

The African Spider Plant (*Gynandropsis pentaphylla* – DC. Syn. *Cleome gynandra* Linn.) (Capparaceae): Phytochemistry, Pharmacological and Biotechnological Properties - A Review

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Abstract

African Spider Plant or Cat's Whisker (*Gynandropsis pentaphylla* syn to *Cleome gynandra* Linn. (Family: Capparaceae) is an important leafy vegetable that grows in wild form as a ruderal weed throughout tropical and sub-tropical regions of the world; mainly near human settlements. It is believed to have originated from African and Southeast Asia and might have spread to other parts of the world. It has been used as a medicinal plant in Ayurveda and other systems of medicine as a curative medicine for several ailments such as neuralgia, headache, cough, wounds, anthelmintic, rubefacient, counterirritant, anti-malarial, anti-cancer, anti-HIV and anti-fever *etc.* Even it has been widely used against snake bite and scorpion stings. Except stem, all other parts (leaves, seed, flowers, and roots) proved to have medicinal properties. In fact, the interest in Phytochemistry has began as early as 1906; so far more than 50 compounds have been isolated from different parts of the plant such as Saponnins, Glycosides, lectins, steroids, flavanoids, tannins, triterpenes, resins, phenolic compounds, Glucosinates and arthoquinones. Nutritionally the leaves are rich in Vitamin C, iron and Ca. The seed has high contents of glutamic acid, arginine, aspartic acid, lysine, tyrosine and histidine. Further, the seed also contain higher levels of polyunsaturated oils with high content of oleic and linoleic acids. It has rich anti-oxidants hence it helps in counteracting carcinogenesis. It has antimicrobial and anti-bacterial property with most species showing sensitivity including those that are highly problematic organisms such as *Alternaria*, *Fusarium*, *Candida Colletotrichum* *etc.* These properties have applications in the fields of Agriculture and human medicines. Biotechnologically it is promising because it is a C₄ species that has high growth rate and has the ability to maintain high photosynthetic activity at elevated day temperature. It is closely related to *Arabidopsis thaliana* (a C₃ species) and has NAD-ME type of photosynthesis mechanism. Through comparative analysis of genes and proteins, it is possible to understand the C₄ photosynthetic pathway in general and gene expression and protein function that have altered the evolution of C₃ to C₄ pathway in particular. Further, the transfer of genes from *G. pentaphylla* to *A. thaliana* cannot be precluded and is the

assertively investigating area of research globally. Genetic transformation using GUS for *G. pentaphylla* has been successful. Technique like RAPD has been used to assess the diversity of the morphotypes. The paper discusses the several of the issues related to its origin, Phytochemistry, pharmacological activities and biotechnological interventions.

Keywords: Cat's Whisker; African Spider Plant; *Gynandropsis pentaphylla*; Pharmacological activities; Biotechnological interventions

Abbreviations: AFB1: Aflatoxin B1; LPO: lipid peroxide; DEET: N-diethyl-toluamide; SOD: Superoxide dismutase; CAT: Catalase; GP_x: Glutathione Peroxidase; GSH: Glutathione.

Introduction

Gynandropsis pentaphylla - DC is an old world underexploited vegetable species that occurs naturally as weed or volunteer crop (Kuhn, 1988), nicked as Spider plant or Cat's Whisker's or African Spider flower [1] *Gynandropsis gynandra* (L.) Brigg.) [Prodr. 1 (1824) 238 (Synnon *Cleome gynandra* L. (Sp. Pl. (1753) or *Gynandropsis gynandra* (L.) Briq., in Ann. Conser. Et Jard. Bot. Geneve 17 (1914) 382; *Cleome pentaphylla* L., Sp. Pl. ed. E,e (1763) 938; *Pedicellaria pentaphylla* (L.) Schrank in Roem et Usteri. Mag. Bot. 3 (1790) 11; *Gynandropsis denticulara* DC., l. c.; *Cleome acuta* Schum. Et Thon., Beskr. Guin. Pl. (1827) 293 [1], belongs to the family Capparaceae (formerly Capparidaceae), subfamily Cleomoideae. This family contains about 700-800 species, divided into 45 genera [2]. The genus *Cleome* consists of highly polymorphic herbaceous plants with over 200 species, mainly found distributed in the tropics and pan tropical regions, common to drier areas. These plants are capable of colonizing in pure form along roadsides, edges of rice fields and sandy river banks or in uncultivated lands. *Gynandropsis* grows as a weed in most tropical countries and semi-cultivated as a leafy vegetable or it may be inter-cropped with other annual field crops. It has been regarded as an important genetic resource [3].

