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*Pedaliium murex* Linn.: An overview of its phytopharmacological aspects

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## ABSTRACT

*Pedaliium murex* Linn (family: Pedaliaceae) (*P. murex*) commonly known as Large Caltrop and Gokhru (India) is a shrub found in the Southern part, Deccan region of India and in some parts of Ceylon. Different parts of the plant are used to treat various ailments like, cough, cold and as an antiseptic. Interestingly, *P. murex* is reported traditionally to have an excellent cure in patients with reproductive disorders which are mainly impotency in men, nocturnal emissions, gonorrhoea as well as leucorrhoea in women. The plant has also benefited in complications like urinary track disorder as well as gastro intestinal tract disorders. Phytochemically the plant is popular for the presence of a considerable amount of diosgenin and vanillin which are regarded as an important source and useful starting materials for synthesizing steroidal contraceptive drugs and isatin alkaloids. Other phytochemicals reported in the plant includes quercetin, ursolic acid, caffeic acid, amino acids (glycine, histidine, tyrosine, threonine, aspartic acid and glutamic acid) and various classes of fatty acids (triacontanoic acid, nonacosane, tritriacontane, tetratriacontanyl and heptatriacontan–4–one). Pharmacologically, the plant have been investigated for antiulcerogenic, nephroprotective, hypolipidemic, aphrodisiac, antioxidant, antimicrobial and insecticidal activities. From all these reports it can be concluded that the plant were found to have a better profile with potential natural source for the treatment of various range of either acute or chronic disease. The overall database of our review article was collected from the scientific sources in regards with all the information of the research article for *P. murex* published so far.

## 1. Introduction

*Pedaliium murex* (*P. murex*) is a member of the sesame family, Pedaliaceae. It is found in different parts of the world such as tropical Africa, Srilanka, India, Mexico and Pakistan. In India, it occurs mainly in the Western and Corommandal coasts as a weed of waste places and is generally called under the Hindi name “Gokhru or gokhar” and in Sanskrit as “gaja–daunstraka, gokshura or titta–gokshura” [1, 2]. Its names vary from one region to another ranging from North to South and from East to West part of the country. It is also called in Kannada (doddaneggilu), Malayalam (motha–malvi–gokharu), Tamil (Ananerinnil), Marathi (Gokhara), Gujarati (Gokhura), Oriya (Yanai nerunjil), Arabic (Khasake kabir), Burmese (Sulegi), Singapore (Ati neranchi), Persian (Khasake Kalan). The fruits of this plant are rich in flavonoids, sapogenin

(diosgenin–0.06%) and soluble proteins (20.14 mg/g)[3–5]. An infusion or extract prepared from the different parts of the plant in cold water is used as demulcent, diuretic and also found to be best used in the treatment of disorders of urinary systems such as gonorrhea, dysuria, incontinence of urine and vice versa[6, 7]. The plant is also used by the local people as analgesic and antipyretic activities[8, 9]. According to a study conducted on the genetic factors revealed that the meiotic characteristics in *P. murex* of different populations have a gametic number of  $n=8$ . The meiotic abnormalities like clumping of chromosome and formation of univalent and multivalent at metaphase I and at anaphase I clumping of chromosome and simple chromosomemal bridges were scored. Half chiasmata per chromosome were found to vary. The meiosis and chiasma difference in various populations are supposed to be due to intrinsic difference in chromosome structure of a taxon concerned[10].

## 2. Traditional uses

Traditionally, *P. murex* was utilized in various ways, either as a whole plant or individual plant parts or sometimes

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in different special preparations. The leaves are cooked and eaten as a vegetable. Leaves and branches, when briskly stirred in cold water yield thick mucilage similar to the white of a raw egg are reported to possess significant medicinal properties<sup>[11]</sup>. According to Ayurveda, *P. murex* is mainly used as tonic, aphrodisiac, improves appetite and useful in strangury, urinary discharges, vesicular calculi, cough, asthma, pain, cures skin diseases and heart troubles, piles and leprosy. It purifies blood, removes stone in the bladder. According to Unani system of medicine, it is used as diuretic, cures strangury, gleet, lumbago, tonic, enriches blood, increases mensural flow, good gargles for mouth troubles and painful gums, stomachic, appetizer, emmenagogue etc<sup>[12–14]</sup>. An infusion prepared from the plant is a highly prized remedy amongst the people of Southern India in the treatment of gonorrhoea and dysuria. It is also given as a remedy for spermatorrhoea, incontinence of urine and impotency<sup>[6, 7]</sup>. In addition, the traditional uses of *P. murex* based upon their different parts are as follows:

