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REVIEW ARTICLE

Distribution, ethnomedicinal uses, phytochemical profile and pharmacological activities of *Kalanchoe pinnata* (Lam.) Pers.: a review

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Abstract

Kalanchoe pinnata (Lam.) Pers. (Crassulaceae), also known as the "Life Plant", has been used in traditional medicine across various cultures for the treatment of numerous ailments such as wounds, respiratory infections, and kidney stones. In recent years, there has been growing interest in the scientific investigation of this plant to validate its traditional uses and to discover potential new therapeutic applications. This review summarizes the current status of traditional and ethnomedical utility, phytochemical profile, and established pharmacological activities of *K. pinnata*. It discusses the traditional uses of *K. pinnata* in various cultures, including India, Africa, and South America, and highlights different parts of the plant used for medicinal purposes. The *Kalanchoe* species consists of about 25 perennial succulent species, which have been propagated by leaf shedding and reported to contain bioactive compounds like bufadienolides, flavonoids, and isoprenoids. This genus is a native of Madagascar, and has homotypic synonyms, like *Bryophyllum pinnatum, Crassula pinnata, Coyledon pinnata* etc. and heterotypic synonyms like *Kalanchoe calcicola, Cotyledon rhizophylla, Bryophyllum calycinum* etc. The pharmacological activities of *K. pinnata*, such as anti-inflammatory, anti-microbial, anti-cancer, and anti-diabetic effects, are also discussed in detail. This article also describes the mechanisms of action underlying the pharmacological activities of the plant, including its effects on various cellular signaling pathways. In addition, the article highlights the potential toxicological effects of *K. pinnata* and the need for further investigation to establish its safety profile. highlights the *B. pinnatum* as a potential source of new therapeutic agents and the need for further research to validate its traditional uses and establish its safety and efficacy for medicinal purposes.

Keywords: *Kalanchoe pinnata*; Life Plant; Traditional Medicine; Phytochemistry; Pharmacology, Therapeutic Potential

1. Introduction

The genus *Kalanchoe* Adans. (Family Crassulaceae) consists of over 25 species which are found wild or cultivated as ornamental or medicinal purposes. This genus is endemic Madagascar and naturally available across tropical and subtropical region of South America, Africa and Asia. In India, the genus is represented by *Kalanchoe pinnata* (Lam.) Pers. which is found growing as a weed in various parts of India and particularly more frequent in the North East India in dry and wasteland ecosystem (García-Pérez et. al., 2021). The worldwide distribution of the genus is demonstrated in Figure 1. *K. pinnata* is a succulent herb of angiosperm with distinct morphological characters that distinguish itself from other plants. The *K. pinnata* has been reported with homotypic synonyms, like *Bryophyllum pinnatum, Crassula pinnata, Coyledon pinnata* etc. and also heterotypic synonyms like *Kalanchoe calcicola, Cotyledon rhizophylla, Bryophyllum calycinum* etc. (POWO, 2022). The *K. pinnata* Adans. is an erect herb, growing up to 1-2 meters tall, with fleshy and juicy stems that are green or reddish in color. The leaves are alternate, ovate to lanceolate, and arranged spirally on the stems. They are succulent and thick, with a crenate margin, and have small plantlets growing on the margins that can reproduce vegetatively. The flowers are small, bell-shaped, and greenish-white in color, arranged in pendulous clusters at the tips of the stems. The plant produces numerous seeds that are small, dark brown or black, and shiny. The root system of *K. pinnata* is fibrous and shallow, with numerous lateral roots that help anchor the plant to the soil. The stem is hollow, and the leaves are held in a rosette-like arrangement at the top of the stem. The plant has a characteristic odor and taste, which is due to the presence of volatile oils and other phytochemicals (Nagaratna and Hegde, 2015). The morphological characters of *K. pinnata* make it a unique and easily identifiable plant. It has a succulent leaves and small plantlets typically growing on the margins of the leaves make it a popular ornamental plant, while its medicinal properties have been recognized in traditional medicine for centuries. The plant is also valued for its ability to grow in a variety of environments, making it adaptable to a wide range of habitats (Prasad et al., 2012). The flowers of *K. pinnata* are small, bell-shaped, and greenish-white in color. They are arranged in pendulous clusters at the tips of the stems. The flowers have a four-lobed corolla, with each lobe being approximately 2-3 mm long. The calyx is cup-shaped, with four sepals that are approximately 4-5 mm long.