The genus *Gynandropsis* is phylogenetically related to Cruciferae (Brassicaceae) [4] and represented by two species in Indian sub-continent viz. *Gynandropsis pentaphylla* and *G. speciosa* DC. The genus *Cleome/Gynandropsis* is and mostly closely related species to *Arabidopsis thaliana* that is known to contain C₄ species is *Cleome* [5,6]. *Cleome* belongs to NAD-ME C₄ subtype. Intriguingly *Gynandropsis pentaphylla* L is a C₄ species [7]

that belongs to NAD-ME type and most closely related to *A. thaliana* genomically [8].

Origin and Centre of Diversity

The origin of *Gynandropsis pentaphylla* is unclear. It is believed to be indigenous to tropical and sub-tropical regions of the world. It is opined to have been originated from southern Asian region or even from Central America. It is believed that it must have originated from tropical Africa and Southeast Asia and have spread to other tropical and sub-tropical countries in the Northern and Southern hemispheres [9]. It occurs in almost all countries of tropical Africa and amazing that it mainly found near human settlements; possibly escapes from earlier introductions. *Cleome gynandra* (Syn: *G. pentaphylla*) is one among the three species of *Cleome* that is known to occur in the weedy form in New World [10]. In India, it colonizes predominantly near human settlements (personal observations). It is interesting that no sightings have been made away from human settlements. The unique behavior of its occurrence indicates that it needs a different manure/soil or organic content or accumulation of household refuse including micro nutrients which may be available in and around human settlements [11,12]. Fascinatingly, even association of microbes for its establishment cannot be precluded. It is an aggressive colonizer and capable to grow in waste lands, dumping grounds, uncultivated crop lands and vacant areas. It has been in abundance in cultivated fields also [13]. In fact, it is the most common weed flora of the arable fields in Egypt [14].

Botanical Description

Gynandropsis pentaphylla is an erect herbaceous edible annual plant, branched, stout and grows up to 1.5 m in height depending on the environmental conditions [15]. It has long tap root, with a few secondary roots with root hairs. Stems and leaf petioles are thickly glandular and rarely glabrous. It exhibits variable pigmentation, on stem,

from green to pink, or violet to purple although its inheritance is obscure. Since homogenous purple or green stem lines could not be established, these variations are thought to be due to pleiotrophism and/or pollination mechanisms. Leaves are alternate, digitatively palmate and petiolate. Most often each leaf has 5 leaflets (hence the name pentaphylla, however varies from 3-7), which are pinnately dissected and sessile, and petioles length varies from 3-23 cm. Cotyledonary leaves have single leaflets and oppositely arranged on the stem. Leaves are obovate/elliptic in shape (~ 2-10 cm long and 2-4 cm wide). Inflorescence is usually 30 cm in length and showy with terminated and auxiliary determinate racemes, bearing flowers with long pedicels, arise singly in the axils of small sessile and simple to trifoliate bracts. The bracts are much smaller than the leaflets. Flowers (floral formula = $K_4C_4A_6G$) are of 1-2.5 cm in diameter, glandular and have 4 sepals, 4 narrow clawed petals (white, pale or pink or lilac) and 6 stamens with long purple (~8 mm in length) filaments. The fruit is a long stalked, dry, dehiscent siliqua, which is a spindle-shaped capsule can grow up to 12 cm and 8-10 mm wide. The capsules are green, turn yellow when ripe and dehisce easily when dry. The seeds are small sub-orbicular and sharply tuberculate, with concentric and irregular cross-ribs. They are rough and grayish – black in color. The seed cleft is narrow, each seed measures 1.0 – 1.5 mm in diameter. The seedling has oblong petiolate cotyledonary leaves, and petiolate trifoliate almost elliptical leaflets. *G. pentaphylla* is listed in the group of poisonous seed producing species [16].

