)-, cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1s-(1.alpha.,2.beta.,4.beta.)]-, 2-methyl-2-[2-(2,6,6-trimethyl-3-methylene-cyclohex-1-enyl)-vinyl]-[1,3]dioxolane, 2-hexadecen-1-ol, 3,7,11,15-tetramethyl-, 9,12-octadecadienoic acid (Z,Z)-, *cis*-vaccenic acid, pentadecanal, 2,5-dimethoxybenzylamine, squalene, olivetol, dimethyl ether, γ-tocopherol, 9,19-cycloergost-24(28)-en-3-ol, 4,14-dimethyl-, acetate, (3-β,4-α,5- α)- 2h-1-benzopyran-6-ol, 3,4-dihydro-2,5,7,8-tetramethyl-2-(4,8,12-trimethyltridecyl)-, acetate, [2R-[2R*(4R*,8R*)]]-, 4-formyl-2-methoxyphenyl acetate, ergost-5-en-3-ol, (3β)-, stigmasterol, stigmast-5-en-3-ol, 2-methylpyrazine, 2,6-dimethylpyrazine, 2-ethylpyrazine, 2,3-dimethylpyrazine, 2-ethyl-6-methylpyrazine, 2-ethyl-5-methylpyrazine, 2,3,5-trimethylpyrazine, 2-ethyl-3,5-dimethylpyrazine, tetramethylpyrazine, 2-ethyl-3,5,6-trimethylpyrazine, 2-pentylpyridine, quinoline, 2-acetyl-pyrrole, guaipyridine, guai-9,11-dienpyridine, epi-guaipyridine, methyl anthranilate, 2-phenylpyridine, cananodine	
88.	*Cyperus enervis*	Apigenin	Harborne *et al.*, 1982
89.	*Cyperus eleusinoides*	Scabiquinone	Allan *et al.*, 1978
90.	*Cyperus eragrostis*	Scirpusin B, cyperusphenol B	Arraki *et al.*, 2017
		Cyperaquinone, hydroxy cyperaquinone	Allen *et al.*, 1978

91.	*Cyperus esculentus*	α-Thujene, α-pinene, camphene, sabinene, β-pinene, myrcene, o-cymene, p-cymene, limonene, m-cymene, eucalyptol	Heba *et al*., 2014
		β-Pinene, cymene, cyperene, coumaran, cyperotundone, p-vinylguaiacol, vanillin, cyprotundone	Gugsa and Yaya, 2018
		Luteolin 7-glucuronide	El-Habashy *et al*., 1989
		Luteolin 7-glucoside, luteolin 7-diglucoside	El-Habashy *et al*., 1989
		2-O-Galloyl-1,4-galactarolactone, scopoletin, imbricantonol, p-hydroxybenzoic acid, L-leucic acid, vanillic acid, ethyl vanillin, 4-vinylphenol, ferulic acid, p-coumaric acid, 3-hydroxyphloretin 20-O-glucoside, kaempferol 3,7-diglucoside, sophoraflavonoloside, luteolin-7,30-di-O-glucoside, dehydrodivanillin, veronicafolin 3-glucosyl-(1-3)-galactoside, sinensetin, sinapyl alcohol, p-coumaric acid ethyl ester, cyanidin, benzoic acid, dihydroxy stearic acid, hydroxy palmitic acid, hydroxy stearic acid, linolenic acid, myristic acid, palmitoleic acid, linoleic acid, methylpalmitic acid, palmitic acid, oleic acid, heptadecanoic acid, stearic acid	Diaz *et al*., 2022
		4-Hydroxybenzaldehyde, p-coumaric acid, ferulic acid, sinapinic acid, cinnamic acid, luteoline, naringenin	Pelegrin *et al*., 2022
		trans-13-Octadecenoic acid, hexadecanoic acid ethyl ester, octadecanoic acid, (E)5-octadecene, 9-octadecenoic acid, behenic alcohol, γ-sitosterol, stigmasterol, campesterol, lanosterol, squalene, vitamin E, benzenepropanoic acid, 2,4-di-	Olukanni *et al*., 2022

		tert-butylphenol, 4-cyclohexylamino 3H-[1,2,3] triazole, 3-cyclohexyl-5-(1H-pyrazol-3-yl) 2,4-dimethyl benzo[H] quinoline, 4-phenyl pyrido[2,3-D] pyrimidine, β-tocopherol, 3,5-bis(1,1-dimethylethyl)-4-hydroxy octadecyl ester 1H-1,3-benzimidazole, 5,6-dimethyl-1-[(2,3,5,6-tetramethylphenyl)methyl]1-methoxy-3-(2-hydroxyethyl) nonane, 9,10-methanoanthracen-11-ol, 9,10-dihydro-9,10,11-trimethyl diltiazem, 5-methyl-2-phenyl 1H-indole	
		Quercetin, stigmasterol, linoleic acid, oleic acid, 4-chlorobutyl oleate, oleamide, myricetin, tyramine, n-feruloyltyramine	Vega-Morales *et al*., 2019
		Oleic acid, palmitic acid, linoleic acid	Coşkuner *et al*., 2002
		2-Oxo-4-hydroxy-4 carboxy-5-ureidoimidazoline, amylose, arginine, ascorbyl glucoside, citric acid, fumaric acid, galactinol dihydrate, gluconic acid, kojic acid, leucine, L-ornithine, malic acid, quinic acid, sucrose, trehalose/maltose, trisaccharide (raffinose), uridine, xylo-manno-nononic acid ɣ-lactone	Saeed *et al*., 2022
92.	*Cyperus exaltatus*	Cyperaquinone	Morimoto *et al*., 1999
93.	*Cyperus fenzelianus*	Luteolin 5-methyl ether, luteolin 7-glucuronide, tricin 5-glucoside, tricin 7-diglucoside	El-Habashy *et al*., 1989
94.	*Cyperus fissus*	Luteolin 5-methyl ether	Harborne *et al*., 1982
95.	*Cyperus flaccidus*	Luteolin 5-methyl ether, quercetin	Harborne *et al*., 1982
96.	*Cyperus flavescens*	Luteolin 5-methyl ether	Harborne *et al*., 1982
97.	*Cyperus fuscus*	Luteolin 7-glucuronide,	El-Habashy *et al*.,

		sulphuretin	1989
		Dehydroaromadendrene, azulenone, α-selinene, α-ylangene, β-caryophyllene	Erdem *et al*., 2018
98.	*Cyperus gigantens*	Cyperotundone, cyperene	Zoghbi *et al*., 2006
99.	*Cyperus globosus*	α-Cadinol	Bordoloi, 1998
100.	*Cyperus glomeratus*	Thunbergin A-B, trans-resveratrol, trans-scirpusin A, trans-cyperusphenol A, aureusidin, luteolin	Arakki *et al*., 2021
		Caryophyllene oxide, humulene epoxide II, β-caryophyllene, α-humulene	Lazarević *et al*., 2010
101.	*Cyperus haspan*	Cyperaquinone, dihydro cyperaquinone, quercetin	Allan *et al*., 1978
		Mangiferin, isomangiferin	Harborne *et al*., 1982
102.	*Cyperus imbricatus*	Luteolin 7-glucuronide	El-Habashy *et al*., 1989
103.	*Cyperus incompletus*	Umbelliferone, scopoletin, 5,7-dimethoxycoumarin, 7,8-dimethoxycoumarin, 5,7,8-trimethoxycoumarin, leptodactylone, prenyletin, 5,7-dimethoxy-8 (γ,γ-dimethylallyloxy) coumarin, 7-methoxy-8- (γ,γ-dimethylallyloxy) coumarin, 7-(γ,γ-dimethylallyloxy) 8-methoxycoumarin	Dini *et al*., 1993
104.	*Cyperus iria*	Aureusidin	Harborne *et al*., 1982
		δ-Cadinene, γ-cadinene, α-cadinol, calamene,caryophyllene, α-copaene, p-cymene, cyperene, dodeca-cis-3-cis-5-dien-1-ol, dodeca-cis-3-cis-5-dienol acetate, limonene, linalool,mariscetin, α-pinene, β-pinene	Iwamura *et al*.,1978
		Cyanidin	Harborne *et al*., 1985
		Myercetin, quercetin, kaempferol, ferulic acid	Myeda Saeed *et al*., 2022
		Methyl (2E, 6E)-farnesoate	Fraga, 1992
		Limonene, β-ocimene, linalool, α-	Jiang *et al*., 2013

		gurjunene, germacrene D, β-elemene, E-β-caryophyllene, α-humulene, α-bergamotene, α-farnesene, elemol, hedycaryol, γ-eudesmol, β-eudesmol, α-eudesmol	
105.	*Cyperus ischnos*	γ-Muurolene	Bordoloi, 1998
106.	*Cyperus javanicus*	2-Hydroxy-5-methoxy-3-heptadec-8-enyl 1-4 benzoquinone, cyperaquinone, hydroxy cyperaquinone	Morimoto *et al.*,1999
107.	*Cyperus kyllinga*	α-Copaene, β-bourbonene, β-elemene, β-caryophyllene, spathulenol, caryophyllene oxide	Vian *et al.*,2008
		α-Humulene, γ-muurolene, germacrene D, β-selinene, α-valencene, δ-cadinene, α-cubebene	Fraternale *et al.*, 2007
		γ-Cadinene, palmitic acid, α-muurolene	Bendimerad *et al.*, 2005
		(Z)-Calamenene, δ-amorphene, *t*-muurolol, α-muurolol, α-cadinol, α-atlantone, farnesol	Boyom *et al.*, 2003
		α-Cyperone, β-selinene, α-humulene	Komai *et al.*, 1989
108.	*Cyperus kyllingiella*	Alanine, phenyl alanine, arginine, aspartic acid, glutamic acid, glycine,histidine, leucine, iso-leucine	Yeoh *et al.*, 1986
109.	*Cyperus laevigatus*	Octadec-1-ene, palmitic acid, stigmasterol, luteolin 5-methyl ether, apigenin	Nassar *et al.*, 2000
		Luteolin 5-methyl ether	Harborne *et al.*, 1982
		Luteolin 7-glucuronide	Harborne *et al.*, 1982
		Luteolin 7-glucuronide-4`-glucoside, apigenin 7-glucoside, apigenin 7-glucuronide, tricin 5-diglucoside, tricin 7-glucuronide, tricin 7,4`-diglucoside, tricin 7-diglucoside	El-Habashy *et al.*, 1989
		Hexahydrofarnesyl acetone, Z-myroxide, phytol, limonene, E-myroxide, cis-carveol	Nassar *et al.*, 2015.

