J. Biol. Chem. Research. Vol. 42, No. 1&2, 76-88, 2025
Ms 42/1&2/23/2025

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REVIEW ARTICLE

Received: 20/09/2025 Revised: 28/11/2025 Accepted: 29/11/2025

The Ethnobotany and Phytopharmacology of *Pavonia odorata*: A Review

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ABSTRACT

The present overview, conferring the chemical nature and biological impact of the complete plant of Pavonia odorata (Malvaceae), is based on the accessible literatures. Quite a lot of phytochemicals have been extracted from P. odorata, including ageratochromene, palmitic acid, hexahydrofarnesyl acetone, β-eudesmol and β-caryophyllene oxide as the major constituents. Different compounds obtained from this species have been evaluated to find out or confirm an array of pharmacological effects. The data analyzed in numerous reports on the chemical and pharmacological characteristics of P. odorata sustain the view that the plant retains many therapeutic properties, signifying its prospects in herbal remedy. Lastly, suggestions for further scope of research and ways to further exploit the pharmacological properties of P. odorata are presented in this appraisal.

Key words: Pavonia odorata, Medicinal Plant, Phytochemicals and Pharmacology.

INTRODUCTION

Since last few years, there has been increase in the demand of herbal medicine and gaining much popularity due to their less or no side effects (Fatima *et al*., 2012). The rise in the number of reviews and research publications, clearly demarcates that medicinal plants are of great use in securing human health (Neto *et al*., 2002; Sundaram *et al*., 2011; Gantait *et al*., 2014a). Medicinal plants forms the major source for constituents in indigenous medicine, modern medicines, food supplements, nutraceuticals, folk medicines, bioactive principles, pharmaceutical intermediates and synthetic drugs (Gantait *et al*., 2014b; Gritto *et al*.,2015). *Pavonia* spp. has recently been focused for many of its medicinal properties. A number of publications have shown that the plant extracts and formulationshave a wide range of potential applications in pharmaceutical and cosmetic industries (Singhai *et al*., 2009; Randive and Hatekar, 2010).The genus *Pavonia* consists of almost 70 species that possesses attractive flowers having pleasant odor. *P. odorata,* commonly known as Sugandhabala, one of the most valuable medicinal plant species under the family Malvaceae.

The shoots and roots of this plant are exceptionally aromatic. In Ayurveda, the plant extract has been evidenced to be pharmaceutically active as cooling, carminative, demulcent, diaphoretic, and fever (Kashima *et al*., 2014).The present chapter summarizes the botanical features, traditional uses and recent advancement regarding the pharmacology of *P. odorata* including the areas requiring further research. The medicinal activities of this genus are so much vigorous that a broader range of study is needed to be carrying out to assess the entire pharmacological role in various ailments. These gaps create a vital research prospect to explore more about the phytochemistry and pharmacology of *P. odorata* considering its medicinal properties. Although this plant confirmed its scientific potential as antioxidant, immunomodulatory, antifungal, antibacterial, antidiabetic, antiulcer, antitumor and cardiovascular activity, they are also reported to contain several types of essential oils, alkaloids and flavonoids as active chemicals that result in its biological effects.

VERNACULAR NAMES

English: Fragrant swamp mallow, fragrant pavonia
Hindi: Bala, Sugandha-Bala, Sugandhabala
Kannada: Bala Raakshasi, Bala Rakkasi, Bala-Rakkasi-Gida, Balaraakshi Gida, Balarakkasi
Malayalam: Iruveli, Kuruntotti
Marathi: Kaalaavaala, Kala-Vala, Kalavala, Randodaki, Sugandhabala, Sughandabala
Sanskrit: Ambu, Ambunamaka, Bala, Balaka, Barhishtha, Harivera, Hribera, Hrivela
Tamil: Anantai, Anantavariti, Anantavariti, Anantavariticceti, Antai, Antaiyitan, Arttavacceti
Telugu: Chirubenda, Chitlebunda, Chitti Benda, Chittibenda, Cittibenda, Erra-Kuti, Errakooti
Tibetan: Ba-La-Ka

TAXONOMY

Kingdom Plantae
Order Malvales
Family Malvaceae
Sub family Malvoideae
Tribe Hibisceae
Genus *Pavonia*
Species *Pavonia odorata*

DISTRIBUTION

*P. odorata*is particularly distributed in the Indian subcontinent, Africa, Sri Lanka, Pakistan and Myanmar (Singhai *et al*., 2009). In India, it is most likely to occur in moist deciduous forests up to an altitude of 1000 m. It generally grows in the warmer parts like Andhra Pradesh, Bihar, Karnataka, Kerala, Orissa, Maharashtra Punjab, Rajasthan, Tamilnadu, Uttar Pradesh and West Bengal (The Wealth of India, 1966) (Figure 1).