Reproductive Biology

Gynandropsis pentaphylla, has the ability to colonize and flower early, is an andro-monoecious, regarded as 'super dioecy [17], but can self- or cross pollinate owing to three types of flowers viz. flowers can be protoandry (shedding of pollen first: leads to no pollination), homogamous (anthers shedding pollen when the stigma are receptive: leads to predominant selfing and protogynous (stigma receptive before pollen shedding: leads to cross-pollination). Pollination is totally passive but helped predominantly through entomophilies (especially honey bees) and to some extent through spiders. Anemophily is another major method of pollination [18]. Islam, et al. [19] Reported that the anthers in Cat's Whisker dehisce longitudinally inward to the centre of the flower. Fruits occur in zones at the inflorescence stalk, alternating with non-fruited sterile zones (caused by pistil abortion or occurrence of flowers having reduced gynophores). In fact, the plants produce bisexual flowers (with anthers and gynophore) first (5-20) depending on growth conditions,

followed by 10-15 male flowers (rudimentary gynophores) and a <10 flowers which are protogynous (gynophores maturing first). Because of this peculiar flowering behavior, there shall be two zones of pods, first zone in the base of the inflorescence that arise predominantly due to selfing and the second whorl pods that arise predominantly due to cross pollination [20]. The pollination mechanism of Cat's Whisker is not fully understood, but is a unique model where the plant tries to exploit both the mechanisms in a temporal way. It has evolved both the strategies of selfing and crossing at individual plant level to maximize the fitness. Observations have indicated that there is a very high uniformity within morphotypes in a given locality and also across localities for plant characters. It is argued that such uniformity can only arise from a predominantly self-pollinating species which needs to be quantified. Sangeetha, et al. [20] made an attempt to understand the complexities related to pollination mechanism of Cat's Whisker in the light of selfing vs siring strategies and discussed from the point of survival strategy of plants through differential seed viability owing to 5-8 month's dormancy [21].

The seed germination of *G. pentaphylla* is highly erratic and may even take up to one year. The species has seed dormancy of 5-8 months depending on the region [21-23]. The dormancy can be disrupted by incubating the seeds at 40°C for 1-5 days, the best mock-up which is on par with natural simulation found in the wild [21].

Genetic Diversity Assessment

Gynandropsis pentaphylla is known to be widely distributed in tropics and sub-tropical regions, hence could lead to geographical diversity. Genetically different morphotypes of *G. pentaphylla* have been primarily attributed to edaphic factors and mutation load. In fact, geographical separation of morphotypes is most common and may differ in phenological patterns. Hence it is expected that they may show high proportion of selfing within morphotype populations. Population more often analogous in phenotype, in a locality, might be the result of pronounced autogamy. Attempts are being made to assess the diversity through taxonomic description and RAPD analysis [24]. One of the way by which species are identified through taxonomic descriptions however, it is interesting that even stomatal frequency, both upper and lower epidermis, can also be used to distinguish between co-generic species [25] or can be extended to morphotypes; *Gynandropsis pentaphylla* has lowest stomatal frequency (upper epidermis = 16.67% and lower = 2.32%) compared to *Cleome viscosa* and *C. rutidosperma*

[26]. Kolberg HH, [27] made an observation that the morphological variation within *Gynandropsis pentaphylla* is not much, however plants differ in smell; aromatic and non-aromatic individuals may be found within a locality, such variation has not been recorded anywhere.

Nutritional Status

Spider plant is an important traditional leafy vegetable crop of African countries and forms a substantial part of the diets in population with low and middle level income groups [28-31]. Purple stem types are nutritious and more tolerant to insects, but susceptible to diseases caused by mildew. *Gynandropsis pentaphylla* is known to contain high levels of beta-carotene, Vitamin C (retained even after cooking; most leafy vegetables lose Vitamin C after cooking) and moderate levels of Calcium and Magnesium. Boiling the leaves may reduce Vitamin C content by 81%, while drying reduces by 95% [32,33]. It has been a major source of iron in diets of lactating woman. It has high crude protein, lipids and phenolic compounds. The crude protein varies from 17.90% (green stemmed plants) to 31.40% (purple stemmed plants). Amino acid profile of spider plant was found to be better and higher than groundnut [34]. Amino acid analysis of defatted meal has indicated that glutamic acid content (about 13%) is highest followed by arginine, aspartic acid, lysine, tyrosine and histidine. Seeds of spider plant contain high levels of polyunsaturated oils and the lipid content varies from 25.10% (green stemmed plants) to 29.60% (purple stemmed plants). Oleic and linoleic acids account for about 81% (oleic about 22% and linoleic about 59%) of total fatty acids. Palmitic and Stearic are about 11% and 7% respectively. Arachidic and eicosenoic fatty acids are in traces [35]. Fascinatingly, *G. pentaphylla* has high antioxidants such as β -carotene (pro Vitamin A carotenoids) and Vitamin C which contributes in humans towards resistance to diseases including diabetes, cancer, coronary heart diseases, neuro-degenerative ailments, rheumatoid arthritis *etc.* Increased soil fertility increases crude proteins but decreases β -carotene, ascorbic acid and