The stamens are four in number and inserted at the corolla tube's base. The pistil is superior and consists of four carpels that are fused at the base, with a single style and stigma. The flowers are bisexual, with both male and female reproductive structures. The flowers of *K. pinnata* are relatively small and inconspicuous, but are characteristic of the plant and play an important role in reproduction (Aejazuddin et al., 2011). The leaves of *K. pinnata* are succulent and thick, with a crenate margin. They are alternate, ovate to lanceolate, and arranged spirally on the stems. The leaves range in size from 5-15 cm long and 2.5-8 cm wide, and are held in a rosette-like arrangement at the top of the stem. One of the distinguishing features of the leaves is the small plantlets that grow on the margins of the leaves, which can reproduce vegetatively and contribute to the plant's ability to spread and colonize new areas. Overall, the leaves of *K. pinnata* are an important morphological feature of the plant, and are an adaptation to its dry and arid habitat (Walters, 2011) which is shown in Figure 2.

K. pinnata is a member of the Crassulaceae family and is widely used as a traditional medicine in several parts of India, primarily to cure kidney stones. Traditional healers utilize this plant to treat a wide range of ailments including hypertension, skin diseases, asthma, colds, insect bites, abscesses, etc. In Bengal regions, where the plant is locally known as *Pathar Kuchi*, *Parnabeeja* in Ayurvedic science it is frequently used as a substitute to *Pashanabheda* (*Berginia ligulata*) for the treatment of urinary stones. With a variety of traditional uses, this plant is also proven to have antilithogenic activity, hepato-protective activity, anticancer property and wound healing properties. Because it contains cardiac glycosides, it is reported to be harmful to cattle (Nagaratna and Hegde, 2015). It contains various bioactive compounds, including alkaloids, flavonoids, saponins, tannins, and phenolic compounds (Daniel et al., 2020). The leaves of *K. pinnata* are particularly rich in bufadienolides, a class of cardiac glycosides that exhibit significant anti-inflammatory, analgesic, antioxidant, and antihypertensive effects (Fernandes et al., 2019). In addition to bufadienolides, the plant also contains several flavonoids, such as kaempferol, quercetin, and apigenin, which have been shown to possess antimicrobial, antifungal, and anticancer activities (García-Pérez et al., 2020). Furthermore, *K. pinnata* is a rich source of phenolic compounds, including caffeic acid, ferulic acid, and quercetin-3-O-rutinoside, which exhibit strong antioxidant and anti-inflammatory properties (Afzal et al., 2012). These compounds are believed to contribute to its medicinal properties by reducing oxidative stress and inflammation in the body. Additionally, the plant is also known to contain saponins, which have been reported to possess hepatoprotective, antidiabetic, and anti-inflammatory effects (Tungmunnithum et al., 2018). The phytochemical profile of *K. pinnata* has attracted considerable attention from researchers, who are exploring its potential applications in modern medicine. The bioactive compounds present in the plant may be useful in the development of new drugs for the treatment of various diseases, including cancer, diabetes, and cardiovascular disorders. However, further studies are needed to fully elucidate the underlying mechanisms of action and potential therapeutic benefits of the phytoconstituents. The *K. pinnata* is found to be rich in content of alkaloids, flavonoids, terpenes, glycosides, steroids, bufadienolides, cardienolides, and lipids (Kamboj and Saluja, 2009). Polysaccharides, minerals, flavonoids, alkanes, organic acids, hydrocarbons, phenolic, bufadienolide orthoacetate, bufadienolides, phenols, tannins, vitamins, minerals, minor vinylic aliphatic alcohol diglycoside, protein, tannins, phenolic acids, phenanthrene alkaloid, cinnamic acids, saponins, glycosides flavonoids, tannins, carbohydrates, amino acids, esters, gums, saponins, tannins, reducing sugars, cardiotonic glycosides, flavonol glycosides, , phenolic glycosides, terpenoids are also present in *K. pinnata* (Fernandes et al., 2019; Kamboj and Saluja, 2009).

