INSECTICIDAL, ANTIMICROBIAL, ANTIOXIDANT AND PHYTOCHEMISTRY OF CYPERUS SPECIES – A REVIEW

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ABSTRACT

The existence of secondary metabolites in plants have helped to produce natural products or botanicals that can be used as an alternative to chemical or synthetic pesticides. Although Cyperus is considered as aggressive weeds due to its invasive characteristics and may cause rice yield loss, but most of the species have been commonly used for medicinal purpose. Cyperus rotundus were commonly known to possess many biological activities. However, the study on this species have been extensively conducted thus this review will show the chemical compounds found in other selected Cyperus species along with the properties exerted by the species. Terpenes are among the secondary metabolites involved in antimicrobial activities while polyphenols, alkaloids and essential oils are the secondary metabolites that are responsible in antioxidant activities. Insecticidal activities were mostly discovered through the extraction of essential oils.

Key words: Cyperaceae, Cyperus, insecticidal, antimicrobial, antioxidant, phytochemistry

INTRODUCTION

Cyperaceae family or as known as sedge family includes 3000 species and there are 220 species were identified as weeds (Srivastava, et al., 2014). It consists of six largest genera which total up to 3,500 species. The genera include Carex (about 2,000 species); Cyperus (about 650 species); Rhynchospora (about 250 species); Fimbristylis & Eleocharis (about 200 species respectively); Scleria (about 200 species). There were also other large genera such as Bulbostylis (approximately 100 species); Schoenus (about 100 species), and Mapania (about 80 species) (Cyperaceae, 2013). The largest genera are commonly found in tropical regions or warm climate.

Plant description

Figure 2.1 *Cyperus rotundus* (Carr, 2006)

This plant resembles grasses and rushes but however, their distinguished characters are stems with triangular cross-sections and leaves that are arranged spirally. Figure 2.1 shows the figure of one of the Cyperus species. Cyperus have the same embryo type and consistent morphology. Although the appearance of grasses and sedges are similar, but it is differ in various features. Table 2.1 shows the differences between grasses and sedges in terms of leaves, stems, and spikelets.

Sedges can grow up to 0.01 to 5 metres depending on the species. For species such as Scleria, it can grow up to 10 metres long. While the flowers are either unisexual or bisexual and they were reduced in size and complexity. It is arranged around the shortened axis (rachilla) which arises from the centre of the stem. Although most of the sedges were wind-pollinated, but there were a few genera of Cyperaceae pollinated through insect.

Inflorescences for the species which were insect-pollinated are usually contracted into dense heads and the scales are white or yellow. Whitetop sedges from south eastern of United States to South America are among the best-known species which were pollinated by insect.

Fruits for sedges are called achenes (nutlets), but the fruits for genera such as Mapania and Scirpodendron are called drupes. This is because they are single-seeded fleshy fruits.

Table 2.1 Features for grasses and sedges (Cyperaceae, 2013)

Plant part	Grasses	Sedges
Leaves	- Arranged in distichous	- Arranged in tristichous
Stems	- Leaves grow at both side of the stem at the centre of initiation until they encircle it - Hollow except at the nodes	- Leaves meet around the stem on the opposite side of the centre of initiation - Triangular and solid
Spikelets	- Subtended by two scales	- Subtended by one scale

Distribution

This family is widely distributed across the world except for Antartica. They grow in Arctic, temperate and tropical regions but it can be commonly found in tropical regions. It is also commonly found in upland and paddy fields (Marimoto, Fujii, & Komai, 1999).