Botany

Macroscopic characters

*P. Odorata*isan annual branching plant that reaches the height of 45-90 cm, stems viscously covered with pubescence and short hairs. Leaves are2.5-7.5 cm long, 3-5 lobed, ovate in shape, the lower ones are entire, stellate-hairy on both surfaces; lower petioles are longer than the blades (Figure 2).

Peduncles are as longas the leaves and flowers are clustered at the end of the branches. Bracteoles and sepals are lanceolate. Corolla is pale pink or white, twice the length of the calyx. Carpels are gibbous on their backs, wingless and unarmed dehiscent (Singhai *et al*., 2009); fruit is spherical, smooth mericarps. Roots are of diverse sizes; surfaces are rough and brown. Cork is peelable and emits musk like aromatic odour (Sethi, 2015).

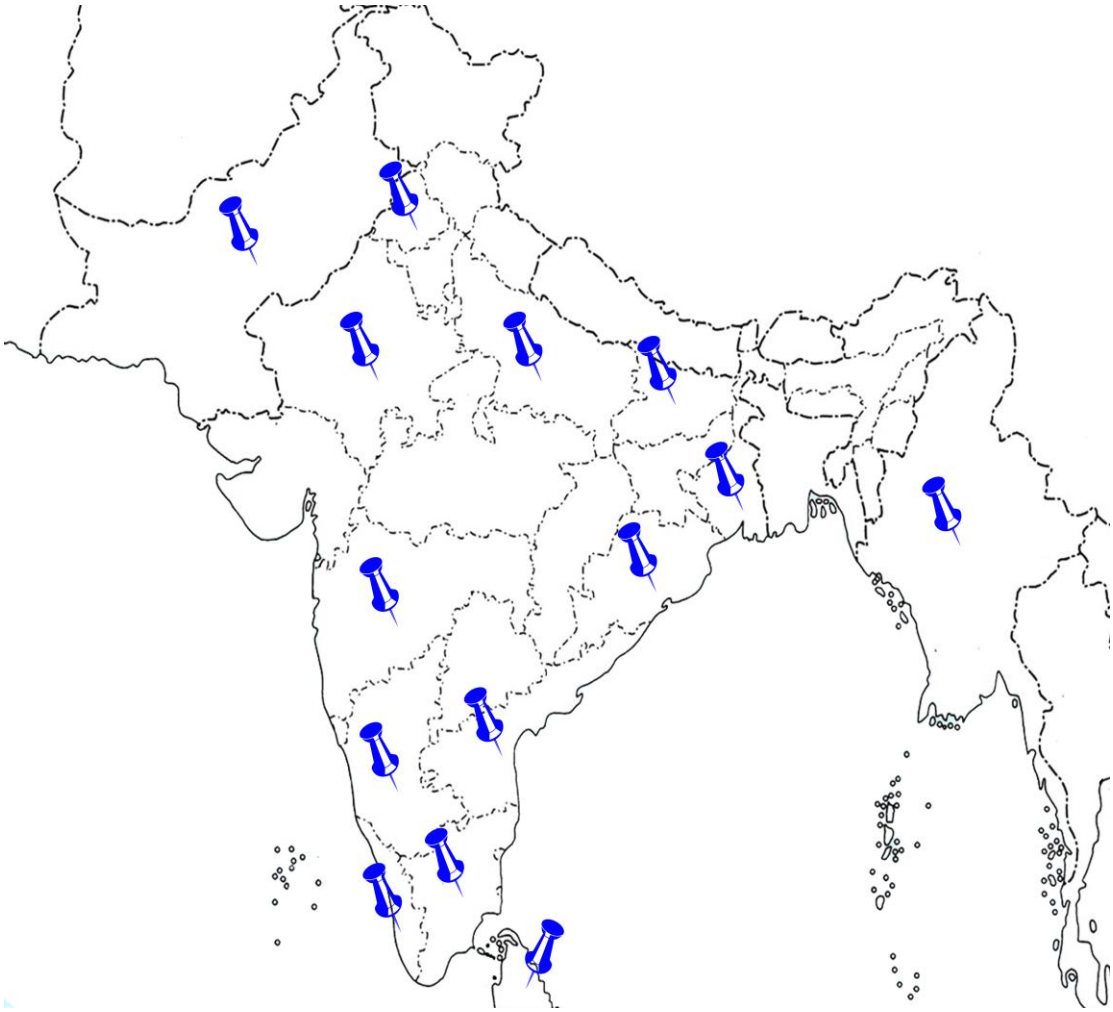


Figure 1. Geographical distribution of *Pavonia odorata* in several places of Indian subcontinent.

Microscopical characters

A transverse section of the root exhibits a narrow zone consisting of phellem, phellogen and phelloderm. Cork is 6to 12 layered, thin walled, irregular shaped, cell content appears brown and rich in starch. Cortex is collenchymatous, circular tooval shaped cells with intercellular spaces. A few raphides are also present. Discontinuous layer of sclerenchymatous cells forms the pericyclic. Vascular bundles are without a bundle cap or limiting layer radial with xylem and phloem alternating with each other and cambium is generally inconspicuous. Many bundles are embedded in the parenchymatous tissue wherexylem intersperse with uniseriate and triseriate medullaryrays and pith is absent (Sethi, 2015).