2. Ethnomedicinal claims

Kalanchoe pinnata (Lam.) Pers., commonly known as the "Life Plant", has been used in traditional medicine across various cultures for the treatment of various ailments. In traditional medicine, *K. pinnata* is used to treat a wide range of ailments, including respiratory infections, gastrointestinal disorders, skin diseases, and

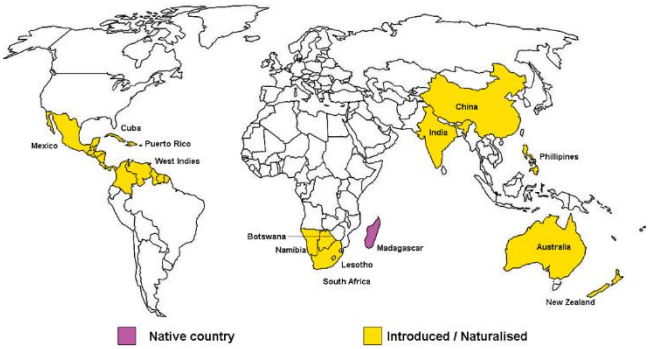

Figure 1. A world map showing the major geographical distribution of *Kalanchoe pinnata* (Lam.) Pers. (Crassulaceae).

inflammation. The plant is also used as a diuretic and in the treatment of kidney stones. In Ayurvedic medicine, the plant is used to treat wounds and ulcers, as well as respiratory and liver disorders. In traditional medicine, the plant is believed to have anti-diabetic properties and is used to lower blood sugar levels. Several studies have investigated the anti-diabetic effects of *K. pinnata* in animal models and have demonstrated hypoglycemic and anti-hyperglycemic effects (Ojewole, 2005b). *K. pinnata* is also reported to be used in the treatment of respiratory infections such as asthma, bronchitis, and pneumonia. It has been reported to have bronchodilator effects useful in the treatment of respiratory infections (Fürer et al., 2016). Another traditional use of *K. pinnata* is in the treatment of skin diseases such as eczema, psoriasis, and boils. The plant has been shown to have anti-inflammatory and anti-microbial properties and has been used to treat skin infections and wounds (Chibli et al., 2014). In addition to its traditional uses, *K. pinnata* has been investigated for its anticancer potential. It has been reported to have anti-cancer properties demonstrated in both *in-vitro* and *in-vivo* models (Mahata et al., 2012).

Despite the popular traditional use of *K. pinnata* in the treatment of various disorders, there is a need for further studies to establish the safety and efficacy for medicinal purposes. Some studies have reported potential toxicological effects, and however, further research is needed to determine the safety profile of the plant and its potential interactions with other medications (Araújo et al., 2022). With a long history of application in traditional medicine to treat respiratory infections, diabetes, skin diseases, *K. pinnata* is reported as potential natural anti-cancer agent. However, further studies are needed to establish the underlying mechanism, safety and efficacy as anti-cancer agent.

K. pinnata, also known as *Pattharcaṭ ṭ a*, has been reported to be traditionally used for the treatment of renal calculi and disorders of the urinary tract, diarrhea and dysentery, skin disorders, insect bites, ear and throat diseases, arthritis, cardiac disorders and dysmenorrhea (Gill, 1992; Yadav et al., 2016). In southern Nigeria, it is utilized to work with the dropping and recuperating placenta injury of recently conceived children. The plant leaf is somewhat presented to warm and the juice is pressed out and applied as poultice to the child's placenta on regular schedule. Likewise, the squashed leaves just as the separated juice are blended in with shear spread or palm oil and scoured on abscesses or different swellings. This is applied on ulcers, consumes and on the groups of little youngsters when they are ill (Akinsulire et al., 2007). The juice of *K. pinnata* is used for the local treatment of periodontal disease, cheilitis, cracking lips in children, bruises, wounds, boils in Brazil (Mourão et al., 1999), insect bites in India and Sri Lanka (Rossi-Bergmann et al., 1994), ear infection, dysentery in Nigeria (Akinpelu, 2000), fever, abscesses, coughs, skin diseases and cytotoxic activity (Kuo et al., 2008), cholera, urinary diseases, whitlow in Africa and Asia, tissue injuries in Taiwan, arthritis and gastric ulcers (Rossi-Bergmann et al., 1994). Leaf paste is rubbed on or tied to the head to bring relief for headache in Africa (Akinpelu, 2000). It is also used in rheumatism in Indonesia (Supratman et al., 2001), treatment of pulmonary

infection, rheumatoid arthritis, immunomodulatory and gastric ulcers (Cruz et al., 2008). Juice extracted from the fresh leaves are used as effective remedies for the treatment of jaundice in India and further confirmed *in-vivo* and *in-vitro* histopathological studies for hepatoprotective activity (Uchegbu et al., 2017)