		Hydroxy dodecenedioic acid, dihydroxy decenoic acid, hydroxy octadecenedioic acid, hydroxy octadecadienoic acid, hydroxy tetradecanoic acid, hydroxy docosanoic acid, hydroxy tetracosenoic acid, hydroxy pentadecanoic acid, hydroxy hexadecenoic acid, hydroxy eicosanoic acid, arachidic acid, hexacosanoic acid, hydroxy tetracosanoic acid, octadecanoic acid, octadecatrienoic acid, trihydroxy octadecenoic acid, hydroxy palmitic acid, hexadecenoic acid, docosanedioic acid, pentacosanedioic acid, eicosanedioic acid, gluconic acid, tetrahydroxy pentanoic acid, hexose, malic acid, fumaric acid, quinic acid, citric acid, isocitric acid, O-caffeoylquinic acid, O-coumaroylhexose, asperuloside, hydroxybenzoic acid, feruloyl quinic acid, feruloyl quinic acid, feruloyl-O-hexoside, caffeic acid, 9 O-syringoylquinic acid, coumaroyl quinic acid, leptosidin-O-dipentoside, luteolin di-O-hexoside, luteolin, isorhamnetin, luteolin-O-hexoside-O-glucuronide, O-syringoylquinic acid O-(hydroxydimethoxybenzoyl)-quinic acid, dicaffeoylquinic acid, O-coumaroylglycerol, O-caffeoyl-O-syringoylquinic acid, tetrahydroxydimethoxyflavone di-O-hexoside, hydroxycinnamic acid, dihydroxy-dimethoxymethylaurone, tetrahydroxy dimethoxy flavonedi-O-hexoside, luteolin-O-deoxyhexoside-O-glucuronide, hydroxyoctanoic acid-O-hexoside, hydroxycinnamoyl-O-	Iriny *et al*., 2022

		malic acid, tetrahydroxyflavone-O-pentosylhexoside, tetrahydroxyaurone-O-glucuronide, aureusidin, tetrahydroxymethoxyflavone O-glucuronide, pentahydroxymethoxyflavone O-glucuronide, ferulic acid, tetrahydroxy methoxyflavone O-glucuronide, luteolin-O-glucuronide, tetrahydroxy methylaurone, luteolin-5-methyl ether, luteolin methyl ether glucuronide, tricin, luteolin-O-deoxyhexoside, trihydroxy flavone-O-glucuronide, tricin-7-O-deoxyhexosyl O-hexoside, tricin-7-O-hexosyl sulfate, tetrahydroxy methoxyflavone-O-sulfate, tricin-7-O-glucuronide, tetrahydroxy aurone-O-hexoside, luteolin-O-hexoside, dihydroxy methoxyaurone, dihydroxy methoxyflavone, tricetin	
110.	*Cyperus laevis*	Quercetin	Harborne *et al.*, 1982
111.	*Cyperus laxus* (Leaves)	Palmitic acid, octadecanoic acid, oleic acid, eichosanoic acid	Casado *et al.*, 2015
112.	*Cyperus longus*	Brevicarine, brevicolline	Nassar *et al.*, 2000
		Cassigarole, catechin, epi-catechin, longusol A-C	Morikawa *et al.*, 2002
		Cyperusol A1, A2, B1, B2, D	Fengming, 2004
		Cyperusol C	Ohira *et al.*, 1998
		Longusol A-C, cassigarol E, cassigarol G, pallidol, longusone A, resveratrol, piceatannol, trans-scirpusin A-B	Morikawa *et al.*, 2010
		α-Caryophyllene oxide, β-himachalene, β-caryophyllene oxide, aristolone, humulene oxide, irisone, longiverbenone, viridiflorol, caryolan-1,9-betadiol, clovanediol, tricyclohumuladiol, p-menth-1-en-7,8-diol, sobrarol,7,15-epoxycaryophyllane-3,5-betadiol	Memariani *et al.*, 2016

	Cyperus longus (Leaves)	Tricin, luteolin 7-arabinosylglucoside	Harborne, 1971
113.	*Cyperus lucidus*	Luteolin 5-methyl ether	Harborne *et al.*, 1982
114.	*Cyperus maculatus*	Mustakone	Nyasse, 1988
		Luteolin 5-methyl ether, luteolin 7-glucuronide, luteolin 7-glucoside, luteolin 7-diglucoside, tricin 5-glucoside	Harbone *et al.*, 1982 El-Habashy *et al.*, 1989
115.	*Cyperus michelianus*	Luteolin 7-glucuronide, luteolin 7-glucoside, luteolin 7-diglucoside, tricin 7-glucoside, tricin 7-diglucoside, sulphuretin	El-Habashy *et al.*, 1989
116.	*Cyperus microbolbos*	Luteolin 7-glucuronide	El-Habashy *et al.*,1989
117.	*Cyperus microiria*	α-Cadinol, α-cadinene	Bordoloi, 1998
118.	*Cyperus nervulosus*	Apigenin	Harborne *et al.*, 1982
119.	*Cyperus nipponicus* (Basal stem)	Cyperaquinone, remirol	Allan *et al.*, 1969 Morimoto *et al.*, 1999
120.	*Cyperus odoratus*	3-Cyclohexene-1-methanol, α-4-trimethylacetate, naphthalene, decahydro-4α-methyl-1-methylene-7-(1-methylethenyl)-, [4α-R-(4a-α-naphthalene, 1,2,3,4,4α,5,6,8α-octahydro-4α,8-dimethyl-2-(1-methylethenyl)-, caryophyllene oxide, squalene, cyclopropa[δ]naphthalen-3-one, octahydro-2,4α,8,8-tetramethyl-oxime, 3,7,11,15-tetramethyl-2-hexadecen-1-ol, 2-pentadecanone, 6,10,14- trimethyl, 9,12-octadecadienoic acid (Z,Z)-, octadecanoic acid, 2,3-dihydroxypropyl ester, 1(2H)-naphthalenone, octahydro-4,8α-dimethyl-6-(1- methylethenyl)-, (4-α-heptane, 2,4-dimethylnonane, 4,5-dimethyl, tetradecane, heptadecane,	Taiba *et al.*, 2022

		dichloroacetic acid, tridec-2-yl ester	
121.	*Cyperus papyrus*	α-Pinene, β-pinene, eucalyptol	Heba *et al*., 2014
		Luteolin 7-glucuronide	El-Habashy *et al*., 1989
		Octopamine	Smith, 1977
		6, 7-Dihydro-2, 3- dimethyl-5-cyclopentapyrazine	Cantalejo, 1997
		Pimpinellin	Harborne *et al*., 1993
		Caryophyllene oxide, cyperene, 1,8-cineole	Lawal *et al*., 2016
		Caryophyllene oxide, humulene epoxide II, aristolene, aromadendrene epoxide II	Lawal *et al*., 2016
	Cyperus papyrus (Rind and pith)	n-Hexadecanoic acid, cis-octadeca-9,12-dienoic acid, cis-octadec-9-enoic acid, n-octadecanoic acid, cis-octadeca-9,12,15-trienoic acid, phytadiene, squalene ergosta-3,5,22-triene, ergosta-3,5-diene, stigmasta-3,5,22-triene, stigmasta-3,5-diene, campesteryl dodecanoate, stigmasteryl dodecanoate, sitosteryl dodecanoate, campesteryl tetradecanoate, stigmasteryl tetradecanoate, sitosteryl tetradecanoate, campesteryl hexadecanoate, stigmasteryl hexadecanoate, sitosteryl hexadecanoate, campesteryl octadecanoate/oleate/linoleate, stigmasteryl octadecanoate/oleate/linoleate, sitosteryl octadecanoate/oleate/linoleate, campesteryl 3-O-β-D-glucopyranoside, stigmasteryl 3-O-β-D-glucopyranoside, sitosteryl 3-O-β-D-glucopyranoside, 7-oxo-campesteryl 3-O-β-D-glucopyranoside, 7-oxo-stigmasteryl 3-O-β-D-	Rosado *et al*., 2022

		glucopyranoside, 7-oxo-sitosteryl 3-O-β-D-glucopyranoside, campesteryl (6′-O-palmitoyl)-3-O-β-D-glucopyranoside, stigmasteryl (6′-O-palmitoyl)-3-O-β-D-glucopyranoside , sitosteryl (6′-O-palmitoyl)-3-O- β -D-glucopyranoside, campesteryl (6′-O-stearoyl/oleyl/linoleyl/linolenyl)-3-O-β-D-glucopyranoside, stigmasteryl (6′-O-stearoyl/oleyl/linoleyl/linolenyl)-3-O-β-Dglucopyranosidesitosteryl (6′-O-stearoyl/oleyl/linoleyl/ linolenyl)-3-O-β-D-glucopyranoside, n-eicosanol, n-heneicosanol, n-docosanol, n-tricosanol, n-tetracosanol, n-pentacosanol, n-hexacosanol, n-heptacosanol, n-octacosanol, oleic amide, triacontanamide, dotriacontanamide, tetratriacontanamide1-monohexadecanoyl glycerol, 1-monoheptadecanoylglycerol, 1-monooctadec-9,12,15-trienoylglycerol, 1-monooctadec-9,12-dienoylglycerol, 1-monooctadec-9-enoylglycerol, 1-monooctadecanoylglycerol, 1-mononondecanoylglycerol, 1-monoeicosanoylglycerol α-tocopherol, β-tocopherol, γ-tocopherol, δ-tocopherol α-tocopheryl dodecanoate, α-tocopheryl tetradecanoate, α-tocopheryl hexadecanoate, α-tocopheryl oleate/linoleate, α-tocopheryl octadecanoate, α-tocopheryl eicosanoate, β-tocopheryl dodecanoate, β-tocopheryl tetradecanoate, β-tocopheryl hexadecanoate, β-tocopheryl oleate/linoleate, β-	