### 2.1. Whole plant

It has been reported that, 1–2 g dried leaves of *Acacia nilotica*, 1 g *P. murex* (gokhru) and kalmishora in small amount crushed and taken with water before going to bed can cure urinary problem<sup>[15]</sup>. The whole plant is also used in the treatment of urinary calculi and renal troubles by village folk of Rayalaseema<sup>[16]</sup>. According to study on the ethno-veterinary usage of wild medicinal plants of Greater Cholisthan desert of Pakistan, *P. murex* was found to have diuretic value<sup>[17]</sup>. In district of Haridwar, Uttarakhand, India the local people, traditional Ayurvedic doctors and vadhya have been using whole plant of *P. murex* as remedy to cure stomachic, headache, diarrhoea, dysentery, cough and cold, intestinal affections etc. <sup>[18, 19]</sup>. The twig of the plant is dipped in water 7–10 times and then taken orally as refrigerant and to cure dysentery<sup>[20]</sup>. 'Yanai nerunji' (*P. murex*) are stirred for two to three minutes in fermented rice water until it froths. This solution is administered to the animal three times to control diarrhoea in cattle, sheep and goats. The tribal healers of Southern Rajasthan use the whole plant to cure sexual diseases, and the healers of Saperas community use it to cure sex problems and male fertility disorders<sup>[2]</sup>. It is also used in treating of various urogenital systems like discontinuance of urine, in waste places spermatorrhoea, nocturnal emission, impotency and tonic<sup>[21]</sup>. Half cup of mucilaginous water of *P. murex* is taken once a day for seven days to cure gonorrhoea by the tribals, and are also used to cure sexual debility in men and is probably useful in male aphrodisiac<sup>[22]</sup>. Plant crushed with root of *Chlorophytum* are made into laddus and are given to women for leucorrhoea<sup>[23]</sup>. In addition to this the whole plant is also used as diuretic, healing of wounds, dysuria, anti-biliousness, antileaves, demulcent, emmenagogue<sup>[24]</sup>, common fever<sup>[25, 26]</sup> and tonic for health and vigor<sup>[27]</sup>.

### 2.2. Fruits

The fruits of the plants have been traditionally used for

the treatment of reproductive disorder where two spoons fruit powder of *P. murex* mixed with *Cleome viscosa* L. leaf juice, given for seven days before going to bed, is used to enhance fertility and other female reproductive disorder. It is also used in the treatment of diabetes<sup>[28]</sup>. The fruits of *P. murex* are traditionally used in cattle and goats as a diuretic. Decoction of the fruits is used for continuance of urine and other complaints of urinary system<sup>[2, 17, 20, 29]</sup>. For the treatment of GIT disorder the fruits are powdered with roots of *Capparis sepiaria*, *Bombax ceiba* and *Chlorophytum* are taken orally with water as cooling agent and tonic<sup>[20]</sup>. Dry fruits grinded and mixed with sugar to make laddu which is taken 2–3 times in a day for increasing the vigor in men<sup>[30]</sup>. The fruits is also traditionally reported to be used as demulcent, antispasmodic and aphrodisiac<sup>[2, 29]</sup>.

### 2.3. Leaf

Leaves soaked in water for 12 hours then crushed with sugar candy and cardamom is used to cure leucorrhoea in women<sup>[20]</sup>. In addition the leaves and unripened fruits of *P. murex* mixed with other plants are given once a day for three days without adding water to treat infertility in animal and in heifer. Eight to ten fresh leaves of *P. murex* rotated in half litre water and half cup of this water taken once a day for 7 days can treat gonorrhoea. In the form of powder that can be applied locally with butter are used for rheumatic pains<sup>[31]</sup>. Leaf decoction is used to treat diabetes<sup>[28]</sup>. Leaves of *P. murex* are used to treat ulcers, dysuria, Bone fracture, diarrhea and in splenic enlargement<sup>[22, 32]</sup>. Leaves of *Aloe vera*, *P. murex* and *Bauhinia racemosa* crushed together and mixed with water can be given to animals three times a day can relief food poisoning in cattle.