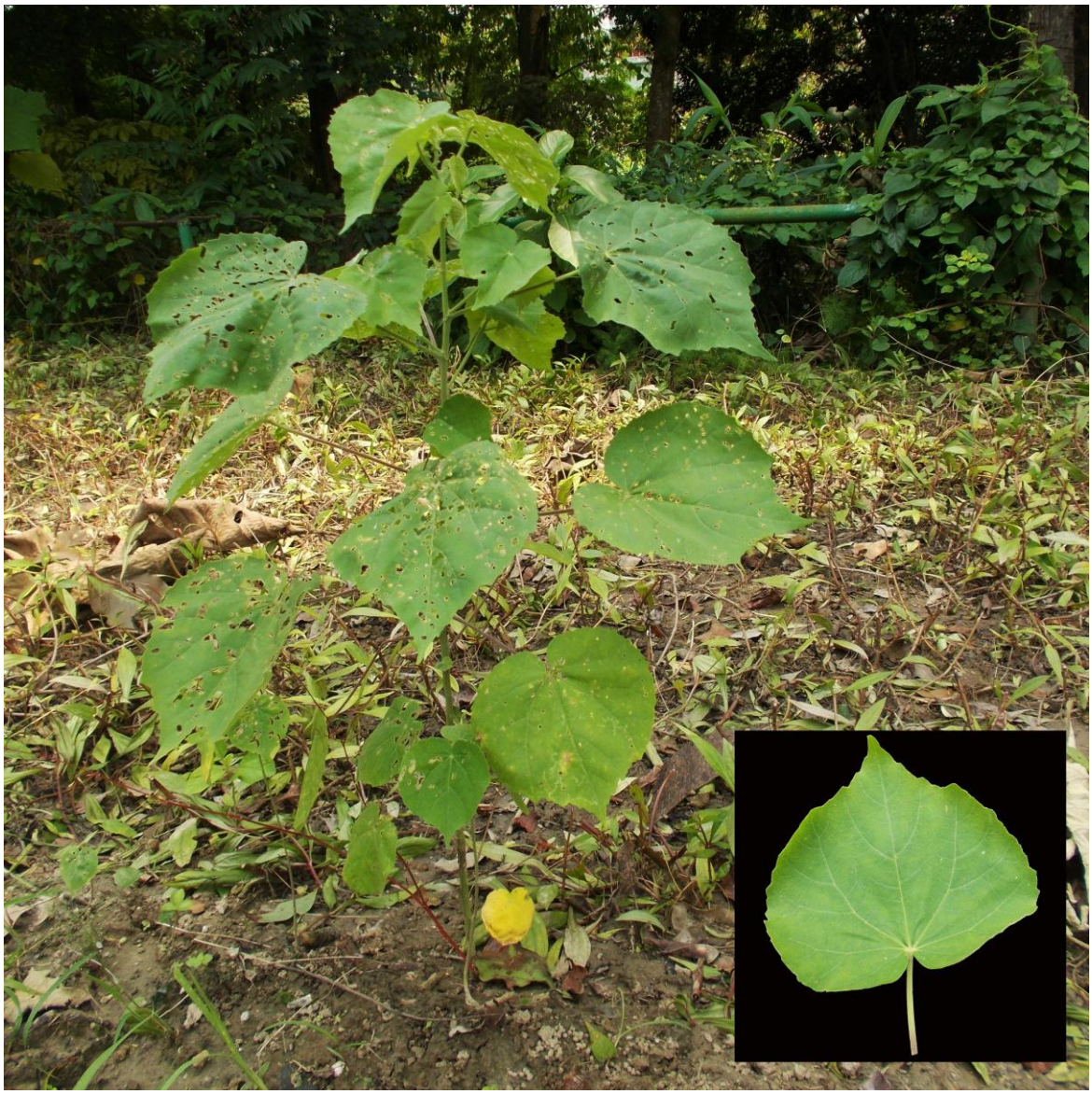


Figure 2. A full-grown*Pavonia Odorata* plant in natural habitat (inset: a three-lobed, ovate typical leaf of *P. odorata*) (Source: Authors).

THERAPEUTIC USES

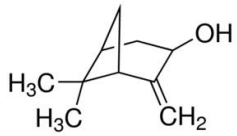
The roots of *P. odorata* are used for the preparation of perfumery like Hina. Moreover, the roots also have medicinal properties against intestinal haemorrhage, inflammation and stomachache. A white and soft fiber can be found in this species that is of good quality and finer texture (Randive and Hatekar, 2010).The wild *P. odorata* produces musk like aromatic odor from the roots. In Ayurveda the therapeutic application of its roots and aerial parts are mentioned in form cooling, demulcent, carminative, diaphoretic and fever along with its action against internal organ hemorrhage and inflammation (Selvan *et al*., 2007).Young shoots and leaves have been used as an emollient (Nadkarni, 1982; Chopra, 1994). The plant was reported to contain sesquiterpene alcohol known as pavonenol ($C_{15}H_{24}O$) (The wealth of India, 1992).

The aromatic roots contain refrigerant, antipyretic, stomachic and astringent properties, and also plays role in controlling diabetes, tumor and blood pressure. The chief pharmacological activities and traditional uses of *P. odorata*are listed in Table 1.

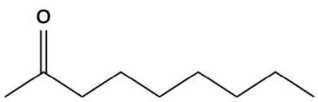
Table 1. Traditional use of *Pavonia odorata* (in chronological order and alphabetical order within each year).

Plant part	Pharmacological activity	Reference
Not specified	Dysentery and inflammation and haemorrhage of intestines	Shukla *et al.* (1961)