		tocopheryl octadecanoate, β-tocopheryl eicosanoate, γ-tocopheryl dodecanoate, γ-tocopheryl tetradecanoate, γ-tocopheryl hexadecanoateγ-tocopheryl oleate/linoleate, γ-tocopheryl octadecanoate, γ-tocopheryl eicosanoate, δ-tocopheryl dodecanoate, δ-tocopheryl tetradecanoate, δ-tocopheryl hexadecanoate, δ-tocopheryl oleate/linoleate, δ-tocopheryl octadecanoate, δ-tocopheryl eicosanoate phytol, phytyldodecanoate, phytyltridecanoate, phytyltetradecanoate, phytyl pentadecanoate, phytylhexadecanoate, phytyl heptadecanoate, phytyl octadeca-9,12,15-trienoate, phytyl octadeca-9,12-dienoate, phytyl octadec-9-enoate, phytyloctadecanoate, phytylnonadecanoate, phytylheneicosanoate, phytyldocosanoate, phytyltricosanoate, phytyl, tetracosanoate, phytylpentacosanoate, phytyl hexacosanoate2-monohexadecanoylglycerol, 2-monotetracosanoylglycerol, 2-monohexacosanoylglycerol, 2-monooctacosanoylglycerol, 2-monotriacontanoylglycerol1,2-dipalmitin, 1,3-dipalmitin, 1,2-palmitoylolein, campestanol, campesterol, stigmasterol, sitosterol, stigmastanol, Δ^5-avenasterol, Δ^7-stigmastenol, 7-oxo-campesterol, 7-oxo-stigmasterol, 7-oxo-sitosterol, ergostane-3,5,6-triol, sitostane-3,5,6-triol, ergosta-3,5-dien-7-	

		one, ergost-4-en-3-one, ergosta-4,6-dien-3-one, stigmast-4-en-3-one, ergostane-3,6-dione, stigmastane-3,6-dione trans-octadecyl ferulate, trans-eicosanylferulate, trans-docosanylferulate, trans-tetracosanylferulate, trans-hexacosanylferulate, trans-octacosanylferulate, trans-feruloyloxyeicosanoic acid, trans-feruloyloxyheneicosanoic acid, trans-feruloyloxydocosanoic acid, trans-feruloyloxytricosanoic acid, trans-feruloyloxytetracosanoic acid, trans-feruloyloxypentacosanoic acid, trans-feruloyloxyhexacosanoic acid, trans-feruloyloxyheptacosanoic acid, trans-feruloyloxyoctacosanoic acid, 1-mono-trans-feruloyloxyeicosanoylglycerol, 1-mono-trans-feruloyloxydocosanoylglycerol, 1-mono-trans-feruloyloxytetracosanoylglycerol, 1-mono-trans-feruloyloxyhexacosanoylglycerol, 1-mono-trans-feruloyloxyoctacosanoylglycerol, 1-mono-trans-feruloyloxytriacontanoylglycerol	
122.	*Cyperus perangustus*	Apigenin	Harborne *et al*., 1982
123.	*Cyperus pilosus*	α-Cadinol, luteolin, luteolin 5-methyl ether, cyperaquinone	Bordoloi, 1998
124.	*Cyperus platystylis*	Dihydrocyperaquinone	Allan *et al*., 1969
125.	*Cyperus polystachyos*	Luteolin 5-methyl ether	Harborne *et al*., 1982
126.	*Cyperus procerus*	Luteolin, tricin	Harborne *et al*., 1982
127.	*Cyperus prolifer*	Mangiferin, isomangiferin, quercetin	Harborne *et al*., 1982
128.	*Cyperus prolixus*	Caryophyllene oxide, α-cyperone,	Zoghbi *et al*., 2006

		14-hydroxy-9-epi-β-caryophyllene	
129.	*Cyperus pygmaeus*	Luteolin, tricin	Harborne *et al*., 1982
130.	*Cyperus reflexus*	Luteolin 5-methyl ether	Harbone *et al*., 1982
131.	*Cyperus rigidellus*	Quercetin 3-methyl ether, quercetin 3,7-dimethyl ether, kaempferol 3,7-dimethylether	Harbone *et al*., 1982
132.	*Cyperus rotundus*	Monoterpenoids, sesquiterpenoids, diterpenoids, triterpenoids, steroids, aliphatic acid derivatives, aurones, chromones, coumarins, iridoids, flavonoids, stilbenoids, lignans, benzofurans, phenolic acids, phenyl propanoids, glycols, sesquiterpene alkaloids, organic acids, aliphatic acids, aliphatic ketones, amides	*Elaborated in chapter 7*
133.	*Cyperus rutilans*	Hydroxydietrichequinone	Allen *et al*., 1978
134.	*Cyperus sanguinolentus*	Luteolin 5-methyl ether	Harbone *et al*., 1982
135.	*Cyperus scaber*	Scabiquinone, dihydroscabequinone, scaberin	Allen *et al*., 1978
136.	*Cyperus scariosus*	trans-Pinocarveol, δ-cadinene	Pandey, 2002 Bordoloi, 1998
		Leptosidin-6-O-β-D-glucopyranosyl-O-α-L-rhamnopyranoside, leptosidin-6-xylosyl-(1,4)-arabinoside	Bhatt *et al*., 1981
		Caryophyllene oxide	Pandey, 2002
		β-Selinene	Kiuchi, 1983
		Rotundene, rotundenol	Uppal, 1984
		Aromadendrene, alloaromadendrene	Pandey, 2002
		α-Gurjunene	Fraga, 1992
		Aristolone	Ha *et al*., 2002
		Asiatic acid	
		epi-Guaipyridine, guaia-9,11-dienpyridine, cananodine, cyperen-8-one, cyperolactone, rotundone	Clery *et al*., 2016
		α-Pinene, thuja-2,4(10)-diene, β-	Bezerra *et al*., 2019

		pinene, myrcene, p-cymene, limonene, eucalyptol, pinol, p-cresol, p-cymenene, guaiacol, linalool, α-fenchol, cis-rose oxide, nopinone, trans-pinocarveol, trans-pinocamphone, pinocarvone, 4-ethylphenol, *cis*-pinocamphone, terpinen-4-ol, α-terpineol, myrtenal, myrtenol, verbenone,trans-dihydrocarvone, 4-vinyl-phenol, carvone, geraniol, cyprotene, α-cubebene, cyperadiene, cyclosativene, isopatchoula-3,5-diene, α-copaene, isolongifolene, β-cubebene, (E)-α-damascone, cyperene, ylanga-2,4(15)-diene, caryophyllene, nor- rotundene, α-copaene, patchoula-2,4(15)-diene, α-guaiene, α-humulene, rotundene, aristolochene, γ-gurjunene, γ-muurolene, 7-epi-selina-4,11-diene, β-selinene, valencene, α-selinene, α-muurolene, isorotundene, δ-guaiene, nootkatene, 7-epi-α-selinene, δ-cadinene, cyperene epoxide, α-calacorene, tetramethyl-4,5,6,7,8,8a-hexahydro-1H-3a,7-methanoazulen-4-ol, β-calacorene, β-caryophyllene oxide, β-caryophyllene oxide, brachyloxide, cyperen-6-ol, humulene epoxide II, cyperen-8-one, cyperen-6-one, cubenol, caryophylla-3(15),7(14)-dien-6-ol, nor-cyperen-4-one, cadalene, mustakone, cyperotundone, rotundone, cis-β-patchoulenone, rotundan-12-one, cyperenal, α-cyperone, nootkatone, cyperolactone, cyperenol, scariodione, patchoulenone, 3-isopatchoulene	
137.	*Cyperus*	Luteolin 7-glucoside, luteolin 7-	El-Habashy *et al.*,

	schimperianus	diglucoside	1989
138.	*Cyperus serotinus*	Calamenene, δ-cadinene	Bordoloi,1998
139.	*Cyperus sexflorus*	Kaempferol 3-methyl ether	Harborne *et al*., 1982
140.	*Cyperus squarrosus*	Quercetin	Harborne *et al*., 1982
141.	*Cyperus stoloniferus*	trans-Resveratrol, piceatannol	Chau *et al*., 2013
		Cyperene, caryophyllene oxide	Dung *et al*., 1995
		Cyperaquinone, hydroxy cyperaquinone	Allan *et al*., 1978
142.	*Cyperus subulatus*	Cyperaquinone, hydroxy cyperaquinone	Allan *et al*., 1978
143.	*Cyperus sulicinux*	Apigenin	Harborne *et al*., 1982
144.	*Cyperus tegetum*	Stigmasterol, 12-O-tetradecanoylphorbol-13-acetate, 7,12-dimethylbenz (α) anthracene	Chatterjee *et al*., 2022
145.	*Cyperus teneriffae*	Eugenitin, tamarixetin, ombuin, 5,7,30,50-tetrahydroxyflavanone, 4,6,30,40-tetramethoxy aurone, 30-hydroxy-4,6,40-trimethoxy aurone, 1-(2,3-dihydro-6-hydroxy-4,7-dimethoxy-2S-(prop-1-en-2-yl) benzofuran-5-yl) ethenone, 2S-isopropenyl-4,8-dimethoxy-5-hydroxy-6-methyl-2,3-dihydrobenzo [1,2-β;5,4-β] difuran	Angel *et al*., 2011
146.	*Cyperus tenuiculmis*	Aureusidin, quercetin, luteolin 5-methyl ether	Harborne *et al*., 1982
147.	*Cyperus tenuispica*	Mangiferin, isomangiferin, quercetin	Harborne *et al*., 1982
148.	*Cyperus tetraphyllus*	Quercetin 3-methyl ether, kaempferol 3-methyl ether	Harborne *et al*., 1982
149.	*Cyperus thunbergii*	Thunbergin A-B, aureusidin, resveratrol, trans-scirpusin A, trans-cyperusphenol A, luteolin	Arakki *et al*., 2021
150.	*Cyperus trinervis*	Luteolin 5-methyl ether	Harborne *et al*., 1985
151.	*Cyperus tuberosus*	δ-Cadinene, α-copaene	Komai *et al*., 1994
		α-Humulene, humulene epoxide II, β-caryophyllene, caryophyllene oxide	Ekundayo *et al*., 1991
152.	*Cyperus vaginatus*	Cyperaquinone, hydroxy	Allen *et al*., 1978