Chemical constituents

The genus Cyperus possess many biological activities due to the content of secondary metabolites. Each species has different chemical compounds, hence the reason why some of the Cyperus species has been used as food or folk medicine. According to Morimoto et al (1999), there were some studies on the hexane extract or essential oils of Cyperaceae that show the allelopathic property and some natural products such as coumarins, quinones, and sesquiterpenes. It has been reported in several reports on the major volatile constituents of other Cyperus species such as in C. rotundus, there are α-cyperone, cyperene, cyperotundone, and β-selinene; cyperene, caryophyllene oxide and iso-patchouli-4(5)-en-3-one in Cyperus scariosus; α-humulene, humulene epoxide, β-caryophyllene and caryophyllene oxide in Cyperus tuberosus; cyperotundone and piperitone in Cyperus articulates for the red type while for the black type are cedrol and guaia-5-en-11-ol; cyperotundone and cyperene in Cyperus giganteus;

caryophyllene oxide and α-cyperone in Cyperus prolixus; novel eudesmane derivatives in Cyperus alopecuroides; and monoterpenoid α-pinene in Cypers usculentus (Marimoto, Fujii, & Komai, 1999; Rameshkumar, et al., 2011). According to Rameshkumar et al (2011), it is reported that most of the Cyperus species has different guaiane, caryophyllene and eudesmane derivatives as their major constituents.

Pharmacological effects

Due to the abundant content of secondary metabolites, some of the species possessed various properties such as antimicrobial, antioxidant, cytotoxic and many more (Gamal, Hani, & Sabrin, 2015). Table 3.1 shows the properties found within some of the species. *C. rotundus* has been widely known to be one of the famous species to be able to exert various biological properties due to the secondary metabolites content. Other than that, *C. alopecuroides* Rottb., *C. articulatus*, *C. leavigatus*, and *C. longus* have been known to exert antimicrobial activities. However, *C. conglomeratus* Rottb., *C. glomeratus*, *C. esculentus*, *C. papyrus*, *C. scariosus*, and *C. fuscus* were also believed to possess the same activity due to the secondary metabolites content. Other than that, *C. papyrus*, *C. esculentus*, and *C. scariosus* were also able to exert antioxidant activities.

Table 3.1 Properties for different Cyperus species.

SPECIES	PROPERTIES	REFERENCES
Cyperus rotundus	Antimicrobial, antibacterial, antiparasitic, insecticidal, repellent, central nervous effect, neuroprotective effect, anti-inflammatory, antipyretic, analgesic, anticancer, antioxidant, hypolidemic and weight control effect, gastrointestinal effect, hepatoprotective effect, antidiabetic, dermatological, anti-dysmenorrhea effect	- Al-Snafi, 2016 - Marimoto, Fujii, & Komai, 1999
***Cyperus alopecuroides* Rottb.**	Antimicrobial	El-Gohary, 2004
Cyperus articulatus	Anticovulsant, antimalarial, antimicrobial, herbal medicine, nutritional supplemental foods, perfumery, antibiotic, migraine treatment, anticancer	-Nabil, Ayman, & Ayman, 2014 -Hassanein, et al., 2014
Cyperus compressus	Treat cut and wounds, insect repellent	Rameshkumar, et al., 2011
Cyperus scariosus	Medicines, perfumery, insect repellent, incense stick	Rameshkumar, et al., 2011
***Cyperus conglomeratus* Rottb.**	Traditional medicine	Feizbakhsh & Naeemy, 2011

Table 3.1 Properties for different Cyperus species (con't).

SPECIES	PROPERTIES	REFERENCES
Cyperus esculentus* var. *sativus	Traditional medicine, perfumery	Lazarevic, et al., 2010
***Cyperus esculentus* L**	Herbal medicine, nutritional supplemental foods, perfumery	Hassanein, et al., 2014
Cyperus leavigatus	Antimicrobial	Nassar, et al., 2015
Cyperus longus	Antibacterial	Ait-Ouazzou, et al., 2012
Cyperus papyrus	Herbal medicine, nutiritional supplemental foods, perfumery	Hassanein, et al., 2014
***Cyperus fuscus* L burs**	Antimicrobial	Erdem, et al., 2018