Aqueous extract of whole plant	Inhibits calcium and phosphate ions deposition, subsequent growth and stimulates the dissolution of the mineral phase thus controls human urinary calculogenesis	Jethi *et al.* (1983)
Whole plant	Increase the ability of the urine samples to inhibit both the initial mineral phase formation and its subsequent growth	Mago *et al.* (1989)
Leaf	The essential oil has shown Antibiotic activity against *Staphylococcus aureus*, *Diplococcus pneumoniae*, *Trychophyton mentagorophytes*, *Chrysosporium indicum*, *Botrydiplodia* sp. etc.	Garg and Nakhare (1992)
Rhizome	Antibacterial and antifungal	Nakhare and Garg (1992)
Not specified	This plant has anti-inflammatory and spasmolytic effect.	Bensy *et al.* (1993)
Root	The roots are generally used in stomachache, demulscent, and astringent. It is used in dysentery, ulcers and bleeding disorders	Bensy *et al.* (1993)
Leaf	The essential oil has shown strong anthelmintic activity against tapeworms and round worms	Garg (2003)
Methanol extract of whole plant	Themethanol extract and its hydroalcoholic, and ethyl acetate fractions possessed cytotoxic and anticancer activity.	Selvan *et al.* (2007)
Leaf	Leaf juice given in two spoonfuls twice a day for about 10 days to cure Gonorrhea	Madhu and Ravindra Naik (2009)
Root	Extract of root is significantly active against the worms (anthelmintic property)	Singhai *et al.* (2009)
Roots	Stomachache, inflammation and haemorrhage of intestine	Randive and Hatekar (2010)
Root	Antipyretic; Diuretic	Sharma *et al.* (2010)
Root	Root decoction is given to drink once daily in morning for 3-4 days to cure dysentery	Shanmugam *et al.* (2011a)
Root	Root decoction is used for dysentery.	Shanmugam *et al.* (2011b)
Root	Athletes foot disease	Deepthy and Remashree (2014)