iron contents of the leaves and no effect on phenolic compounds or on the calcium and sodium content [15]. Raja KM, [36] estimated carotenoid composition and vitamin A activity, exclusive in leaves, of *Gynandropsis pentaphylla* along with several other Green leafy vegetables and showed that it has good amounts of Neoxanthin, Lutein (32%) and Zeaxanthin (Xanthophylls) and β -carotene (34%) with no α -carotene (provitamin A carotenoids). Sheela K, et al. [37] showed that *Gynandropsis pentaphylla* has high fiber (2.6 gm/100 gm of dried leafy vegetable), iron (20.18 mg), Calcium (233 mg), Ascorbic acid (17mg) and Oxalic acid (28.80 mg).

Spider Plant Usage in Medicine/Traditional Medicine

Cat's whisker has been used for years in Indian traditional medical practices *vis a vis* African countries [30,38-42]. *Gynandropsis pentaphylla* has been scripted as an important medicinal plant in *Amarakosam*, a text written between 1-6 AD from among 176 plant species [43]. Except stem, most parts (leaves, tender pods, seeds, roots, flowers and whole plants) have several medicinal properties such as anti-inflammatory, anti-cancer, anti-fever, anti-malarial, anti-HIV, anti-bacterial, anti-mycotic/fungal, anti tick and anti-insecticidal *etc* [15,44]. The aqueous extract of *Cleome gynandra* when consumed in small quantities facilitates childbirth which has been reasoned to be presence of Oxytocin; a hormone that promotes uterine contractions [45]. The use of *Cleome gynandra* in Indian ethnopharmacology for treatment of bronchitis, boils, earache, eye wash, disinfectant and nasal congestion, analgesic, headaches, epileptic fits, facilitates childbirth in pregnant women, stomach-ache, constipation, conjunctivitis, thread-worm infection, chest pains, arthritis, inflammation, neuralgia, rheumatism, localized pains, pus, anaemia, uterine complaints, malaria, pneumonia, head lice and reduce coughing is well documented [46]. (Table 1).

Plant/Part	Traditional uses	References
Whole plant	Anthelmintic and rubefacient	[47,48]
	Treatment of malaria, piles, rheumatism and in tumor	[49]
	Treatment of migraine, vomiting, diphtheria, vertigo, headache, pneumonia septic ears, and stomach ailments	[50]
	Treatment of scorpion stings and snake bites.	[51,15]
	Digestive aid and treatment for stomach disorders	
	Medication for oral infection and diarrhoea	