		cyperaquinone	
153.	*Eleocharis microcarpa*	11 Hydroxy-14-(3,5-dihydroxy-2-methyl cyclopentyl)-tetradec-9-ene-12-yn eoic acid	Van Aller *et al.*, 1983
154.	*Kobresia nepalensis*	Nepalensinol A-G	Yamada *et al*., 2006
155.	*Kyllinga alba*	Luteolin, pelargonidin	Williams and Harborne, 1977
		Manoyl oxide, 13-epi-manoyl oxide, 11α-hydroxymanoyl oxide, 1β-hydroxymanoyl oxide	Guilhon *et al*., 2008
156.	*Kyllinga brevifolia*	Okanin Quercetin-3-O-β-apiofuranosyl 2-β-Glucopyranosyl-7-O-α-rhamnopyranosylvitexin Kaempferol 3-O-β-apiosyl-(1-2)- β-glucoside, isorhamnetin 3-O-β-apiosyl-(1-2)- β-glucoside, quercetin 3-O-β-apiofuranosyl-(1-2)- β-glucopyranoside 7-O-α-rhamnopyranoside,occadinol, τ-muurolol, germacrene D-4-ol	Apers *et al*., 2002
		Occadinol, τ-muurolol, germacrene D-4-ol	Paudel *et al*., 2012
	Kyllinga brevifolia var. *leiocarpus*	epi-Afzelechin, orientin, quercetin, vitexin	Lew *et al*., 1998
157.	*Kyllinga crassipes*	Cyanidin, luteolin, tricin	Williams and Harborne, 1977
158.	*Kyllinga erecta*	Myristic acid, octadeca-9-12-dienoic acid, tetradecanoic acid, octanoic acid, palmitic acid, pentadecanoic acid, ambreinolide, nor-ambreinolide, β-bourbonene, capric acid, caryophyllene oxide, β-caryophyllene, 1-8 cineol, α-copaene, cyperene, cyperotundone, β-elemene, hexahydro farnesyl acetone, germacrene D, lauric acid, manoyl oxide, 1-β-hydroxy manoyl oxide, 11-α-hydroxy	Dolmazon *et al.*, 1995 Dolmazon *et al.*, 2001 Mahmout *et al*., 1993 Mahmout *et al*., 2001

		manoyl oxide, 11-oxo manoyl oxide, 13-epi manoyl oxide, 13-epi 11-α-hydro manoyl oxide, 13-epi16-hydroxy manoyl oxide, 16-hydroxy manoyl oxide, β-pinene, sativene, β-selinene, spathulenol, thymol methyl ether	
159.	*Kyllinga monocephala*	σ-Cyperone, β-selinene, α-humulene, α-cadinol, caryophyllene oxide, α-muurolol, α-atlantone	Raju *et al.*, 2007
		α-Cyperone, β-selinene, α-humulene	Komai and Tang, 1989
160.	*Kyllinga odorata*	Myricitrin, quercetin, luteolin, chrysin	Bezerra *et al.*, 2019
		Dihydrokaranone, aristolochene	Tucker *et al.*, 2006
161.	*Kyllinga pumila*	Methyl E,E-10,11-epoxyfarnesoate, β-elemene, Z-caryophyllene, germacrene D, E-caryophyllene	Jaramillo-Colorado *et al.*, 2016
162.	*Kyllinga triceps*	Caryophyllene, β-sitosterol, stigmasterol, ferruginol, eudesmol, quercetin, rutin	Abhijeet Vishnu Puri, 2022 Verma *et al.*, 2017
163.	*Lepidosperma* sp. *Montebello*	3-O-Prenylpiceatannol, 3-O-prenyl-3'-O-methyl piceatannol, p-coumarate ester, (E)-2,4-bis(3-methyl-2-buten-1-yl)-3,30,40,5-tetrahydroxystilbene, (E)-2,6-bis(3-methyl-2-buten-1-yl)-3,4,5-trihydroxy-30-methoxystilbene, 2-prenyl-3-methoxy-5-hydroxy-E-stilbene	Duke *et al.*, 2016 Abu-Mellal *et al.*, 2012
164.	*Oxycaryum cubensis*	Catechin, chlorogenic acid, luteolin	Bezerra *et al.*, 2019

165.	*Rhynchospora corymbosa* (Whole plant)	Oleanane 3-(3'R-hydroxy)-hexadecanoate, β-sitosterol, β-sitosterol glycoside, oleanolic acid, trans-cinnamic acid, dendrotriol, (24R)-24-ethyl-5α-cholestane-3β,5,6β-triol, glycerol, docosanoic acid 2-hydroxy-1-hydroxymethyl-ethyl ester, tricin, diacetyl tricin, monoacetyl tricin	Annie *et al*., 2016
		Myricitrin, quercetin, luteolin, chrysin, catechin, apigenin	Bezerra *et al*., 2019
166.	*Scirpus californicus*	Piceatannol, scirpusin A, scirpusin B	Schmeda Hirschmann *et al*., 1996
167.	*Scirpus cubensis*	Catechin, chlorogenic acid, rutin, luteolin, apigenin	Bezerra *et al*., 2019
168.	*Scirpus fluviatilis*	trans-Resveratrol, piceatannol, scirpusin A-B, 3,3',4,5'-tertrahydroxy stilbene	Nakajima *et al*., 1978
169.	*Scirpus holoschoenus*	Scirpusin B, cyperusphenol	Arakki *et al*., 2017
		2-Prenyl-3,5,4'-trimethoxystilbene, 2-prenyl-3-hydroxy-5,4'-dimethoxystilbene, 2-prenyl-3,4'-dihydroxy-5-methoxy-stilbene, 3,5,4'-trimethoxystilbene	Abdel-Mogib *et al*., 2001
		Luteolin, morine, tricine	Noori *et al*., 2012
170.	*Scirpus lacustris*	Apigenin, kaempferol, luteolin, morine, quercetin, rutin, tricine	Noori *et al*., 2012
171.	*Scirpus litoralis*	β-Sitosterol, quercetin 3-β-glucoside, quercetin 3,7-β-diglucoside, isorhamnetin 3,7-β-glucoside	Nassar *et al*., 2000
		Apigenin, chrysin, kaempferol, luteolin, morine, myricetin, quercetin, tricine	Noori *et al*., 2012
172.	*Scirpus maritimus*	trans-Resveratrol, ε-viniferin, piceatannol, scirpusin A-B	Powell *et al*., 1987
		Myricetin, quercetin, rutin, vitexin, trans-resveratrol, ε-viniferin, scirpusin A, scirpusin B	Noori *et al*., 2012
173.	*Scirpus multicaule*	Luteolin, morine, quercetin, tricine	Noori *et al*., 2012
174.	*Scirpus nodosus*	Aureusidin	Clifford and Harborne, 1969

			Abdel-Mojib *et al.*, 2001
175.	*Scirpus tuberosus*	Lupeol, betulin, betulinaldehyde, apigenin, β-sitosterol	Nassar *et al.*, 2000
176.	*Scirpus wichurai*	Quercetin, kaempferol, apigenin, luteolin	Abdel-Mojib *et al.*, 2001
177.	*Scirpus yagara*	trans-Resveratrol, scirpusin A-B, p-hydroxycinnamic acid	Yang *et al.*, 2010
178.	*Scleria hirtella*	Nonanal, geranial, neral	Maia *et al.*, 2005
179.	*Scleria lithosperma*	α-Pinene, 1,8-cineole, cyclosativene, β-cedrene, cis-thujopsene, β-barbatene, aromadendrene, α-acoradiene, cuparene, δ-cadinene, γ-cuprenene, elemol, caryophyllene oxide, cedrol, neo-intermedol, neocembrene, myristic acid, palmitic acid, linoleic acid, oleic acid, stearic acid	Rameshkumar *et al.*, 2009
180.	*Scleria striatinux*	Okundoperoxide, sclerienone A-B	Kennedy *et al.*, 2008
		Benznidazole, miltefosine, melarsoprol, podophylotoxin	Kennedy *et al.*, 2017
		Sclerienone C	Kennedy *et al.*, 2016
		α-Pinene, β-pinene, cyperene	Mve-Mba*et al.*, 1996
		Okundoperoxide	Mbah *et al.*, 2012
	Scleria striatinux (Fruit)	Caprylic acid, capric acid, palmitic acid, α-linolenic acid, linoleic acid	Abdou Bouba *et al.*, 2016

Phenolic compounds reported from Cyperaceae members

Literature review revealed that, in addition to the volatile chemicals, the Cyperaceae have been investigated generally for their polyphenols such as phenolic acids, benzoic acids, cinnamic acids, flavonoids, stilbenes, aurones and quinones (Clifford and Harborne, 1969; Harborne, 1971; Williams, and Harborne, 1977; Harborne *et al.*, 1982; Harborne *et al.*, 1985; El-Habashy *et al.*, 1989). The availability of standard polyphenol compounds, and the established extraction and analytical protocols make polyphenols an easy target for phytochemical analysis. Investigation of polyphenolics has significance in chemotaxonomy, nutritional, medicinal and ecological aspects. Plants having different types of polyphenolic compounds have been used as potential therapeutics due to the anti-oxidative, anti-cancerous and anti-inflammatory properties associated with the polyphenolics (Gil *et al*., 2000).

Flavonoids

Flavonoids are the most widely distributed phenolic compounds in Cyperaceae members (**Table 1, Figure 1**). The two-dimensional chromatographic analysis by Harborne (1971) revealed the presence of five pharmacologically important flavonoids such as kaempferol, quercetin, glycoflavone, luteolin and tricin in the leaves of different members of the tribe *Scirpae*, *Rhynchosporae* and *Cypereae*. El-Habashy *et al*. (1989) investigated 20 *Cyperus* and four *Pycreus* species for their flavonoids and glycosides and the data was used for chemotaxonomy. Recent phytochemical investigation using HPLC revealed the presence of gallic acid, phloroglucinol, catechin, caffeic acid, coumaric acid, ferulic acid, rosmarinic acid, quercetin and biochanin in different *Carex* species (Rajak and Ghosh, **2022**). The coumarin remirol and the quinones cyperaquinone and scabequinone were identified as the antifeedant compounds in the stem of *Cyperus nipponicus* and *Cyperus distans* (Morimoto *et al*., 1999).