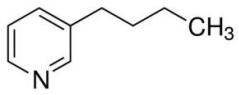
Not specified	Skin diseases, fever	Nandagopalan *et al.* (2014)
Leaves	Foot infection and fever	Ranjithkumar *et al.* (2014)
	Antipyretic, stomachache, refrigerant, dysentery, intestinal haemorrhage	Gritto *et al.* (2015)
Stem and root	Febrifuge	Johnson *et al.* (2015)
Root	Root extract possess blood glucose lowering effect in alloxan induced diabetic rats	Rayar and Manivannan (2015)
Methanol extract of whole plant	Clonogenic inhibition of Human Breast cancer (MD-MB-231), Prostate cancer (PC-3) and Lung cancer (Calu-6) cell lines	Girish *et al.* (2016)



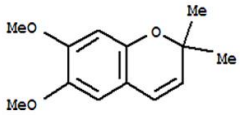
(i) (E)-pinocarveol



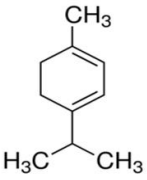
(ii) 2-nonanone



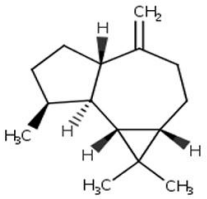
(iii) 3-butylpyridine



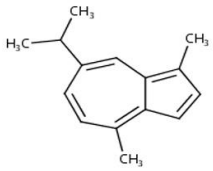
(iv) Ageratochromene



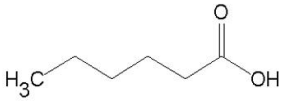
(v) Alpha-terpinene



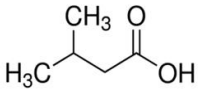
(vi) Aromadendrene



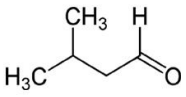
(vii) Azulene



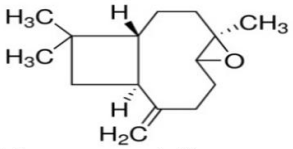
(viii) Caproic acid



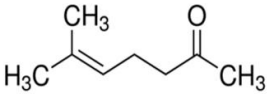
(ix) Isovaleric-acid



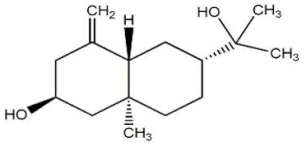
(x) Isovalerylaldehyde



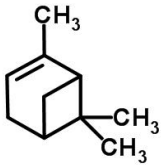
(xi) Beta-caryophyllene



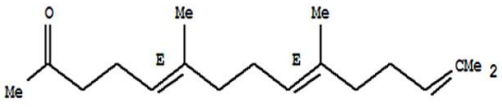
(xii) Methyl heptenone



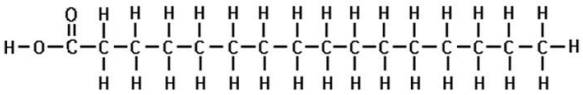
(xiii) Beta-eudesmol



(xiv) Alpha-pinene



(xv) Hexahydrofarnesyl acetone



(xvi) Palmitic Acid

Figure 3. Chemical Structures of major phyto-constituents found in *Pavonia odorata* extracts.