3. Pharmacological activities

3.1. Anticancer activity

Bufadienolides from *Kalanchoe pinnata* were analyzed for their inhibitory impacts on Epstin Barr infection early antigen enactment in Raji cells actuated by the cancer advertiser, all bufadeinolides shows good potential, while Bryophyllin A shows highest activity (Stefanowicz-Hajduk et al., 2020; Wang et al., 2012). Several studies have investigated the anticancer activity of the extract of *K. pinnata*. Another study by Omosa et al. (2018) demonstrated that the ethanolic extract of *K. pinnata* had significant cytotoxic activity against various human cancer cell lines, including breast, cervical, lung, and colon cancer cells. The extract was found to induce apoptosis and inhibit the proliferation of cancer cells. Another study by Chen et al (2015) evaluated the antitumor activity of the polysaccharides extracted from *K. pinnata* in *in vitro* and *in vivo*. The results showed that the polysaccharides inhibited tumor growth and metastasis in a mouse model of melanoma (Lee et al., 2018; Yao et al., 2015).

3.2. Anticonvulsion activity

The anticonvulsant activity of the extract of *K. pinnata* has been demonstrated in various studies. For instance, a study by Ojewole (2005) investigated the effects of the aqueous extract of *K. pinnata* on seizures induced by pentylenetetrazol in mice. The results showed that the extract exhibited significant anticonvulsant activity, reducing the severity and frequency of seizures. Another study by Sabiu et al (2016) evaluated the anticonvulsant activity of the methanolic extract of *K. pinnata* in rats using the maximal electroshock-induced seizure model. The extract was found to have a dose-dependent anticonvulsant effect, suggesting its potential use in the treatment of epilepsy and other seizure disorders (Mora-Pérez and Hernández-Medel, 2016; Yemitan and Salahdeen, 2005b).

3.3. Antidiabetic activity

Patil et al (2013) studied antidiabetic activity of *K. pinnata* in streptozotocin-induced diabetic rats by glucose independent insulin secretagogue action. The dichloromethane fraction of *K. pinnata* demonstrates excellent insulin secretagogue action and can be useful in treatment of diabetes mellitus (Patil et al., 2013). George et al (2018) studied *in vitro* anti-diabetic activity and GC-MS analysis of bioactive compounds present in the methanol extract of *K. pinnata*. It was found that the aqueous fraction of the plant potentially inhibits the enzymes that is responsible for the formation of glucose from polysaccharides (George et al., 2018). Another such study conducted by Kumar et al (2017) evaluated the hypoglycemic and antihyperglycemic effects of the aqueous extract of *K. pinnata* leaves in streptozotocin-induced diabetic rats. The study found that the extract significantly reduced blood glucose levels and increased insulin levels, indicating its potential as an antidiabetic agent (Balakrishnan et al., 2018).

3.4. Antimicrobial and immunomodulatory activity

A study conducted by Tchinda et al (2012) evaluated the antifungal activity of the methanolic extract of *K. pinnata* against various fungal strains. The study found that the extract exhibited significant antifungal activity against *Candida albicans*, a common fungal pathogen in humans. Another study conducted by Abdulrahman et al (2015) investigated the antifungal activity of the aqueous extract of *B. pinnata* against dermatophytes, a group of fungi that cause skin infections. The study found that the extract had significant antifungal activity against all tested dermatophytes. These findings suggest that *K. pinnata* may have potential as a natural antifungal agent. The plant's extracts could be used in the development of new antifungal drugs or as an alternative to conventional antifungal agents (Akinsulire et al., 2007; Nwadinigwe, 2011).