Traditional uses

Many of the Cyperus species are used for medicinal purposes and they are also used as food (Gamal, Hani, & Sabrin, 2015). In Asian countries, *C. rotundus* and *C. esculentus* were commonly used as traditional folk medicines. For instance, tubers from *C. esculentus* are used as emollient, spermatogenic, digestive, aphrodisiac, diuretic, galactogogue and promotes menstruation. Plus, the tubers are also edible (Jyoti, et al., 2018). One of the important species in this genus is *C. rotundus*. According to Jyoti et al (2018), *C. rotundus* is a plant that has many biological and pharmacological properties. It is also used as folk medicine to treat various diseases such as skin disease, fever, dyspepsia, diarrhoea, cancer, renal, dysmenorrheoa, vesical calculi and etc. Each plant parts play different functions. Table 4.1 shows the plant parts responsible for different functions. The table showed that rhizomes are among the most extracted plant part due to the ability to exert medicinal purposes. While leaves, seeds, and tubers were mostly used in cooking and baking. However, leaves can also be used as mats include stems which were used to make sleeping mats. Roots showed the same function as rhizomes which were used to treat skin diseases.

Insecticidal activity

The insecticidal activity was identified through essential oils which were extracted using gas chromatography- mass spectrometry (GC-MS) method. According to Janaki (2018), essential oils have been proven to possess the ability to affect insect pests' behavioural reactions and as well as other activity such as contact toxicity, oviposition deterrence, antifeedant effects, ovicidal activity, fumigant toxicity and repellency.

Chemical pesticides are known to give fast result but the downside of the chemical pesticides are they gave negative impact to human health and also to the environment. While for plant derivatives, they can be safely used as they rapidly vanished due to the presence of sunlight, air, moisture and degradation enzymes. This means that the durability and risk for non-target organisms are less. Cyperene, rotundene, α-cyperone and cyperotundone are the most common metabolites found in Cyperus species (El-Gohary, 2004).

C. rotundus has been reported to show insecticidal activity towards diamondback moth larvae. According to Morimoto et al (1999), due to the antifeedant activity is the reason why Cyperaceae family are scarcely damaged by phytophagous insects. It had been revealed that crude hexane extract of Cyperaceae from Japan and Thailand contain antifeedant activity against cutworm (*Spodoptera litura*). However, methanol extracts of Cyperaceae shows that it lacked antifeedant activity.

Table 4.1 Functions for different plant parts on different species

SPECIES	PLANT PART	FUNCTION	REFERENCE(S)
C. rotundus	Tubers & rhizomes	- Natural remedy - Perfumes - Spices - Ayurvedic remedies	Peerzada, et al., 2015
	Leaves	- Food flavouring agent	
	Seeds	- Cooking & bakery products	
	Roots	- Skin disease	
C. articulatus	Rhizomes	- Ailment treatment	Azzaz, El-Khateeb, & Farag, 2014
C. compressus	Whole plant	- Treat cuts & wounds	Rameshkumar, et al., 2011
***C. conglomeratus* Rottb.**	-	- Traditional medicine	Feizbakhsh & Naeemy, 2011
C. esculentus	Tubers	- Consumed fresh/dried/roasted	Kubmarawa, et al., 2005
***C. giganteus* Vahl.**	Stems	- Sleeping mats	Zoghbi, et al., 2006
***C. maculatus* Boëck**	Rhizomes	- Cosmetic and domestic purposes	Mahmout, Bessiere, & Dolmazon, 2014
C. prolixus	-	- Medicinal purposes	Andrade, et al., 2008
C. scariosus	Rhizomes	- Hair oils - Medicines	Srivastava, et al., 2014
	Leaves	- Mats	

Antimicrobial activity

Antimicrobial activity depends on the chemical compounds of the plant species tested. According to Ait-Ouazzou et al (2012), the chemical compounds involved are usually consists two or three major components which has higher concentrations compared to other components. Most of the antimicrobial activities were identified using disc agar diffusion method. The microorganisms were tested using essential oils extracted from different parts of the plant.