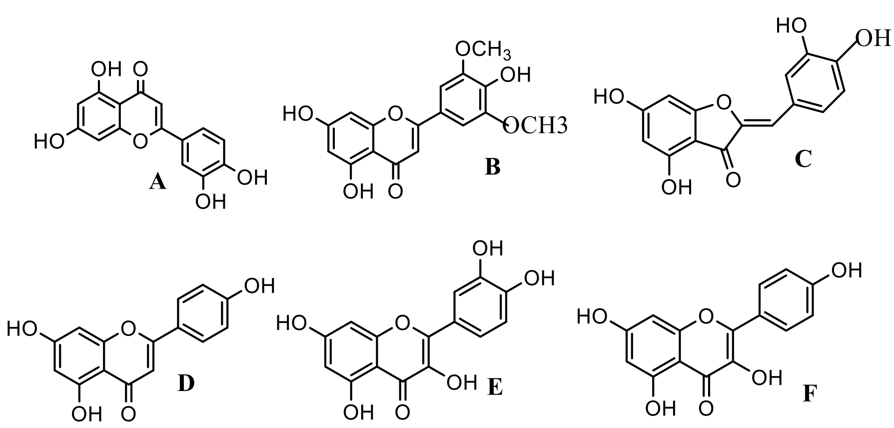


Figure 1. Major flavonoids reported from *Cyperaceae* species. **A-** Luteolin, **B-** Tricin, **C-** Aureusidin, **D-** Apigenin, **E-** Quercetin and **F-** Kaempferol

Gamal *et al.* (2015) reviewed the phenolics in *Cyperus* species. Among the different flavonoids, luteolin is present in around 120 *Cyperus* species, while luteolin derivatives such as glycosides and methyl ethers were also abundant in various *Cyperus* species. The O-methylated flavone tricin is another widely distributed flavonoid compound reported in around 90 *Cyperus* species. The tetrahydroxy aurone 'aureusidin' is reported from around 60 *Cyperus* species. Apigenin, quercetin and kaempferol are other major flavonoids reported from Cyperaceae members (Gamal *et al.*, 2015).

Stilbenes in Cyperaceae members: Among the polyphenolic compounds, stilbene derivatives are important bioactive components reported in several Cyperaceae species (Gamal *et al.*, 2015; Giri *et al.*, 2015; Dávid *et al.*, 2021). Stilbenes with 1,2-diphenylethylene nucleus is a class of plant phenolics that occur in a number of heterogeneous and phylogenetically unrelated plant families such as Cyperaceae, Dipterocarpaceae, Gnetaceae, Leguminosae, Polygonaceae and Vitaceae. Stilbenes, formed by the general phenylpropanoid pathway, are found as monomers, dimers and complex oligomers. Stilbenes are important from chemotaxonomic point of view, and they play a key role in plant defence mechanisms as well. The compounds are attributed with several pharmacological properties, and the monomeric stilbene trans-resveratrol is one of the most important bioactive phytochemicals with prominent role in the prevention and treatment of neurodegenerative diseases, diabetes and cancer. Resveratrol, the active molecule of red wine, is present in more than 70 plant species. Piceatannolis a monomeric stilbene, while scirpusins are dimerized stilbenes.

Stilbenes can be found in relatively high amounts in several Cyperaceae species, for instance the total content of stilbenes in the roots and rhizome of *Carex fedia* var. *miyabei* was estimated over 0.15% (w/w of fresh material), and in case of *Carex pumila*, the main constituent was miyabenol A present at 0.23% (w/w of dried material) in the plant. Dávid *et al.* (2021) has reviewed around 70 stilbenoids from 28 Cyperaceae members, of which around 18 were isolated from *Carex distachya*. Scirpusins A and B are abundant stilbene dimers in *Scirpus* and *Cyperus* species. *Cyperus longus*, *Cyperus capitatus*, *Cyperus conglomerates* and *Cyperus rotundus* are also reported to possess stilbenoids (Gamal *et al.*, 2015; Majeed *et al.*, 2022).

The major stilbene derivatives reported from Cyperaceae plants are; hydroxy stilbenes (resveratrol, carexinols, scirpusins, 3,3',4,5'-tertrahydroxystilbene), prenylstilbenoids (carexanes), tetrastilbenes(cis-miyabenol A) and oligostilbenes (kobophenols, pallidolviniferins, smiglasids, virgatanol and piceatannol) (**Figure 2)** (Meng *et al.*, 2001; Lee *et al.*, 2013; Rajak and Ghosh, 2022). As Cyperaceae members are very good sources of a wide variety of stilbenes, and several of them occur in large quantity, they are worthy for further phytochemical and pharmacological investigations.

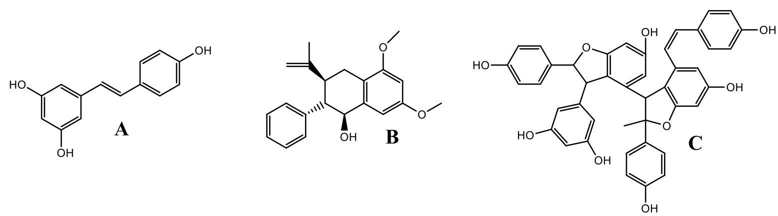


Figure 2. A- Hydroxy stilbene, resveratrol, **B-** Prenyl stilbene, carexane, and**C-** Tetrastilbene, cis-miyabenol A

Discovery of novel prenylated cinnamates and stilbenes in *Lepidosperma* sp. Propolis is the natural resinous mixture produced by honeybees from plants exudates, and is attributed with potential bioactivities, mainly due to the presence of characteristic polyphenols. The composition of propolis varies region wise, depending on the vegetation around. Propolis samples collected from the beehives of Kangaroo Island, Australia was found to have novel compounds belonging to prenylated cinnamate and stilbene classes (Abu-Mellal *et al.,* 2012). Ligurian honey bees, *Apis mellifera* sub sp. *ligustica* Spinola, were found to produce the propolis from the resin exuded by the Australian native sedge plant *Lepidosperma* sp. Montebello (Cyperaceae). There had been no previous reports of bees foraging for propolis on plants of the Cyperaceae family so these widespread plants had not been considered a likely source. Samples of plant exudates, resinous material carried on bee legs, and freshly deposited propolis in the hive were analysed by TLC and high field ^{1}H NMR spectroscopy, and found to be with similar chemical profile, with prenylated cinnamate and stilbene compounds (**Figure 3)** (Duke *et al.*, 2017).

Figure 3. Honey bee, propolis and stilbenes in *Lepidosperma* species

Coumarins in Cyperaceae members

Diversity of coumarin structures such as umbelliferone, xanthotoxol, 7-(γ,γ-dimethylallyloxy)-8-methoxycoumarin, 7-methoxy-8-(γ,γ-dimethylallyloxy) coumarin, 5,7-dimethoxy-8-(γ,γ-dimethylallyloxy) coumarin, prenyletin, leptodactylone, 5,7,8-trimethoxycoumarin, 7,8-dimethoxycoumarin, 5,7-dimethoxycoumarin, scopoletin, and isoscopoletin have been reported from various *Cyperus* species such as *Cyperus alopecuroides*, *Cyperus incompletes* and *Cyperus papyrus* (**Figure 4)** (Mohamed *et al*., 2015).

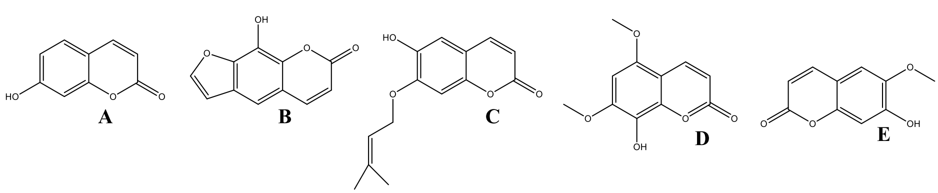


Figure 4. Coumarins reported from Cyperaceae members. **A-** Umbelliferone, **B-** Xanthotoxol, **C-** Prenyletin, **D-** Leptodactylone, and **E-** Scopoletin

Quinones in Cyperaceae members: Cyperaceae members have been shown to be prolific source of quinones with wide structural diversity such as difuran benzoquinones (Allan *et al.,* 1969; Allan *et al.,* 1978; Nassar *et al.,* 2002). Cyperaquinone, conicaquinone, scabiquinone, breviquinone, capiquinones and alopecuquinone are the major quinones reported from various Cyperaceae members (**Figure 5)** (Gamal *et al.*, 2015).

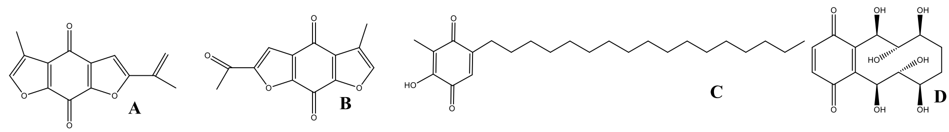


Figure 5. Major quinones reported from Cyperaceae members. **A-** Cyperaquinone, **B-** Scabiquinone, **C-** Capiquinone, and **D-** Alopecuquinone

Cyperus capitatus contains a homologous series of 11 6-alkyl-2-hydroxy-3-methyl-1,4-benzoquinones, with chain length C17 to C27 (Alves *et al.*, 1992).