### 2.4. Root

Traditionally the roots of *P. murex* are used to treat leucorrhoea and nocturnal emission. The powdered roots are also taken with water as tonic for 7–8 days to calm body heat <sup>[20]</sup>. Pellets prepared from root paste and given daily with boiled cow milk can be used for virility or vigour in men<sup>[28]</sup>. The decoction of the root is anti-bilious, where juice is used in aphthae as a local application<sup>[29]</sup>.

### 2.5. Seed

Laddus prepared from the seeds of *P. murex* are given to patients suffering from joint pain & lumbago and also given for keeping health<sup>[27]</sup>. The seeds are crushed with the root of *Chlorophytum tuberosum* and are given to female suffering from leucorrhoea<sup>[20]</sup>.

Kokwaro reported that *P. murex* roots were used for gonorrhoea. On the other hand, Watt and Breyer-Brandwijk reported that an infusion of the leaf of *P. murex* has been used in Tanganyika for treatment of bladder troubles and gonorrhea. However, the clinical studies of both the leaf and root were screened in 164 patients suffering from gonorrhoea, it showed no significance<sup>[33–35]</sup>. *P. murex* were used traditionally to treat both male and female reproductive

disorder, gastrointestinal as well as urinary tract disorders. Milk mucilage produced from the plant when agitated is recommended as a treatment for gonorrhoea<sup>[36]</sup>. The petroleum ether extract of *P. murex* is effective against Japanese encephalitis vector culex<sup>[37]</sup>. The aqueous extract of the whole plant has been found to possess analgesic and anti-inflammatory properties<sup>[38]</sup>. 'Prostane' an ayurvedic formulation which is used to treat urogenital disorder consists of five medicinal plants of which *P. murex* is used as major ingredient and reported to have good diuretic property<sup>[39]</sup>.

### 3. Botanical description

*P. murex* is a shrubby herb having a stiff-stemmed<sup>[5]</sup>. It is a diffuse annual, much branched, spreading, succulent, glandular plant up to 50 cm tall. Leaves alternate, repandangulate, flower axillary, pedicel with a pair of yellow glands<sup>[30]</sup>. The plant is classified and placed taxonomically under the Kingdom- plantae, division- magnoliophyta, class- magnoliopsida, order- lamiales, family- pedaliaceae, genus- *Pedaliium* L. Microscopic studies of the leaf of *P. murex* showed prominent midrib, slightly thicker lateral veins, uniformly thick lamina with smooth surface, spindle shaped thin walled epidermal cell, flat petiole with slight concavity on the adaxial, glandular type of trichomes on both abaxial and adaxial sides, reticulate venation with thick and straight veins and anisocytic type stomata was found to present in the abaxial surface<sup>[40]</sup>. Generally there are more than hundred species present and they differ taxonomically from each other in various ways. Among the subtypes of longitudinal dehiscence, latrorse type is most common found in 114 species, followed by extrorse and introrse types in 49 and 28 taxa respectively. The poricidal anther types were specific for only few genera such as *Pedaliium*<sup>[41]</sup>.

### 4. Phytochemistry

Extensive phytochemical investigations on the plant revealed the presence of various phytoconstituents such as triterpenoids, fatty acids, steroids, flavonoids, tannins, saponins, vitamins, proteins, sugars, vanillin, ursolic acid (Figure 1) [16, 42–44]. Qualitative phytochemical investigation on petroleum ether extract was studied and reported to contain higher concentrations of steroids and sterols, and moderate concentrations of flavanoids, phenols, glycosides, alkaloids, proteins, terpenes, carbohydrates, gums and mucilage. It has been reported that steroidal constituents found in the plants possess fertility potentiating properties, and they have been found to be useful in the treatment of impotence<sup>[37]</sup>. Several compounds have been isolated and characterized so far from different parts of *P. murex*. Ethanolic extract of the fruits shows the presence of the two new components which were isolated and characterized as 2', 4', 5'-trihydroxy-5, 7-dimethoxyflavone and triacontanyl dotriacontanoate. Luteolin, rubusic acid, nonacosane,