	Insecticidal, anti-feedant and repellent property	[15,52-55]
	Anti tick property	
	Has insecticidal property	
	Insecticidal property against Amaranth leaf caterpillar (<i>Hymenia recurvalis</i> Fabricius)	[36,54,56]
	Insecticidal activity against Diamond Back Moth (<i>Plutella xylostella</i>)	
	Diet for lactating woman and blood formation	[15]
	To induce labor during childbirth (Uganda)	[45]
	To induce labor during childbirth (Uganda)	[45]
	Mosquito repellent property	[57]
	Acaricidal property	[55]
	Has anti-microbial property	[58]
	Curative medicine for neuralgia, headache, cough, wounds, anthelmintic, rubefacient, counterirritant	[51]
	Used for stomach ailment and to treat headaches	[3]
	Has anti-HIV and anti-bacterial activities	[59]
Alcoholic extract of entire plant	Anti-cancer activity against human epidermal carcinoma of the nasopharynx in tissue culture and hepatoma 129 in mouse	
Leaves/tender leaves and young shoots	As disinfectants	[47]
	Inhalation of the leaves relieves headaches to treat neuralgia and stiff neck	[15]
	Leaf juice and oil is used for earache and eye wash	[29,60]
	External application to prevent sepsis	[15,61]
	Nostrils application to treat epileptic fits	
	As vesicant and rubefacient for treatment of rheumatism and localized pains	
	Sap is used to cure recurrent malaria	
	Applied as poultice	
	Anti irritant	
	Administered to persons who has lost blood and treat anemia (Ex. Warriors)	
	Treatment of arthritis and skin diseases	
	Treatment of uterine complaints	
	Pharmacognostical and <i>in vitro</i> anti-oxidant property	[62]
Antinociceptive activity	[63]	
Leaf decoction/ juice / boiled leaves/ paste	Leaf juice is applied externally during pyorrhea and used as wormicide	[64]
Flower	Juice of leaves is a remedy for pain in the ear	
	Orally administered to facilitate child birth, to relieve stomach ache, beneficial in constipation, thread-worm infection, conjunctivitis, oral ailments, convulsions and bilious disorders	[62]
	Decoction used in Chronic fever treatment	[65]
	To relieve chest pain	[15,61]
	Are chewed or cooked or are sun dried and drank in tea to treat sexual impotence or erectile dysfunctions in men	[45]
	Used in the prevention of miscarriages and treatment of colic pains when boiled or cooked as food.	
	Used to cure Scurvy	[15,31]
	Leaf paste is used in rheumatism, neuralgia, headache and stiff neck	[66]
Used in the prevention of miscarriages and treatment of colic pains when boiled or cooked as food.		
Are chewed or cooked or are sun dried and drank in tea to treat sexual impotence or erectile dysfunctions in men	[45]	

Stem	Methanol extract has anthelmintic activity	[67]
	Methanol extract has antibacterial property	[46]
	Antinociceptive and anti-inflammatory property	[68]
Root/s	Decoction is used to treat fevers	[15]
	Juice is used to relieve scorpion stings	
	Are chewed to induce uterine contractions and removal of retained placenta and control post partum bleeding in childbirth process	[45]
	Are chewed or cooked or are sun dried and drank in tea to treat sexual impotence or erectile dysfunctions in men	
	Used in the prevention of miscarriages and treatment of colic pains when boiled or cooked as food.	
	Infusion of the roots is used to ease child birth	
Seed	Have anthelmintic property and rubefacient	[69,70]
	Internally used for expelling round worms	[71]
	Externally used as counter-irritant	
	Can be used as substitute for mustard	
	An infusion is administered to reduce coughing	[15,61]
	Used to treat stomach ache in equines by veterinarians	
	Used as piscicide	
	Anthelmintic, carminative and antispasmodic.	[72]
	Used to feed birds	
		Are mixed with oil and applied to scalp to treat head lice.
Seed Oil	Fish poison	[69,70]
	Anthelmintic activity against <i>Pheritima posthuma</i>	[72]
	As insecticide especially against ticks in livestock	[50]
Seed cake	Used as animal food.	
Seed Paste	Is applied externally to expel the vermin from the hairs	[65]
Seed powder	Expulsion of Round-worms	[15,61]

Table 1: Plant and Plant parts of *Gynandropsis pentaphylla* which is having medicinal property compiled.

Phytochemistry

Gynandropsis pentaphylla is known to produce several compounds like alkaloids, flavanoids, sugars, amino-acids, steroids, saponins and essential oils which have high value in both folk and traditional medicine. Various species of *Cleome* are used medicinally in India-China, Philippines, Island, North and Central America. Glycinebetaine was the only betaines compound found in *Cleome* species while betaines were not detected in *Gynandropsis* [73]. *G. pentaphylla* leaves are rich in phytochemical substances like Saponnis, Glycosides, lectins, steroids, flavanoids, tannins, triterpens, resins, phenolic compounds and arthoquinones. Capparaceae contain considerable amounts of Glucosinates [74]. Leaf extracts are found to be rich source of free radical scavengers -glutathione and superoxide dismutase. Seeds contain glucosinolates, cleomin and glycocapparin and an acrid volatile oil comparable with mustard oil [71].