Sesquiterpenoids in Cyperaceae members

Sesquiterpenoids are abundant in the essential oils of various Cyperaceae members. *Cyperus articulates*, a common medicinal and aromatic species yielded several interesting sesquiterpenoids such as isopatchoul-4 (5) en-3-one, corymbolone, α-corymbolol, mandassidione, isopatchoulenone and mustakone (Nyasse *et al.*, 1988). The systematic approach on the structure elucidation of complex sesquiterpenoids using conventional characterization techniques was revealed by the revision of the structure of the bicyclic ketone articulone isolated from *Cyperus articulates* to isopatchoul-4 (5) en-3-one. Couchman *et al*. (1964) proposed the structure as the bicyclic ketone articulone, which was further reinvestigated by Nigam (1965), Hikino *et al*. (1965), Nerali *et al*. (1965) and Neville *et al*. (1968) and confirmed the structure as isopatchoul-4 (5) en-3-one. *Scleria striatonux* rhizomes afforded novel bicyclic cyclofarnesyl endoperoxide class of sesquiterpenoids; okundoperoxide, sclerienone A-C (**Figure 6)** (Kennedy *et al.*, 2016).

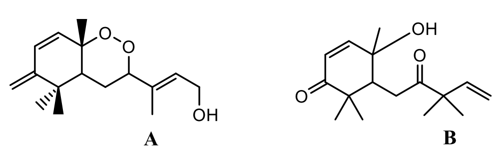


Figure 6. Bicyclic cyclofarnesyl endoperoxide **A-**Okundoperoxide, **B-**Sclerienone A

Diterpenoids inCyperaceae members

Various Cyperaceae members have been reported as rich source of diterpenoids as well. The diterpenoids manoyloxide, 16-hydroxymanoyloxide, llα-hydroxymanoyloxide, lβ-hydroxymanoyloxide, ambreinolide and norambreinolide were reported from *Kyllinga erecta* (**Figure 7)** (Dolmazon *et al*., 1995).

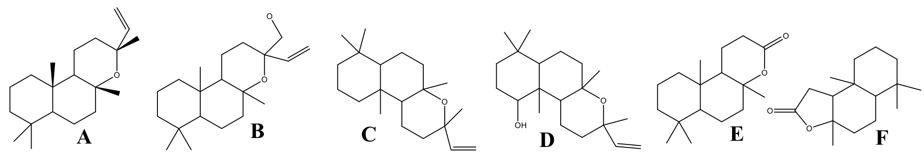


Figure 7. Major diterpenoids reported from *Kyllingaerecta*- **A-**Manoyloxide, **B-** 16-Hydroxymanoyloxide, **C-** llα-Hydroxymanoyloxide, **D-** lβ-Hydroxymanoyloxide, **E-** Ambreinolide and **F-** Norambreinolide

Fatty acids in Cyperaceae members

Fatty acids are extracted from the crude plant material by hexane solvent, and analysed by the GC-MS of volatilised Fatty Acid Methyl Esters (FAME). Generally, Cyperaceae members have the C18:3 fatty acid biosynthetic pathway as prominent. *Cyperus esculentus* is the major oil rich Cyperaceae member, and several reports are there on the oil composition of *Cyperus esculentus* (Lopéz-Cortés *et al.*, 2013). Ekeanyanwu and Ononogbu (2010) reported that the lipid found in *Cyperus esculentus* is non-drying and suitable for soap making. The fatty acid composition of *Cyperus esculentus* tuber oil (chufa oil) included oleic acid 689.2-732.9 g kg^{-1}, palmitic acid 125.5-141.2 g kg^{-1} and linoleic acid 99.6-154.6 g kg^{-1}, which is comparable with that of olive oil (**Figure 8)** (Coşkuner *et al.*, 2002).

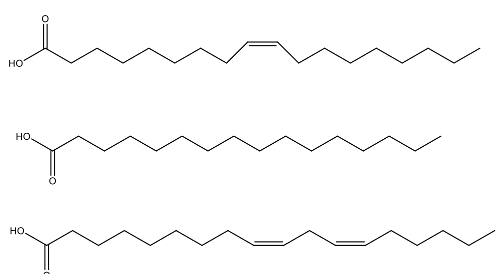


Figure 8. The major fatty acids in *Cyperus esculentus,* oleic acid, palmitic acid and linoleic acid

The fatty acid profile of the leaves of *Cyperus laxus* showed palmitic acid, octadecanoic acid, oleic acid and eichosanoic acid. Casado *et al.,* (2015) showed that the weathered hydrocarbons drastically affect the lipidic composition of *Cyperus laxus* at the fatty acid level, suggesting that this species adjusts the lipid composition in its vegetative organs, mainly in roots, in response to the weathered hydrocarbon presence and uptake during the phytoremediation process. Bogucka-Kocka and Janyszek (2010) examined the fatty acid profiles of 13 *Carex* species and found linoleic acid, oleic acid, α-linolenic acid and palmitic acid as the major fatty acids.

For papyrus (*Cyperus papyrus*), the lipid content accounted for 4.1% in the rind and 4.9% in the pith, and several lipidic compounds such as hydrocarbons, fatty acids, 2-hydroxyfatty acids, fatty alcohols, phytol, phytol esters, alkylamides, glycerides, steroids, tocopherols and ferulates (Rosado *et al.*, 2022). n-Hexadecanoic acid, cis, cis-octadeca-9,12-dienoic acid, cis-octadec-9-enoic acid, n -octadecanoic acid, cis, cis-octadeca-9,12,15-trienoic acid were the major fatty acids in rind and pith of the plant.

Phytochemistry of *Cyperus* species other than *Cyperus rotundus*

In addition to *Cyperus rotundus*, few other *Cyperus* species such as *Cyperus esculentus*,*Cyperus scariosus*,*Cyperus conglomeratus*,*Cyperus distans*,*Cyperus articulatus* and *Cyperus longus* have also been investigated in detail for the constituents. Gamal *et al*. (2015) and Taheri *et al.* (2021) have summarized the phytochemicals of different *Cyperus* species. Literature review revealed that 97*Cyperus* species have been investigated for their phytochemicals (**Table 1**). In addition to *C. rotundus*, *C. alopecuroides*, *C. alternifolius*, *C. articulates*, *C. conglomerates*, *C. difformis*, *C. dubius*, *C. esculentus*, *C. laevigatus*, *C. longus* and *C. scariosus* are the major species investigated for the phytochemicals.

***Cyperus esculentus*:** The plant, also known as tiger nut, earth almond or yellow nut sedge, has sweet tubers and reported to have health and nutritional benefits (Venkatachalam and Sathe, 2006; Zhang *et al.*, 2022). The plant is also considered as the world's 16th worst weed (Holm *et al.*, 1977). The plant was cultivated in the Nile valley by ancient Egyptians, and was discovered in tombs in Egypt, and now the plant is being cultivated in several countries across the world, especially the Eastern Hemisphere, as animal feed, side dish for human consumption, and for preparing the beverage *Horchata*. The plantexists in three varieties; black, brown and yellow, amongst which the yellow one is the most solicited for human and animal consumption.

The plant has been reviewed intensively for its chemical constituents and potential biological activities (Zhang *et al.,* 2022). The findings of recent research showed high content of nutrients and bioactive phytochemicals such as alkaloids, glycosides, flavonoids, crude fibres, tannins, proteins, carbohydrates, oxalates, phytates and fats in tiger nut. The tuber is particularly rich in fixed oil, with high oleic acid content. The tuber of *Cyperus esculentus* is used as a snack and also for making a sweet and tasty beverage. *Horchata de chufa* is a traditional Spanish beverage produced from tiger nuts, and the drink is popular in Spain (Pascual *et al.,* 2000). In Cameroon, more than 17,000 tons tiger nuts are produced per year (Djomdi *et al.,* 2013). In Spain, around 8,360 tons of dried tiger nuts are produced annually, and the annual value of production in Spain has risen to 3.3 million Euros (Carlos *et al.,* 2022; Pelegrin *et al.,* 2022; *Zhang et al*., 2022).

The plant is a potential source of carbohydrates, fiber and polyphenols, and could be used as potential ingredients in the food industry (María del Carmen Razola-Díaz *et al.,* 2022). Tiger nuts are rich in carbohydrates (58.9%), lipids (24.5%), calcium (100.2 mg/100g), potassium (487.1 mg/100g), phosphorus (128.6 mg/100g), magnesium (94.8 mg/100g), but poor in proteins (8.1%) and zinc (4.0 mg/100g) (Okoye and Ene, 2018). Both the volatile and non-volatile phytochemicals were investigated in detail. The rhizome oils of two varieties (brown and black) of Nigerian *Cyperus esculentus* were found to be potential sources of α-pinene (70.5-75.5%). In addition, different chemotypes have also been reported for these species (Kubmarawa *et al.,* 2005). Investigation of the ethanolic extracts identified more than 40 polyphenols with promising medicinal applications (Olukanni *et al.,* 2022; Pelegrin *et al.,* 2022; Diaz *et al.,* 2022).

Cyperus scariosus: Tubers of the plant is the source of cypriol oil, the essential oil with ambery, balsamic, spicy, warm and woody notes, which is widely applied in various perfumes and medicines and of high demand in perfume industry (Bhawna *et al.,* 2013; Kumar *et al.,* 2016). Kumar *et al.* (2016) analysed *Cyperus scariosus* oils from 13 locations in India and the oil yield varied from 0.2 to 0.5 %v/w. The major compounds were cyperene, longifolin, caryophyllene oxide and longiverbenone. Characteristic nitrogenous components such as epi-guaipyridine, guaia-9,11-dienpyridine and cananodine have been reported from *Cyperus scariosus* oil (**Figure 9)** (Clery *et al.,* 2016). Rotundone was found as the volatile compound responsible for the woody amber odour of cypriol oil together with other ketones such as cyperen-8-one (Clery *et al.*, 2016).

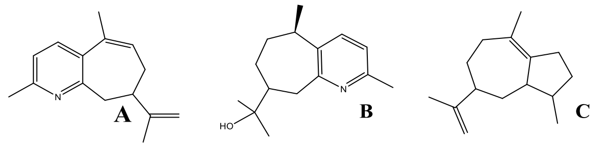


Figure 9. Major nitrogenous components and odoriferous components identified in *Cyperus scariosus* essential oil. **A-** epi-Guaipyridine, **B-** Guaia-9,11-dienpyridine, **C-** Cananodine

Cyperus articlulatus: The tropical sedge *C. articlualtus* is widely used in traditional medicine, as well as in perfumery. Characteristic sesquiterpenoids such as isopatchoul-4 (5) en-3-one, corymbolone, α-corymbolol and mandassidione were isolated from the rhizome essential oil (**Figure 10)** (Nyasse, 1988). The sesquiterpenoids cyperotundone, mustakone, 1,2-dehydro-α-cyperone and sesquichamaenol were identified as lead molecules in *Cyperus articulatus* with antiseizure activity (Brillatz *et al*., 2020).