tritriacontane, triacontanoic acid, tritriacontanoic acid and sitosterol-  $\beta$ -D-glucoside were also isolated, and identified from spectral and chemical data<sup>[2]</sup>. A flavones class Pedalitin (5, 6, 3, 4-tetrahydroxy-7-methoxyflavone) were isolated from the leaves stem and fruit part of the plant. In addition to this, another flavones dinatin (5, 7, 4-trihydroxy-6-methoxy flavones) were also reported to be isolated from the stem and fruit part of *P. murex* [45, 46]. Triterpenoids such as  $\alpha$ -amyirin acetate, rubusic acid, ursolic acid, and lupeol acetate are also reported (8). Steroids such as  $\beta$ -sitosterol, sapogenins and diosgenin have also been reported<sup>[47, 48]</sup>. Lipids, phenolic acids such as caffeic acid, ferulic acid, protocatechic acid, vanillic acid, and amino acids such as aspartic acid, glutamic acid, histidine are other phytoconstituents present in *P. murex*<sup>[2, 49]</sup>. Other compounds like diosmetin, hispidulin, pedalitin 6-O-glucoside, diosmetin 7-O-glucuronide and hispidulin 7-O-glucuronide have also been reported to be isolated from the leaf part of the plant, luteolin and 2, 4, 5-trihydroxy-5, 7-dimethoxyflavone from fruits. Moreover, the evaluation of ascorbic acid contents of the plant were studied and found to be maximum in case of fruits. Phenol, 2-(5, 6-dimethyl pyrazinyl) methyl (molecular weight 214); O-Terphenyl-13C (molecular weight 230) and 3,3A, 4,9B-Tetrahydro- 2H-Furo (3, 2-C) Benzopyran (molecular weight 206) were also identified from the ethanol root extract of *P. murex* by using GC-MS<sup>[2, 9, 44, 45]</sup>. The total organic carbon, total nitrogen and protein contents of the plant were estimated and found to be significant. In addition to the organic compounds *P. murex* had also been reported to contain a good amount of inorganic component like Zn and K contents found in the leaves and Ba content in the fruits<sup>[50]</sup>. The seed oil from the plant were also analyzed for their proximate composition, amino acid and fatty acid composition and were found to be good sources of protein and fat. Fatty acid profiles of fat from this oil seeds revealed a low proportion of unsaturated fatty acids<sup>[51]</sup>.

### 5. Tissue culture

According to the micropropagation techniques which have been reported in *P. murex*, nodal, internodal segments of *P. murex* were cultured on Murashige and Skoog (MS) medium supplemented with 3 mg/L 2, 4-D, which were found to be most suitable for the successful callus initiation. The callus was then cultured on MS medium consisting of MS basal salts, 0.8% agar and 3% sucrose supplemented with BAP with a concentration of 3 mg/L, which lead to the highest rate of multiple shoot bud initiation. The highest rates of flower initiation were in the culture media supplemented with 1.5 mg/l 2, 4-D and 1.5 mg/L BA<sup>[52]</sup>. Various growth regulators of auxin (planofix 40 ppm), steroid (hydrocortisone 100 ppm) and organic phosphates (4, dimethyl amino-2 methyl phenyl phosphonic acid 500 ppm) were tried at the time of active growth period (flowering stage) of *P. murex*, and were found to be increased photosynthetic efficiency in terms of structural composition (total chlorophyll) and functional efficiency (soluble protein) compared to untreated

control[53].

## 6. Pharmacological activity

### 6.1. Toxicity report

The acute toxicity studies of the *P. murex* plant were reported to be safe up to the dose level of 2 260 mg/kg, p.o. in mice. The study were performed on the male Swiss albino mice (20–25 g) which was orally administered with ethanolic extract of *P. murex* and observed for any symptoms of toxicity for 48 h as per CPCSEA guidelines. LD<sub>50</sub> were estimated by Karber's method and were reported to be 2 260 mg/kg, p.o. Based on these results, the dosages for further pharmacological study were fixed at 250 mg/kg, p.o.[54]. Administration of alcoholic extracts of *P. murex* orally to male Swiss albino mice produced no observable side effects up to 2 260 mg/kg, p.o. body weight even after 48 h of observation[9]. An acute toxicity study of *P. murex* mucilage showed no manifestations of toxic syndromes and has been found to be safe. (LD<sub>50</sub> > 2 000 mg /kg)[55].