Gynandropsis pentaphylla leaves possess surface flavonoids [75]. Ten methylated flavonoids were isolated and identified as 5,7,4'-trihydroxy-3-methoxyflavone (isokaempferide), 5,7,4'-trihydroxy-3,3'-dimethoxyflavone, 5,7,4'-trihydroxy-6,3'- dimethoxyflavone (jaceosidin), 5,4'-dihydroxy-3,6,7-trimethoxyflavone (penduletin), 5,7,3',4'-tetrahydroxy-3,6-dimethoxyflavone (axillarin), 5,7,4'-trihydroxy-6,3'-5'-trimethoxyflavone, 5,4'-dihydroxy-3,6,7,3'-tetramethoxyflavone (chrysosplenetin), 5,3'-dihydroxy-3,6,7,4',5'-pentamethoxyflavone, 5,4'-dihydroxy-3,6,7,8,3'-pentamethoxyflavone and 5-hydroxy-3,6,7,3',4',5'-hexamethoxyflavone. It was found that *G. pentaphylla* is a rich source of several secondary metabolites like sitosterol, kaempferol, 5-7-dihydroxychromone, 5-hydroxy-3,7,4-trimethoxy flavones, (20S, 24S)-epoxy-19, 25-dihydroxydammarane-3-one hemietal, luteolin and cyanogenetic glycosides. The leaves are rich source of anti-oxidants that are known to inhibit carcinogenesis [76]. Twenty eight compounds have been identified so far using Gas chromatography and/or Mass Spectroscopy

techniques in *G. pentaphylla* oil. Carvacrol, was found to occur in largest quantity ($\approx 30\%$) followed by trans-phytol ($\approx 24\%$), linalool ($\approx 13\%$), trans-2-methylcyclopentanol ($\approx 8\%$) and β -caryophyllene ($\approx 5\%$), The repellent compounds, in oil, were m-Cymene, nonanal, 1- α -terpineol, β -cyclocitral, nerol, trans-geraniol, carvacrol, β -ionone, trans-geranylacetone and neroidol against Tick (*R. appendiculatus*). Methyl isothiocyanate which occurred in *G. pentaphylla* oil, at a relatively high percentage (2.1%) was the most significant component to repellency [44,47,68,77-79] and Jain AC, et al. [78] had reported isolation of Hexacosanol, a-D-glucoside of a sitosterol, a free a-sitosterol and kaemperol in addition to minor compounds such as 5,7-dihydroxychromone, 5-hydroxy - 3,7,4- trimethoxyflavone and leteolin.

Pharmacological Activities

Antimicrobial Property

G. pentaphylla is known to possess antibacterial property and suppress the growth of several bacteria, which are either gram positive or gram negative, such as *Staphylococcus aureus*, *Bacillus subtilis*, *EntE. coli*, *Salmonella* sp. *Shigella* spp. *Salmonella typhimurium* and *Salmonella enteritidis*. Uma B, et al. [80] and fungal species - *Candida albicans*, *Candida tropicalis* and *Candida krusei* isolated from diarrhoeal patients *Penicillium* sp. *Fusarium oxysporium*, *Aspergillus niger*, *A. flavus* and *Alternaria*. Sp (Table 2). Bobbarala V, et al. [81] showed that leaf tannins of *Gynandropsis pentaphylla* had antifungal activity against phyto-pathogenic fungi *Aspergillus niger*.

Plant tissue	Solvent for extraction	Growth of Bacterial/ Fungal organisms	Effect	Reference
Species of Bacterial origin				
Seed	Acetone	<i>E. coli</i> ,	Highly susceptible	[46,81]
		<i>Staphylococcus aureus</i>		
	Methanol	<i>Aspergillus niger</i> ,	Highly susceptible	
		<i>A. flavus</i> , <i>Metarhizium anisopliae</i>		
Leaves	Ether, Benzene	<i>Agrobacterium tumefaciens</i>	Highly sensitive	[46]
Leaves	Methanol	<i>Aspergillus niger</i>	inhibited	[81]
Leaves Stem		<i>Bacillus cereus</i> ,	Sensitivity	[47]
		<i>B. subtilis</i> , <i>Staphylococcus aureus</i> <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i> , <i>Streptococcus faecalis</i>	<i>B. subtilis</i> > <i>S. faecalis</i> > <i>B. cereus</i> > <i>E. coli</i> > <i>S. aureus</i> > <i>P. aeruginosa</i>	
		<i>Streptococcus pyogenes</i> <i>Bacillus cereus</i> <i>Staphylococcus aureus</i>	Sensitive	
Species of Fungal origin				
Leaves	Benzene, Ether	<i>Penicillium notatum</i>	Highly sensitive	[46]
Leaves	Methanol	<i>Candida albicans</i> ,	Sensitive	[44,47]
		<i>Penicillium spp.</i> ,		
		<i>Fusarium oxysporium</i> , <i>Aspergillus niger</i> ,		
		<i>Aspergillus flavus</i>		