PHYTOCHEMISTRY

The volatile oil obtained from *P. odorata* has been assessed for its chemical properties employing Gas Chromatography-Mass Spectrometry (GC-MS) and its aroma active compounds were identified using Gas Chromatography-Olfactometry (GC-O) and Aroma Extraction Dilution Analysis (AEDA). Amongst the 85 compounds detected by GC-MS; the major constituents reported were β-eudesmol (4.53%), β-caryophyllene oxide (3.08%), ageratochromene (11.95%), hexahydrofarnesyl acetone (5.96%), and palmitic acid (9.95%) (Kashima *et al*.,2014).Using GC-MS, GC-O and AEDA techniques the most characteristic aroma compounds screened were 3-butylpyridine, 2-nonanone, β-caryophyllene oxide and (E)-pinocarveol. It was found that sweet and spicy odor that comes from its aerial parts is produced by these characteristic aromatic compounds. Earlier many other compounds were also identified in the volatile oil extracted from roots such as α-pinene, α-terpinene, aromadendrene, azulene, caproic acid, isovaleric acid, isovaleraldehyde, methyl heptenone, pavonene, pavoneol and palmitic acid (Baslas, 1959; Kumar *et al.,* 1965).The chemical structures of typical constituents extracted from *P. odorata* have been shown in Figure 3.

PHARMACOLOGY

The discussed traditional implications of *P. odorata* have been confirmed by the recent pharmacological studies. The traditional uses of this species revealed to possess a broad spectrum of medicinal properties. For example, it has been used to treat tumor, inflammation, microbial infection, diabetes, fever, skin disease, athletes' foot disease, dysentery, gonorrhea, intestinal haemorrhage, ulcers and bleeding disorders. But, based on the literature review, thorough pharmacological evaluations have been not carried out yet. Only a few biological activities have been examined from this species involving antioxidant, antitumor, anti-inflammatory, antimicrobial, antidiabetic, anthelmintic, mosquitocidal and reduction in blood pressure.

Antioxidant activity

The antioxidant activity of the *P. odorata* volatile oil was examined by Kashima *et al.* (2014) through Oxygen Radical Absorbance Capacity (ORAC) assay employing fluorescein as the fluorescent probe. The ORAC value of the oil was found to be 594.2±25.9 mM TE/g. The results signified that the volatile oil extracted from aerial parts of *P. odorata* could be considered as a natural antioxidant agent.

Antitumour activity

Methanol extract of *P. odorata*, hydroalcoholic, and ethyl acetate fractions were evaluated for their cytotoxic effects (Selvan *et al.,* 2007). The result yields the fact that methanol extract, its hydroalcoholic, and ethyl acetate fractions indeed contain cytotoxic and anticancer property. Using acute toxicity study, it has been found out that methanol extract is non-poisonous and safe to the mark of 2000 mg/kg. The effectiveness of methanol extract with respect to clonogenic inhibition on human breast cancer (MDMB-231), lung cancer (Calu-6) and Prostate cancer (PC-3) was examined by Girish *et al.* (2016).It was seen that in the dose dependent manner, methanol extract could quite induce cytotoxic effect upon MD-MB-231, Calu-6 and PC-3 cell lines when subjected to different concentrations (0-500 µg/ml). Upon comparison, considerable cytotoxicity (up to ~80%) of methanol extract was exaggerated against MD-MB-231 and Calu-6, rather than PC-3cells, according to IC50 values.

Anti-inflammatory activities

The living injured tissue involves various mechanisms such as enzyme activation, release of mediators, cell migration, breakdown of tissue and repair, the response is collectively known as inflammation (Katzung, 2004).For acute inflammation, the standard experimental design conducted was carrageen an induced hind paw edema (Turner, 1965), which occurs in three phases-first phase serotonin and histamine that are released from mast cells after one hour of carrageen an induction, in second phase, kinins was provided after two hours and the third phase is regulated by lipoxygenase, prostaglandins and cycloxygenase subsequent to three hours (Vinegar *et al*., 1969). To evaluate the anti-inflammatory mechanism, ethyl acetate, methanol and chloroform extracts of *P. odorata* were affected for one hour upon carrageen an induced rat paw edema and compared with that of control. The results reflected the fact that the paw volume was inhibited in a dose dependent manner by the extracts. When tested for the fifth hour paw edema was inhibited significantly due to ethyl acetate, methanol and chloroform extract doses. But paw edema was inhibited at the maximum concentration of 3.76±0.08, 3.85±0.04 and 3.78±0.04 during, first hour interval and 2.86±0.05 3.28±0.02 and 3.01±0.02 during fifth hour at dose of200 mg/kg body weight, respectively. The anti-inflammatory effect was quite significant in case of extracts when evaluated against Diclofenac sodium (100 mg/kg), the paw volume was reduced to 2.72±0.05. In case of ethyl acetate extract the paw edema inhibition was much less in comparison to Diclofenac sodium at a dose of 100 mg/kg body weight, however, the longevity of action was similar to that of the later until the fifth hour of experiment. One thing was common that the hind paw edema thickness decreased relatively in various percentages by all extracts and standard groups upon comparing to the controlled group. Ethyl acetate and chloroform extracts has been evaluated to inhibit the induced inflammatory response to carrageenan more than the methanolic extract. Chloroform extract have lower activity than ethyl acetate extract and this may due to the absence of bioactive ingredients that is available in others, thus enabling the future path for discovery of natural bioactive products which would pave the way for new pharmaceutical development (Rayar*et al.,* 2015).