### 6.2. Antiulcerogenic activity

Aqueous extract of leaves of *P. murex* on ethanol induced gastric lesions at a dose of 200 mg/kg, p.o. in a single schedule and 100 mg/kg, p.o. for 15 and 30 days treatment was investigated and was found to posses significant effect in the treatment of gastric ulceration by ascertaining the content of total acid, acid volume, total protein, ulcer index and glutathione where famotidine used as a reference drug[56].

### 6.3. Nephroprotective activity

The nephroprotective activity of the ethanolic extract of the dried fruits of *P. murex* were evaluated in Cisplatin induced renal damage model on Wistar rats using serum creatinine, blood urea and change in body weight as indicators of kidney damage. Cystone was used as standard drug. The results revealed that there was a significantly change in body weight, serum creatinine and urea levels at a dose of 250 mg/kg, p.o. it was reported that the ethanolic extract of dried fruits of *P. murex* showed significant nephroprotective when compared to cystone[9]. The ethanolic and aqueous extracts of fruits of *P. murex* (300 and 600 mg/kg, p.o. body weight) were also evaluated against cadmium chloride-induced (3 mg/kg/s.c.) renal toxicity in rats, using blood urea nitrogen, serum creatinine, urinary protein, urine to serum creatinine ratio, lipid peroxidation, glutathione, catalase in kidney as the main parameter. The result reveals that ethanolic and aqueous extract with CdCl<sub>2</sub> significantly prevented the renal injury in dose dependent manner[57].

### 6.4. Anti hyperlipidemic activity

The anti-hyperlipidemic potential of the ethanolic extract of fruits (*P. murex*) in high fat diet fed rats had been

reported. The study revealed that at doses level of 200 and 400 mg/kg, p.o. of the ethanolic extract was reported to show a significant decrease in triglycerides, low density lipoprotein (LDL), very low density lipoprotein (VLDL), total cholesterol (TC), and a significant increase in high density lipoprotein (HDL) level at the tested doses. The studies were done by comparing with standard drug treated group (Gemfibrozil and Atorvastatin)[58].

### 6.5. Aphrodisiac activity

The aphrodisiac activity of the petroleum ether extract of *P. murex* was evaluated and found that it has ability to increase aphrodisiac activity and to cure ethanol induced germ cell damage and infertility in male rat models. Different doses level (200 mg/kg and 400 mg/kg, p.o.) of petroleum ether extract of *P. murex* showed a positive significant increase in mating, mounting behavior, total body weight, percentage of pregnancy, sperm motility, litter size as compared with the ethanol-treated group. Moreover, the total protein, total cholesterol and testosterone were also reported to have increased significantly. Histopathological study of the testes of animals treated with 400 mg/kg, p.o. petroleum ether extract of *P. murex* revealed that it exhibits a significant restoration and recovery of germinal cells and the luminal spermatozoa[59].

### 6.6. Antioxidant activity

The antioxidant activities of different fraction of *P. murex* was reported using total antioxidant assay, DPPH assay, reducing power, nitric oxide scavenging, hydrogen peroxide scavenging and deoxyribose scavenging assays were investigated in vitro. The ethyl acetate fraction was found to exhibit a good antioxidant capacity and reducing power as compared to other fractions. It is also reported to have a significant activity to scavenge various free radicals which are DPPH radical scavenging activity [(135.11±2.95)  $\mu$ g/mL], nitric oxide radical [(200.57±4.51)  $\mu$ g/mL], hydrogen peroxide radical [(217.91±6.12)  $\mu$ g/mL] and hydroxyl radical [(250.01±4.68)  $\mu$ g/mL]. Thus it was seen that ethyl acetate fraction obtained from this plant has potent free radical scavenging activity thus implying their importance to human health[60]. Antioxidant activity of methanol extract of *P. murex* fruits has also been reported in vivo using carbon tetrachloride (CCl<sub>4</sub>) induced hepatotoxic model in rats at 70 mg/kg, p.o. body weight for 90 days were investigated and found that decreased activity of antioxidant enzymes, such as superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPX) and glutathione reductase (GRD) in CCl<sub>4</sub>-induced rats, and its retrieval towards near normal signifies its antioxidant activity and hepatoprotective activity[61].