Table 2: Plant and plant parts of *Gynandropsis pentaphylla* effective against bacterial and fungal growth compiled

Anticancer Activity

The alcoholic extract of the entire plant of *Gynandropsis pentaphylla* has been showed to possess anti-cancer property (human epidermal carcinoma of the nasopharynx

and hepatoma in mice [82,83]. Phytochemical analysis of the plant revealed that the seeds contain Cleomin, hexacosanol, free β -sitosterol and kaempferon, with antioxidant activity are known to inhibit carcinogenesis.

The glucosinolates and isothiocyanates found in the plant are good chemo preventing agents [84]. Pretreatment with *G. pentaphylla* extract was shown to impart protection to the antioxidant enzymes which are associated with carcinogenesis viz. Superoxide dismutase (SOD), Catalase (CAT), glutathione peroxidase (GP_x), reduced glutathione (GSH), either directly or indirectly [83]. It was found to reduce the effect of Aflatoxin B1 (AFB1), a potent mycotoxin and mutagen. Increased levels of malondialdehyde and reduced GSH were observed in mice which were pretreated with *G. pentaphylla* extracts. Petit GR, et al. [85] reported the isolation of six cancer cell growth inhibitors known as flavone apegenin and flavonols which inhibited the murine P₃₈₈ lymphocytic leukemia.

Antinociceptic and Anti-Inflammatory Activity of *Cleome gynandra*

G. pentaphylla is known to possess antinociceptive activity [68] (traditionally used in the treatment of pains) and possibly flavonoids and tannis modulate the opioid receptors in the region of action [63]. Ethanolic extract of *Cleome gynandra* leaves has anti-inflammatory activity [86,87]. The extract significantly decreased the lipid peroxide (LPO) content of the exudates, liver and spleen and the activity of Y-glut amyl transpeptidase.

Anti-Tick Property

G. pentaphylla is also known as anti-tick pasture plant [53,55] and exhibit repellent and acaricidal effects. Seeds of *G. gynandra* contain glucosinolate degradation products such as methyl isothiocyanate, known to be toxic to arthropods. Lwande W, et al. [55] Identified and tested the repellent effects of *G. pentaphylla* seed oil on *R. appendiculatus* ticks and found that the repellent effect was comparable with that of N,N-diethyl-toluamide (DEET) at higher dosage. Fractionation studies of the oil revealed identification of m-cymene, nonanal, 1- α -cyclocitral, β -cyclocitral, nerol, trans-geranyl, carvacrol, α -ionone, trans-geranyl acetone, nerolidol and cedrene as the main repellent compounds. All these compounds have repellency effect on par with DEET. Nyalala S, et al. [88] Reported planting of *G. pentaphylla* in beds of cut-flower roses reduced the incidence of red spider mite (*Tetraanychs urticae*) infestation significantly without any detrimental effect on productivity or flower quality. This has opened up a possibility of eco-friendly and cost effective method to control incidences of ticks in rose cultivation, saving them from using hazardous chemicals. *G. pentaphylla* seed paste is being externally applied to

expel the vermin from the hairs by the people living in Nara desert of Pakistan [65].

Anti-Insecticidal and Anti-Mosquito Repellent Property

G. pentaphylla has long known to possess insecticidal, anti-feed ant and insect repellent properties [52-54,89-93]. Cabbage and related crops intercropped with spider plant was found to suffer less from diamond back moth larvae. French bean intercropped with spider plant, the beans are less affected by flower thrips and the seed are found better for export. Herbal extract of *G. pentaphylla* was effective in reducing the population of Amaranth leaf caterpillar (*Hymenia recurvalis* Fabricius) when sprayed before flowering [56].