Antimicrobial activity

The rhizomes of *P. odorata* was employed for 0.2% yield extract of essential oil using hydro-distillation technique and tested against 13 fungi and 10 bacteria employing paper disc agar diffusion method for their antibacterial and antifungal response. The oil concentration of 0.55 inhibited the growth of *Diplococcus pheumoniae*, *Escherichia coli, Klebsiella* sp., *Staphylococcus aureus*. The growth of keratinophilic fungi *Trichophyton mentagreophytes* and *Chrysosporium indicum* along with *Aspergillus* sp., *Botrydiplodia* sp. *Fusarium solani* was also found to be inhibited by the oil (Nakhare and Garg, 1992).In this case, Ageratochromene is more possibly responsible for its antimicrobial activity (Kashima *et al*., 2014).

Antibacterial activity

P. odorata root extracts showed antimicrobial activity against five tested organisms namely, *Escherichia coli*, *Staphylococcus aureus*, *Aspergillus niger*, *Aspergillus flavus* and *Candida albicans* (Rayar *et al.,* 2015). In case of *S. aureus* and *C. albicans,* 24±0.69 mm and 19±0.24 mm zone of inhibition, respectively was obtained using its chloroform extract but its response was low for other organisms.

Another noble antibacterial activity was demonstrated by ethyl acetate extract against *C. albicans* (18±1.02 mm) and *S. aureus* (22±1.38 mm). However, methanol extracts did not show profound anti-bacterial activity as for *S. aureus,* the maximum zone of inhibition was 18±0.43 mm.

Antifungal activity

The oil extract has also demonstrated good antifungal activity against *Aspergillus flavus* (38 mm). *A. niger*(40 mm), *Botrydiplodia* sp. (55 mm), and *Fusarium solani* (44 mm).The neat oil has been shown better antifungal activity when compared to well known Griseofulvin (1000 ppm). The oil also has antifunfgal activity against *Alternaria* sp., *C. capsici, Helmintho sporium* sp., *Rhizoctonia* sp. and *Rhizophus nodosus.* However, upon serial dilution there was decrease in the antifungal activity. Also, keratinophilic fungi such as *Chrysosporium indicum* and *Trichophyton mentagrophytes* revealed their susceptibility against the essential oil, hence, can be employed against these dermatophytes (Nakhare and Garg, 1992).

Antidiabetic activity

It is known that the metabolic disorder, diabetes decreased the nation's development due to it being a major reason for high economic loss. Further, various chronic complications like blindness, heart failure, and renal failure arise if not controlled. As such to reduce the alarming health issue, new potentially antidiabetic and hypoglycemic agents have been the keen area of research. According to ethno-pharmacological information tribal, tropical and subtropical areas have been employing *P. odorata* extracts to treat diabetes. However, regarding its antidiabetic activity, there is only one scientific literature reported by Rayar and Manivannan (2015) is available. They found out that the plant extracts when evaluated in Alloxan treated diabetic rats for their anti-diabetic activity in doses of 100 mg/kg of $CHCl_3$, 100 mg/kg of EtOAc and 200 mg/kg of MeOH, did not produce any toxic symptoms. Moreover, root extracts of *P. odorata* exhibited antidiabetic properties. When root extracts of *P. odorata* was administered orally in form of 100 mg/kg $CHCl_3$, glucose level in blood was observed to be decrease (157±4.36) after 15days.Thus, a conclusion can be drawn that reduction in the glucose level of blood in diabetic rats depends upon the action time and doses, thus enabling it to be useful for treatment of in toxic diabetes.