### 6.7. Antimicrobial activity

Benzene, butanol and dimethylformamide extracts of the leaves of *P. murex* were tested against three *Aspergillus* species viz. *A. flavus*, *A. fumigatus* and *A. niger* by disc diffusion assay. The aqueous extract contributes minimum



activity where as organic solvent extracts were reported to have moderate to least activity against most of the organisms tested[62]. *P. murex* leaf extracts were reported to have antifungal activity and were tested against the fungal strain *Magnaporthe grisea*, the causative organism of blast disease of rice and found to control the disease in a significance level. Based on all these observations, it was suggested that *P. murex* extract could be used as source of pesticide of plant origin to combat blast disease of rice in the field[63].

## 6.8. Miscellaneous activities

### 6.8.1. Insecticidal activities

The control of pest is vital to human health and comfort as they are responsible for potential transmission of more than 100 pathogens associated with the fly. They spread diseases including enteric, certain helminth, eye and certain skin infections. An impact of ethanol extract of *P. murex* root (0.1, 0.2, 0.4, and 0.8%) was screened for its antifeedant and insecticidal activities against third, fourth and fifth instar larvae of *Spodoptera litura* by leaf-dip method. The larval mortality more than 50 percent at higher concentration (0.8%) was observed in the ethanol root extract. *P. murex* reduced the food consumption index, growth rate, approximate digestibility, efficiency of conversion of ingested food, efficiency of conversion of digested food of *Spodoptera litura* (*S. litura*) indicating the antifeedant activity and might be due to the presence of saponins and tannins present in this extract. *P. murex* impacts were reported to be more than the neem based biopesticide neem gold. Hence *P. murex* can be explored as biopesticidal plant in the near future[9]. Moreover a report has also been evaluated on the insecticide action of *P. murex*. The study was done evaluating the  $LC_{50}$  values of *Spodoptera litura* with *P. murex* treated castor leaves. It showed that *S. litura* with higher concentration of *P. murex* (above 0.4%) died at the early period of the treatment, but those insects, which were fed with lesser concentration (below 0.2%), failed to complete the moulting and died either in the larva or in pupae. Those which were fed with least concentration (0.1%) were transformed into normal adults. But some of the larvae failed to experience normal growth and development. Because, haemolymph were expelled out from the *S. litura* larvae and they died after two to four hours of haemolymph expulsion. The result revealed that the  $LC_{50}$  values were life stage dependent factor. For instance  $LC_{50}$  value for third instars *S. litura* were reported to be 0.100% and it gradually increased when the pest grew older (0.118 and 0.258% for fourth and fifth instars respectively)[64]. A study on the ovicidal activity on the eggs of *Dysdercus cingulatus* (*D. cingulatus*) was also done with *P. murex* root ethanol extract along with neem based pesticide like neem gold and water. In the study neem gold was reported to be more toxic to the eggs of *D. cingulatus* than *P. murex* root extract. *P. murex* treatment delayed the premating period, period between mating and egg laying, ovipositional time, number of egg laid and hatching percentage, male and female adult longevity and adult weight compared to neem gold and control[65]. In addition, the insect repellent activity of different extracts

(Hexane, dichloromethane and ethyl acetate extracts) of *P. murex* were also reported to be tested at 5% concentration against *Callosobruchus maculatus* at different durations and the maximum activity was reported to be with that of ethyl acetate extract[66].