Biotechnological Interventions

Gynandropsis pentaphylla is a C₄ species characterized by rapid growth and high dry matter production (3-5 times more per unit leaf area and unit time than C₃ plants [3] and has been attributed partly to diheliotropic leaf movement [94] capable of withstanding high day time temperatures, intense sunlight and drought. Lowest stomatal frequency of *G. pentaphylla* compared to co-generic species can be an indicative of drought resistance mechanism. It is reported to exhibit high photosynthetic activity at high temperature and radiation. *Cleome gynandra* (*G. pentaphylla*) also has very high intrinsic ability of tolerance to water stress and high recovery compared to *C. speciosa* [95]. The most closely related genus that known to contain C₄ species is *Cleome* [5,6]. *Gynandropsis* belongs to the NAD-ME C₄ subtype. Cat's whisker has several properties that can be used in human health programs and crop protection. Nutritionally it has high levels of β -Carotene and Vitamin C and moderate levels of calcium, magnesium, iron, zinc. The plant contains high crude protein, lipids and phenolic compounds. Trypsin inhibitor activity in spider plant is low (0.45 and 0.32 μ g/mg dry weight of plant respectively before and after boiling for 5 min) compared with the soybean (1.32 and 1.03 μ g/mg dry weight). Interestingly spider plant retains Vitamin C even after cooking and the reason for it is obscure. Human body has an antioxidant defense system that is believed to be strengthened by antioxidant rich-diets. β -carotene (pro-vitamin A caretonoids) and Vitamin C which are high in Spider plant can contribute to the total dietary antioxidant capacity.

It is known to have antibacterial, antimycotic, antifungal, anti-tick, anti-acaricidal, anti-inflametary [86,87] anti-helminthic [67,72], anti-insecticidal and anti-

malarial properties. Aflatoxin B₁ induce lipid peroxidation is one of the main manifestations of oxidative cellular damage. Oxidation of AFB₁ results in the formation of 8, 9-epoxide intermediate, dihydrodiol metabolite and eventually dialcohol product via the action of AFB₁ aldehyde reductase. DNA damage and formation of DNA adducts may be the critical step in carcinogenesis as these radicals initiate lipid peroxidation, a damaging processing in biological systems that leads to diminished antioxidant status. Malondialdehyde, end product of lipid peroxidation cross link with DNA, and proteins, thereby promoting carcinogenesis. *G. pentaphylla* extracts effectively control the rate of lipid peroxidation (kaempferol- potential inhibitor of lipid peroxidation) [62,96].

Arabidopsis thaliana has been regarded as a model plant species, of eukaryotic origin, for molecular studies. One area where it has highest applications is in assessing gene functions through gene reporter studies and candidate genes either knocked down or mis-expressed strategies. Interestingly, *Gynandropsis pentaphylla* is most closely related species to *A. thaliana*. While *A. thaliana* is a C₃ plant, *G. pentaphylla* is a C₄ plant with NAD-ME type of photosynthesis mechanism. It is very interesting that it exhibits age dependent plasticity of C₄ decarboxylation biochemistry where young leaves show C₃-C₄ intermediate state, mid-aged leaves show C₄ with NAD-ME type and in older leaves it is PEPCK type [97]. It is argued that through comparative analysis of genes and proteins, it is possible to understand the evolution of C₄ photosynthetic pathway in general and gene expression and protein function that have altered the evolution of C₃ pathway to C₄ pathway. It is possible to transfer a few candidate genes from *G. pentaphylla* to *A. thaliana* for meaningful comparative analysis. Genetic transformation of *G. pentaphylla*, a C₄ plant which is NAD-ME type [98] has been successful using *Agrobacterium tumefaciens* [99]. In fact, previously an attempt has been made to propagate *Cleome gynandra* through tissue culture [100]. Thalamus, gynandrophore and root segments were used as explants and cultured on MS medium with various combinations and concentrations of auxins, cytokines and coconut water. Multiple shoots were induced from thalamus culture directly on medium fortified with kinetin and coconut water. Callus generated shoot buds were in highest frequency (95 per cent) from thalamus explants followed by gynandrophore. Rooting from shoots was obtained on medium containing IBA. A high BA to NAA ratio produced leathery leaves in culture besides shoot differentiation, 2,4-D was not suitable for organogenesis. Finally regenerates were successfully transferred to soil [101].

Conclusion

In conclusion, the *Gynandropsis pentaphylla* has high potentiality for exploitation from the point of biotechnological interventions mainly from the point C₄ photosynthetic mechanism. In addition, it has several pharmacological properties which can be exploited in the field of medicine, agriculture, livestock management etc.

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