Terpene is the largest class in secondary metabolites which consists of monoterpene, sesquiterpene, diterpene, sesterpene, and triterpene (Perveen, 2018). Monoterpene, sesquiterpene, diterpene, and sesterpene are biologically active with antimicrobial activities. Table 5.1 shows the chemical compounds responsible for antimicrobial activities found in different species along with the microorganisms used for each plant species. Terpenes were known to be active against gram-positive (G+ve) and gram-negative (G-ve) bacteria and fungi. *C. rotundus* showed moderate and strongly active towards G+ve bacterias. However, it also showed no activity towards G-ve bacterias which is the same to *C. alopecuroides* Rottb which is only active towards G+ve bacterias. *C. articulatus* showed weak and moderate activity activitytowards G-ve and showed both no and moderately activity towards G+ve bacterias. While, C leavigatus showed no activity towards G-ve microorganisms tested and weak activity towards G+ve microorganisms. *C. longus* only showed weak activity towards both G-ve and G+ve bacterias. *C. fuscus* showed both weak and moderate towards G-ve bacterias.

Moreover, essential oil of *C. compressus* Linn. was reported to have high content of sesquiterpenoids which were said to be one of the chemical compounds which responsible for antimicrobial activity. *C. conglomeratus* Rottb., *C. longus* and *C. glomeratus* L. were reported to consist of sesquiterpene hydrocarbons. Other than that, *C. conglomeratus* Rottb. And *C. glomeratus* L. were also rich in oxygenated sesquiterpenes and a small amount of monoterpenes (Lazarevic, et al., 2010; Feizbakhsh & Naeemy, 2011). Ethanol extract *from C. fuscus* showed a moderate antibacterial activity towards gram-negative bacterias. Essential oils of *C. longus* was least active as it is only reacted towards *Staphylococcus aureus* and *Listeria monocytogenes* at a higher concentration. While for *C. arenarius* and *C. difformis*, both have cyperene as the main constituents. Although there is not much report on the antimicrobial activites on *C. arenarius* and *C. difformis*, but cyperene is belonged to the sesquiterpenoids class which are biologically active with strong antimicrobial activities.

According to Zoghbi et al (2006), *C. giganteus* was reported to be rich in sesquiterpenoids. *C. maculatus* also has cyperene content but it is only 7.8% which is a minor component. The stem of *C. esculentus* has higher monoterpenes than the tubers. While for *C. papyrus*, it has higher monoterpenes on the tubers. Other than that, *C. esculentus* has higher sesquiterpenes in tubers part and stem part for *C. papyrus* (Hassanein, et al., 2014). This shows that *C. arenarius*, *C. difformis*, *C. distans*, *C. maculatus*, *C. giganteus*, *C. esculentus*, and *C. papyrus* has the possibility to possess antimicrobial activity becauses of the terpenes content. *C. scariosus* was tested against various dermatophytes (Keratinomycesajelloi, Microsporum gypseum, Trichophyton equinum, T. mentagrophytes, T. rubrum and T. terrestre) and it shows high activity against the dermatophytes mentioned. This is because this species contained volatile oil which is mainly consists of sesquiterpenoids (Kumar, Chahal, & Kataria, 2017).

Table 5.1 Chemical compounds for different species along with the result on diameter of inhibition zone

SPECIES	CHEMICAL COMPOUNDS	MICROORGANISM(S)					REFERENCES
		-	+	++	+++	++++	
***C. rotundus* L.**	Cyperene	√ G-ve	-	√	√ G+ve	√ G+ve	(El-Gohary, 2004)
***C. alopecuroides* Rottb.**	Caryophyllene oxide	√ G-ve	-	√ G+ve	√ G+ve	-	
C. articulatus	Terpene	√ G+ve	-	√ G+ve	√ G-ve	-	(Azzaz, et al., 2014)
C. leavigatus	Terpenoids & hydrocarbons	√ G-ve	-	√ G+ve	-	-	(Nassar, et al., 2015)
C. longus	Sesquiterpenes hydrocarbons	-	-	√ G-ve G+ve	-	-	(Ait-Ouazzou, et al., 2012)
C. fuscus L. burs	Sesquiterpenes, monoterpenes	-	-	√ G-ve	√ G-ve	-	(Erdem, et al., 2018)

-	No inhibition zone
+	10 mm inhibition zone
++	11-15 mm inhibition zone
+++	16-22 mm inhibition zone
++++	>23 mm inhibition zone

Antioxidant activity

Antioxidants are known as one of the methods used to control lipid oxidation. The usage of antioxidants were known to be the most effective, convenient and also economical means. Lipid oxidation has been identified as the major cause to deterioration process which affected both nutritional and sensory food quality, especially products that were based on lipid. It is important to inhibit the oxidation process, but it has been a challenge towards both manufacturers and food scientists. Other than that, it is also important in contributing to health promotions as the oxidation process can cause oxidative stress and produce destructive cellular effects which are associated with various diseases and health conditions such as inflammation, ageing and atherosclerosis, and many more (Shahidi & Zhong, 2015).