### 6.8.2. Other activities

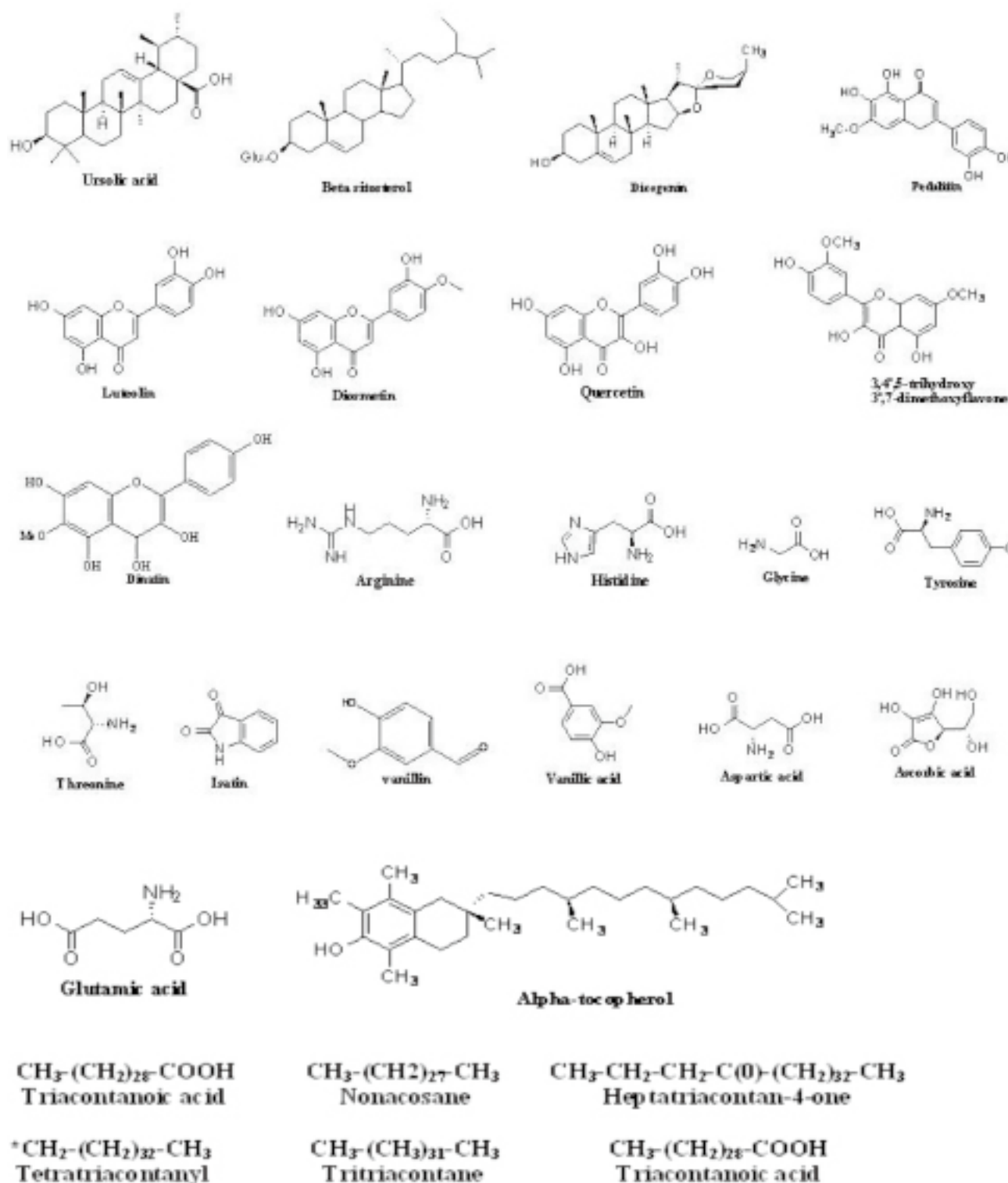
The alcoholic extract of the fruits of *P. murex* reduced blood pressure in dog and rat, which was blocked by atropine sulphate. It also caused contraction of the smooth muscle of guinea ileum and rabbit intestine. The decoction of the fruits showed diuretic activity in rats. The alcoholic extract showed abortifacient activity in rats[67]. Prostate a herbal formulation containing *P. murex* were evaluated for its  $5\alpha$ -reductase inhibitory activity and  $\alpha$ -antagonistic activity in vitro, and its activity against experimental prostatic hyperplasia in rats[68]. The importance of *P. murex* as a source of diosgenin and vanillin (useful starting materials for synthesizing steroidal contraceptive drugs and isatin alkaloids, respectively) was emphasized[7].