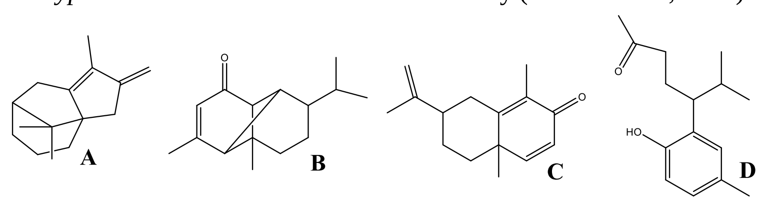


Figure 10. Sesquiterpenoids reported from *Cyperus articulatus* with antiseizure activity. **A-** Cyperotundone, **B-** Mustakone, **C-** 1,2-Dehydro-α-cyperone, and **D-**Sesquichamaenol

Cyperus conglomeratus: The plant is another important *Cyperus* species with wide distribution, especially in the extreme dessert conditions, and has traditional medicinal uses such as analgesic, diuretic, stimulant, pectoral, emollient and anthelmintic and revealed pharmacological activities such as antimicrobial and anti-candidal properties. Cyperene was the major component of the rhizome essential oil of *Cyperus conglomeratus* collected from Iran (Feizbakhsh and Naeemy, 2011). In additional to essential oils, several metabolites such as flavonoids, triterpenoids, steroids and aromatic shikimates were isolated and characterized from the species (Abdel-Mogib *et al.,* 2000). Elshamy *et al.* (2020) reported 70 metabolites belonging to phenolic acids, organic acids, cinnamic acid derivatives, flavonoids, stilbenes, aurones, quinones, terpenes and steroids from *Cyperus conglomerates* through UPLC-qTOF-MS/MS analysis. The fatty acid profile of the tubers comprised of mainly stearic acid, myristic acid, palmitolic acid and behenoic acid (Ghaferah *et al.*, 2018).

Cyperus distans: The plant, an annual herb, is native to tropical and subtropical wetlands. The phytochemical study of *Cyperus distans* revealed the presence of scabequinone with antifeeding effects (Morimoto *et al.,* 1999). Zierone has been identified as the major component of the rhizome essential oil (**Figure 11)** (Lawal and Oyedeji, 2009).

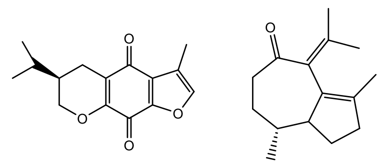
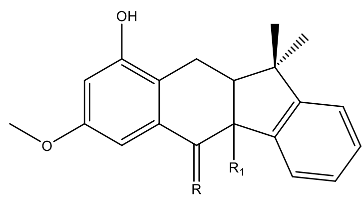


Figure 11. The quinone scabequinone and the sesquiterpenoid zierone reported from *Cyperus distans*

Phytochemical studies on *Carex* species: *Carex* L. with more than 2000 species is the largest genus of the family Cyperaceae, and also one of the largest vascular plant groups. They occur in very differentiated habitats, both in wet and moist localities and also in extremely dry habitats. The genus *Carex* has attracted the attention of phytochemists, especially due to the characteristic phenolic constituents. Literature review revealed that 53*Carex*species have been investigated for their phytochemicals (**Table 1**). Among various *Carex* species, the widely investigated species is *Carex distachya*.

Harborne (1971) had performed two-dimensional chromatographic investigation on the distribution of kaempferol, quercetin, glycoflavone, luteolin and tricin in leaf extracts of different *Carex* species. Bogucka-kocka *et al*. (2011) estimated the phenolic acids (caffeic, ferulic, p-coumaric, p-hydroxybenzoic, protocatechuic, sinapic, syringic and vanillic acid) in the aerial parts of 18 *Carex* species from Central Europe. Several new lignan glycosides and furofuran type lignan aglycones were reported from the polar extract of *Carex distachya* (Fiorentino *et al*., 2008). Ricci *et al*. (2008) investigated in detail the fragmentation pattern of the complex lignans by tandem mass spectrometry. Novel class of dibenzoxazepinones were also reported from the species (Fiorentino *et al*., 2007). Stilbenoid derivatives are another characteristic class of phenolics identified from several *Carex* species. Oligostilbenes formed by 2-4 monomers of resveratrol and tetracyclic prenylated stilbenes are characteristic of the genus (D'Abrosca *et al.*, 2005). The stilbenoidscaraxanes with unusual tetracyclic structure with a hydroxyl group at the C-3 carbon and a methoxyl group at the C-5 were reported from *Carex distachya* (**Figure 12)**.



1	R= βOH, αH	R1= βH
2	R= O	R1= αOH
3	R= O	R1= βOH

Figure 12. Caraxanes A-C (1. Caraxane A, 2. Caraxane B and 3. Caraxane C)

Phytochemical studies on *Kyllinga* species: *Kyllinga,* frequently referred to as spike sedges, is another widely distributed genus in the Cyperaceae family. Alkaloids, coumarins, flavonoids, glycosides, lignins, phenols, steroids, tannins and terpenoids were reported from the genus (Verma *et al.,* 2017). The essential oil of fragrant kyllinga, *Kyllinga odorata* Vahl showed dihydrokaranone and aristolochene as the major compounds (Tucker *et al.,* 2006). Literature review revealed that 8 *Kyllinga* species have been investigated for their phytochemicals.

Phytochemical studies on *Rhynchospora* species: Though the genus *Rhynchospora* Vahl. is widely distributed globally, with about 270 species, it is least investigated for the phytochemicals, except for *Rhynchospora corymbosa* (Strong, 2006; Annie *et al*., 2016; Bezerra *et al*., 2019).

Phytochemical studies on *Scleria* species: The genus *Scleria*, commonly known as nutrush, consists of perennial herbs. *Scleria* has not attracted much attention from phytochemists, except for a few reports on essential oils. *Scleria striatonux* rhizome is used in some parts of Cameroon as a spice and possessed a very pronounced inhibitory activity. The rhizomes afforded novel bicyclic cyclofarnesyl endoperoxide class of sesquiterpenoids; okundoperoxide, sclerienone A-C (Kennedy *et al.*, 2016).

Phytoremediation potential of Cyperaceae species

Hyperaccumulators can tolerate, take up and translocate high levels of certain metals that would be toxic to most organisms. Many of the Cyperaceae members have heavy metal phytoremediation potential from contaminated water sources and can be considered as hyperaccumulators. The sedge plant *Cyperus alopecuroides* was found as a powerful phytoremediator to remove heavy metals from contaminated water bodies. *Cyperus alopecuroides* roots accumulated concentrations of all measured heavy metals, except Ni, Cu, Zn, and Pb, more significant than the shoot. The bioconcentration factor was generally > 1, while the translocation factor of all elements, except Pb, was < 1 (Galal *et al.*, 2021). It has been demonstrated that *Cyperus laxus* significantly reduces the hydrocarbon levels from soils containing up to 325,000 mg THC Kg^{-1} soil (Casado *et al.*, 2015). *Cyperus alternifolius* and *Cyperus dives* were found as effective phytostabilizers of Arsenic, Cadmium and Lead metals with greater than one biocentration factor values, while translocation factor values were less than one. *Cyperus alternifolius* also reduced significantly the total nitrogen content of the influent water in a vertical-flow constructed wetland model (Cui *et al.*, 2009). The plant was also efficient in removing phenolic compounds up to 98.8% from waste water. The plants accumulated trace elements, especially in the roots, with the order of Fe > Mn > Cu > Zn > B > Pb > Cr > Ni > Co > Cd (Goren *et al.*, 2021).*Cyperus rotundus* and *Cyperus alternifolius* were found to eliminate fluoride from water (Neetin Desai, 2020).

Evaluation of the phytoremediation potentiality of *Cyperus articulatus* revealed maximum accumulation for iron (105.5 and 900 µg/g dry wt.) in wastewater, while minimum values were obtained for the accumulation of cadmium (0.9 to 1.95 µg/g d.wt.), among the tested metals As, Cd, Cr, Cu, Fe, Hg, Mn, Ni and Pb (Farrag and Fawzy, 2012). *Cyperus articulatus* plants accumulated most of the heavy metals, except Pb, in their roots than in the shoots, and the bioaccumulation factor was > 1, and the translocation factor of most heavy metals, except Pb was <1 (Galal *et al.*, 2017).

Antifeedant, insecticidal and repellent phytochemicals in Cyperaceae species

Cyperaceae are generally not affected by pests in upland and paddy fields, and are seldom damaged by phytophagous insects, because they contain insect antifeedants. Morimoto *et* *al*., (1999) observed the insect repellent property of many of the *Cyperus* species and showed that the hexane extract of *C. amuricus, C. brevifolius, C. ceperinus, C. cyperoides, C. difformis, C. diffuse, C. distans, C. flavidus, C. haspan, C. iria, C. javanicus, C. microiria, C. monophyllus, C. nipponicus, C. nutans, C. odoratus, C. orthostachyus, C. pilosus, C. sanguinolentus, C. serotinus* and *C. stoloniferous* were strongly insect repellent. From the basal stem of *Cyperus nipponicus* and *Cyperus distans* the antifeedants remirol, cyperaquinone and scabequinone were identified (**Figure 13)** (Morimoto *et al*., 1999). Hexane extract of *Cyperus compresses* also possess strong insect repellent property (Al-Shamma *et al*., 1979). Hexane extract of *Cyperus rotundus* rhizomes was found to be effective against the mosquitos *Anopheles culicifacies*, *Anopheles stephensi* and *Culex quinquefasciatus*. *Cyperus rotundus* was found as more effective insecticidal than carbamate and has almost the same efficacy as that of organophosphate (Bañez and Castor, 2011). Essential oil of *Cyperus rotundus* rhizomes showed remarkable activities on eggs and instar larvae of *Aedes albopictus* (Imam and Chandra, 2014). The sesquiterpene ketone, α-cyperone, a constituent of several Cyperaceae members showed significant insecticidal activity against diamond back moth (DBM) larvae (Dadang *et al.*,1996).