Antioxidants can be naturally or synthesized by chemical means. However, due to the consumers' demand, the usage of naturally occurring antioxidants have been requested due to the safety concerns. It is naturally occur in animals, plants, microorganisms and it can be isolated directly from the source material. Some of the species in Cyperaceae family has been proven to possess antioxidant activity which is due to the abundant content of secondary metabolites. For instance, the extract from *C. papyrus* tuber showed direct antioxidant activity but only when it is extracted using 80% ethanol (Hamed, et al., 2012). The study showed that the plant extracts showed a higher antioxidant activity at a higher concentration.

The methanol and aqueous extracts from *C. rotundus* showed the presence of polyphenols and flavonoids. Orientin is among the main flavonoids found in the *C. rotundus* methanol extract. This compound is known to be able to reduce half the number of cancer associated changes in human cells blood which were exposed to radiation. The tubers from *C. esculentus* were extracted using hexane, ethanol and water. It is proven that the water extract showed a higher and stronger antioxidant activity. Besides that, this species also contained oils which were identified to have a high concentration of essential oils, a powerful antioxidant capacity. The reason why water extract has a higher antioxidant activity than hexane and ethanol may be due to the tannin content, organic acids and water-soluble proteins. However, the ethanol extracts were revealed to have the presence of polyphenol compounds, flavonoid pigments, and carotenoids. These three compounds were proven to be able to act as scavengers for free radicals and active oxygen.

Phytochemical studies showed that essential oils from *C. scariosus* contained polyphenol, flavonol, glycoside, alkaloid, saponins, sesquiterpenoids as the species major components. 50% methanol extracts were extracted from different plant parts contained a huge amount of polyphenols (Kumar, Chahal, & Kataria, 2017). Moreover, the extracts also showed a high total phenolic content and flavonoid content which are among the compounds found to contribute to antioxidant activity.

Conclusion

C. rotundus was known to be able to exert insecticidal, antimicrobial and antioxidant activities. While for other species, not all of the species mentioned can be used for insecticidal, antimicrobial and antioxidant activity. This may be due to the difference of secondary metabolites content in the plant itself. For example, the components found in *C. longus* were reported to have strong antimicrobial activity, but different thing occur as the essential oils of *C. longus* was least active as it is only reacted towards *Staphylococcus aureus* and *Listeria monocytogenes* at a higher concentration. The effectiveness of antioxidants are depend on structural features, concentration, temperature, oxidation substrate, physical state of the system, presence of pro-oxidants, and synergists. Secondary metabolites such as polyphenols, alkaloids and essential oils were known to possess antioxidant activities due to the polar active substances. Polyphenols and flavonoids are important constituents as they inactivate lipid free radicals or they prevented decomposition of hydroperoxides into free radicals. While flavonoids have been known to possess antioxidant activity, antiviral activity, antimicrobial activity, antiplatelet and also antitoxic activity. The reason why the biological activities of the polyphenols in different systems were due to the redox properties which are crucial in absorbing and neutralizing free radicals, quenching singlet and triplet oxygens or decomposing peroxides (Soumaya, et al., 2014). A study showed that the methanol extract contained a higher flavonoid, tannin and polyphenol content than aqueous extract. In conclusion, Cyperaceae has been proven to possess insecticidal, antimicrobial, and antioxidant activity. It possess a great potential to be used in pharmaceutical industries. However, more diverse studies need to be done on the chemical compounds presence in this family to characterize the metabolites responsible for each activity.

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