Anthelmintic activity

In the tropical regions, helminthic infections can be attributed to be a major factor for chronic disease and sluggishness. The disease grows to be the strong constraint in livestock productivity mostly of the small ruminants. As such, the cost of control in developing countries becomes very high due to helminth parasites, for they are responsible for direct and potential productivity decline (Perry *et al*., 1999).For evaluation of the anthelmentic properties in *P. odorata* aqueous and alcoholic extracts, were applied according to dose, whereas times of paralysis and death were set as parameters. Upon comparison with standard drugs, the alcoholic extracts gave significant and more potent results than the aqueous extract. In another study by Singhai *et al.* (2009), it was found that both *P. odorata* root extracts were much more significantly active in comparison to the piperazinecitrate (popular anthelmintic drug). Thus, the study provides a future platform to employ *P. odorata* extracts as anthelmintic agent.

Mosquitocidal Activities

Even though lots of control efforts have been going on through centuries, mosquitocidal diseases are spreading worldwide.

Mosquito borne disease are responsible for global mortality and morbidity with a significantly affecting children and adolescents. In terms of both, mosquitoes affect millions of people since they are the principle vectors of disease causing pathogens (Hotez *et al*., 2004). Throughout the world malaria is potentially transmitted by *Anopheles* mosquitoes (Karunamoothy and Illango, 2010). The most important vector of yellow fever virus, dengue virus and chikungunya virus is *Ae. Aegypti.* In comparison to any other vector-borne viral infection major human morbidity and mortality is caused by dengue. Virus transmission through *Ae.aegypti*is primarily because it can uniquely adapt to form a close relationship with humans (Morrison *et al.,* 2008). In order to check mosquito-borne diseases, vector control is currently the only effective way as antiviral therapy/vaccine is unavailable (Mariappan, 2007).Conventional mosquitocidal pesticides like pyrethroides, malathian and DDT cause environmental problems such as pollution, residual effects and resistant to mosquito species. Thus, the need for research and production of cost efficient, environmentally feasible indigenous techniques for vector control has aroused. Selvakumar *et al*. (2015) examined the repellent and larvicidal properties of benzene and methanol extract of *P. odorata*. Interpreting the results, *P. odorata* crude extracts has the significant potential to control, *Aedes aegypti, Anopheles stephensi* and *Culex quinquefasciatus* mosquitoes.

Reduction in blood pressure

In anaesthetized dog, *P. odorata* oil extracts when administered intravenously (60mg/kg) showed remarkable reduction in blood pressure that lasted for around three minutes but considerable reduction in blood pressure happened when a dosage of 120 mg/kg was injected. Even, atropine sulfate and pheniramine maleate (both 1mg/kg) was unable to check the oil's hypotensive effect (Nakhare *et al*., 1997).

Future directions

For centuries, extracts of *P. odorata* have found its use in traditional medicine across different regions of the world. Varied pharmacological activities and presence of many bioactive compounds have been confirmed by studies though many of them are yet to be quantified. Depending on its phytotherapeutical importance, research for identification of many new secondary metabolites is needed as the plant carries huge potential as an established medicinal plant but not yet exploited to its maximum. As such wide prospect arises if new pharmacological properties are discovered from this genus resulting in the development of new drugs, such as for cancer, hernia, skin and digestive diseases, etc. Different types of diseases have been treated using traditional methods from this species but the assessment of a particular phytochemical corresponding to the type of disease treatment is lacking. Here current traditional methodologies of *P. odorata* extract usage along with research on its pharmacological, botanical and phytochemical properties have been summarized. Information from the available data can be used to form a practical guideline in order to pursue further scientific activities on *P. odorata*. However, at present, results have been based mostly on *in vitro* bioassay but in vivo study employing laboratory animals is also required. It is nonetheless a fact that *P. odorata* is widely discussed but its clinical studies have yet not been undertaken. Hence, in the near future, clinical evaluation should form a benchmark for safe therapeutic applications of this species.

ACKNOWLEDGEMENTS

Support and help provided by friends and colleagues are gratefully acknowledged.

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