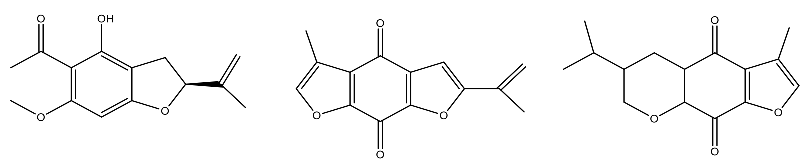


Figure 13. The antifeedants isolated from Cyperaceae plants. **A-** Remirol, **B-** Cyperaquinone and **C-** Scabequinone

Allelochemicals in Cyperaceae species

Plants produce a wide variety of allelochemicals to protect themselves from pathogens, herbivores and from neighbouring plants. Allelochemicals are particularly significant in inhibiting the growth of neighbouring plants. The organic solvent extracts, essential oils and isolated compounds from various Cyperaceae members showed allelopathic properties, and several natural products, *viz*., coumarins, quinones and sesquiterpenes have been identified as potential allelochemicals (Dini *et al*., 1992; Dini *et al*., 1993). Morimoto and Komai (2005) reported that the sesquiterpenoids cyperotundone and α-cyperone produced in *Cyperus rotundus* can inhibit the growth of other plants nearby (**Figure 14)**. Stilbenoids and flavonoids from *Carex distachya* have been shown to act as allelochemicals in the Mediterranean macchia vegetation (Fiorentino *et al*., 2008).

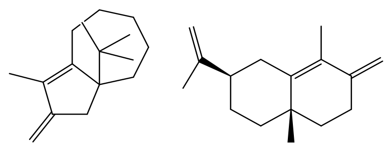


Figure 14. Allelochemicals in *Cyperus rotundus*, cyperotundone and α-cyperone

Chemotaxonomic evaluation

Plant chemosystematics is the application of chemical data to systematic problems, and explored for explaining relationships between plants and inferring phylogeny (Singh, 2016). Among secondary metabolites, flavonoids with wide structural features are more useful for studying relationships within the species and genus level (Harborne, 1994). Generally, the angiosperm flavonoid evolution involves a progressive reduction in the number of different flavonoid structural classes; the reduction of a flavonol-glycoflavone profile to glycoflavones alone is often used as an example.

Most of the systematic classifications of Cyperaceae are based on the classical taxonomic features, obtained as a result of morphological and anatomical analyses. However, the diversity of flavonoids, oligostilbenes, phenolic acids and fatty acids are described as useful chemotaxonomic markers for Cyperaceae. Flavonoids are common phytochemicals in Cyperaceae. Earlier studies on the flavonoid chemistry included generalized acid-hydrolysis surveys of the Cyperaceae, that suggested possible putative relationships between the Cyperaceae, Gramineae and Juncaceae, but yielded little information below the generic level. Harborne *et al* have extensively studied the distribution pattern of flavonoids in around 100 Cyperaceae plants in Australia and arrived at significant correlations (Clifford and Harborne, 1969; Harborne, 1971; Harborne *et al.*, 1985).

Flavones, such as tricin and luteolin are very common in Cyperaceae species. Luteolin 5-methyl ether was found in several Cyperaceae genera, while luteolin 7-methyl ether, diosmetin and acacetin were limited in the Cyperaceae. Flavonols and their methyl ethers were detected in over one-third of the species, particularly in the leaves of the genera *Fuirena, Gahnia, Lepidosperma* and *Mesomelaena*. Myricetin was found only in two *Baumea* species. The 3-desoxyanthocyanidin carexidin was found in the inflorescences of eight Cyperaceae species (Harborne *et al.*, 1985). The presence of the characteristic leaf flavonoids (glycoflavones, tricin) of the grasses showed that the Cyperaceae and the Gramineae are more closely linked chemically than a previous study of their inflorescence pigments suggested (Harborne, 1971). Aurone pigments, the most distinctive Cyperaceae family constituents, were found in the leaves of 25% of the species and in the inflorescences of 40% species. The absence or presence and type of quinonoid constituents in the roots and rhizomes of the genus *Cyperus* have proved consistent with the accepted divisions within this genus (Allan *et al.*, 1978). The abundant aglycones of the inflorescence spike of Fraser's sedge (*Cymophyllus fraseri*) indicate a biochemical feature differentiating leaf and floral tissues. This is contrary to the general concept that high concentrations of water-soluble glycosides are expected in flower tissues (Robert and James, 1988). Among the five *Scirpus* species; *S. holoschenus, S. lacustris, S. littoralis, S. maritimus* and *S. multicaule* collected from Iran, all the taxa contain flavonoid sulphates, flavone C and C-/O-glycosides and aglycones, while *Scirpus maritimus* was distinct by the distribution of flavonoid aglycones (Noori *et al.*, 2012). Bogucka-Kocka *et al.* (2011) used phenolic acids from the aerial parts of *Carex* species as chemotaxonomic markers for delimitation of the species. However, several attempted tests of aggregative cluster analysis showed no similarity to the real taxonomical structure of the genus *Carex* with the phenolic acid distribution. There is scope for further investigation using modern analytical techniques such as LC-MS/MS, ambient analytical techniques and head space analytical techniques for the rapid comparison of various taxa among the Cyperaceae family.

Conclusions

The Cyperaceae family is the 10th largest flowering plant families and is ranked the third largest monocot family after Orchidaceae and Poaceae. Across the diverse traditional systems of medicine, plants coming under the Cyperaceae family are popularly employed as potent ethnomedicines owing to the plethora of pharmacological attributes and the presence of diverse phytochemicals. The highly potential trans-stilbene resveratrol and its derivatives are reported from several Cyperaceae members. However, though nearly 5,500 species are reported in the family, literature review revealed only 180 species have been investigated phytochemically, and majority are studied for the volatile chemicals or distribution of flavonoids only. There is scope for detailed phytochemical studies involving solvent extraction, separation through various chromatographic techniques, and characterisation using different spectroscopic techniques, and also through modern hyphenated techniques such as LC-MS/MS and LC-NMR.

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Rameshkumar joined JNTBGRI as a scientific staff in 1998, and took his Ph.D in Chemistry on the topic, 'Phytochemical investigation of some Indian medicinal plants' from the University of Kerala, Thiruvananthapuram, under the guidance of Dr. V. George, former HoD, Phytochemistry Division, JNTBGRI. He had identified new compounds, new natural sources of aromatic and bioactive compounds, in addition to new plant species. He received the prestigious 'Young Scientist' award by KSCSTE, Govt. of Kerala, and the Fellowship of Kerala Academy of Sciences, and published nearly 70 research papers, one book on Phytochemistry of *Garcinia* species, and produced 6 Ph.Ds. He is the Scientist-in Charge of the Central Instrumentation Facility at JNTBGRI, and currently holding the position of Principal Scientist in the Phytochemistry and Phytopharmacology Division of KSCSTE-JNTBGRI, Thiruvananthapuram.

B. Sruthy

Sruthy has excellent academic track record with laurels like First Rank in M.Sc Chemistry, and she took her Ph.D in Chemistry on the topic 'Scientific evaluation of the Ethnoveterinary medicinal plants *Allium cepa* and *Boerhavia diffusa* for the treatment of Bovine mastitis', under the guidance of Dr. M.S. Latha, SN College, Kollam. After her Ph.D, she had exposure in teaching field as guest lecturer in various colleges, and joined the Phytochemistry and Phytopharmacology Division of KSCSTE-JNTBGRI in 2021 as a Senior Research Fellow in a DST, Govt. of India funded project entitled 'Phytochemical profiling of the aromatic Cyperaceae members of south India'. She has several journal publications, seminar presentations and book chapters on various aspects of phytochemistry.

A. R. Viji

Viji took her PhD on the topic 'Taxonomic studies of the family Cyperaceae in Nilgiri Biosphere Reserve, India', from Kannur University, under the guidance of Dr. AG Pandurangan, former Director, JNTBGRI. She has expertise is Plant Taxonomy and Ecology, especially of the Sedges. She has discovered 6 new plant species, in addition to several new records, and has 19 international papers, 1 book chapter, and has worked as Principal investigator of a KSCSTE-WSD research project. She is currently working as Assistant Professor and HoD, Department of Botany, Iqbal College, Peringammala, Thiruvananthapuram.

T. Dhruvan

Dhruvan, after his M.Sc in Botany, started his research activities in plant taxonomy as a Research Fellow in the Calicut University in 1991 and subsequently joined JNTBGRI and has extensive experience in the field of plant taxonomy. He took his Ph.D from Kannur University, on the topic 'Floristic Studies of the Coastal Region of Kerala State', under the guidance of Dr. N. Mohanan, JNTBGRI. He had reported several new records, varieties, and subspecies and has extensive field exposure in coastal plants. Dr. Dhruvan has retired as Scientist in Plant Systematics and Evolutionary Sciences Division of JNTBGRI in 2022.

Diversity of Cyperaceae Plants in South India: Phytochemical Perspective

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The aromatic plant family Cyperaceae, with around 5500 species, is the 10th largest plant family of flowering plants with wide distribution. Most of the Cyperaceae members are treated as notorious weeds mainly because their constitution or potential utilities are less understood. The book provides comprehensive information with regards to the diversity and morphology of Cyperaceae taxa. The traditional medicinal uses and the pharmacology of Cyperaceae members have also been discussed. The major attraction of the book is the compilation of the phytochemistry of Cyperaceae members. Out of the around 5500 Cyperaceae members, only 180 species have been investigated for their phytochemicals, and the phytochemicals reported are listed in the book. In addition, the phytochemistry of *Cyperus rotundus* has been dealt in detail, enlisting 684 compounds reported so-far from the species. We hope the book could be useful, especially to the botanists, environmentalists, agriculturists, phytochemists and pharmacologists, and the compiled data could be useful for chemotaxonomy, phylogeny, chemical ecology and standardization of economically important Cyperaceae species.

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