## 7. Discussion

The use of plants, parts of plants and isolated phytochemicals for the prevention and treatment of various health ailments has been in practice from time immemorial. It is estimated that about 25% of the drugs prescribed worldwide are derived from plants and 121 such active compounds are in use. Of the total 252 drugs in WHO's essential medicine list, 11% is exclusively of plant origin[69]. Nearly 80% of African and Asian population depends on traditional medicines for their primary healthcare[70]. In India, about 80% of the rural population uses medicinal herbs or indigenous systems of medicine[71]. About 960 plant species are used by the Indian herbal industry of which 178 are of high volume exceeding 100 metric tonnes a year[72].

Nature is the source of all the raw materials that we need. About 2–3 decades ago, most of the drugs were of herbal origin. A variety of reasons underpin why people like to use natural medicines as it is evident that patients are getting even more distressed after using chemically synthesized drugs, rather than natural means, that can conquer life claiming diseases, leaving no side effects on human health. To maintain proper growth, the pharmaceutical industries needs to innovate and access to high output rate on low-cost materials with reasonable safety. The combination of modern chemistry with bio-based starting materials, like, bio-metabolites, offers the scope for revolutionizing pharmaceutical industries. In the near future, bio-metabolites extracted from medicinal *P. murex* will have a role that compares with that of oil and gas crackers today.

From the overall above information it is understood that *P. murex* can be considered as a potential drug used in the treatment of various range of disease especially the disease of the urinary tract and reproductive system. It is a very popular medicinal plants and its use throughout the country is still under high demand particularly in remote regions where tribes and local people persist. The phytochemical study on *P. murex* has been reported to contain the presence of certain important secondary metabolites like diosgenin, vanillin and other protein and acidic compounds. Plants containing diosgenin as a secondary metabolite can be



**Figure 1.** Structures of the phytoconstituents isolated in the *P. murex*.

used as an alternative source which can fulfill the need of such steroidal drugs in human being<sup>[3–5]</sup>. However, the constituents responsible for the demonstrated activity are still unknown and their mechanisms of action still remain to be determined. Application of tissue culture techniques might prove to be beneficial for mass multiplication of this plant and for commercial exploitation. Development and application of new genetic based molecular techniques which have not been reported so far could further help in exploration of this plant for industrial purpose.

Nevertheless several pharmacological studies were also reported on different parts of *P. murex* and proven to be the basic potential source with significant results. *In vivo* studies using animal models have been confirmed the aphrodisiac, nephroprotective, antihyperlipidemic, antioxidant and anti-ulcerogenic properties of the plant extract of *P. murex*<sup>[9, 56–63]</sup>. The scientific research on *P. murex* suggests a huge biological potential for its species. The number of important secondary metabolites found to be present in the plants (steroids, phenolics and flavonoids) together with their

pharmacological activity proves that, it could be further exploited in the future as a source of a wide range of health promoting compounds for the pharmaceutical industry as well as for comprehensive pharmacological and toxicological studies. Comparing available data on the traditional uses of a plant species and published results supporting (or not) these uses, is essential so as to establish well-ascertained data and specify the as-yet uninvestigated fields of interest [6, 7, 11–14, 34–39].

*P. murex* has been traditionally claimed for a large number of pharmacological actions and its uses in traditional system of medicine. Indiscriminate and imprudent exploitation of the natural resources by mankind is accountable for the current status of this plant. Emphasis should be given to increase productivity and enhancement of *P. murex* to meet the industrial demand. The scientific research on *P. murex* suggests a huge biological potential of this plant. It is strongly believed that detailed information as presented in this review on the phytochemical and various biological properties of the extracts might provide detailed evidence for the use of *P. murex* in different system of medicines. However other parameters like toxicity studies, bioactivity guided fractionation, and identification of chemical biomarker should be scientifically investigated in order to support the traditional use of *P. murex* in folklore medicine.

### Conflict of interest statement

The authors report no conflict of interest.

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