Da Silva et al (1995) used BALB/c mice for the experiment and *Leishmania amazonesis* (lma) was used to induce the disease, the work demonstrate that the aqueous extract of plant protects mice against progressive infection with lma by oral route of administration. Muzitano et al (2006) studied about the antileishmanial activity of few unusual flavonoids from *K. pinnata*. The three flavonoids were tested separately against *Leishmania amazonenis amastigotes* in comparison with quercitrin, quercetin and afzelin. The quercetin aglycone – type structure, as well as a rhamnosyl unit linked at C-3, seem to be important for antileishmanial activity (Muzitano et al., 2006). Various studies have been undertaken to investigate the potential of *K. pinnata* extract as an immunomodulatory agent. In one such study, the immunomodulatory activity of the ethanolic extract of *K. pinnata* leaves in rats. The study found that the extract significantly increased phagocytic activity, lymphocyte proliferation, and delayed-type hypersensitivity response, indicating its potential as an immunomodulatory agent (Elufioye et al., 2022). Another study investigated the immunomodulatory activity of the aqueous extract of *K. pinnata* leaves in mice. The extract significantly increased

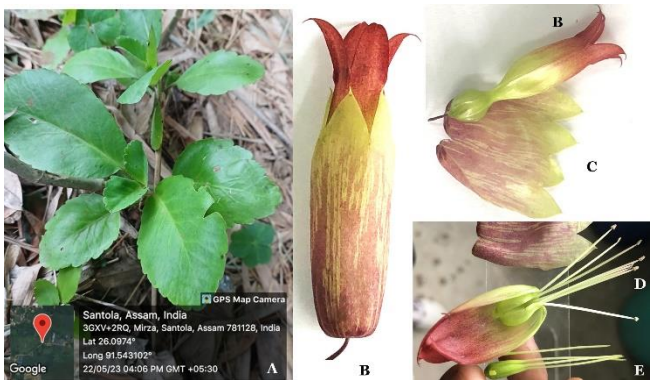

Figure 2A. *Kalanchoe pinnata* (Lam.) Pers. (Crassulaceae) in the natural habitat and its morphological characters. B. Individual flower with tubular corolla exposed after removing calyx; C. Tubular Calyx removed from tubular corolla; D. Stamens with anthers exposed from tubular corolla; E. Carpels with ovary at base.

phagocytic activity and lymphocyte proliferation, and also showed a significant increase in antibody production (Okpoho et al., 2018). Raj et al (2012) studied the *in vitro* antimicrobial action of *K. pinnata* leaf which demonstrated that the water and chloroform concentrates of the leaf had effectively restrain the zones of microorganism (Raj et al., 2012).

3.5. Anti-nociceptive and anti-inflammatory activity

The *K. pinnata* leaf fluid concentrates (BPE, 25-800mg/kg i.p.) delivered critical antinociceptive outcomes against thermally and synthetically actuated nociceptive torment improvements in mice. The plant leaf watery concentrate (BPE, 25-800mg/kg i.p. or on the other hand p.o) essentially repressed new egg whites incited intense irritation of the rat hind paw (Ojewole, 2005).

3.6. Antiproliferative activity

A study by Thakur et al. (2011) investigated the antiproliferative activity of *Bryophyllum pinnatum* on various cancer cell lines including breast cancer, colon cancer, and prostate cancer. The results of the study indicated that *Bryophyllum pinnatum* exhibited significant antiproliferative activity against all the cancer cell lines tested, with the strongest activity observed against breast cancer cells. The study also revealed that the antiproliferative activity of *Bryophyllum pinnatum* was mediated through induction of cell cycle arrest and apoptosis (Araújo et al., 2022; Hernández-Caballero et al., 2022).

3.7. Anti-ulcer activity

Pal and Chaudhuri (1991) studied the anti-ulcer activity of a *K. pinnata* (*B. pinnatum*) leaf extract in experimental animals. They

found that the leaf extract of *K. pinnata* enhanced the healing of acetic acid-induced gastric ulcers in rats (Pal and Chaudhuri, 1991). Kouitcheu et al. (2017) studied the treatment of *Helicobacter pylori* infected mice with *K. pinnata*, which resulted in a reduced bacterial load. They concluded that the methanol extract of *K. pinnata* could inhibit *H. pylori* growth, and also acted as an antioxidant to protect gastric mucosa against reactive oxygen species (Brigitte et al., 2017).

3.8. Diuretic activity

A study by Yadav et al (2008) investigated the diuretic activity of *K. pinnata* in rats. The results of the study indicated that the plant extract exhibited significant diuretic activity, with an increase in urine volume and electrolyte excretion. The study also revealed that the diuretic activity of *K. pinnata* was mediated through inhibition of Na^+-K^+-ATPase activity, which resulted in increased renal blood flow and glomerular filtration rate (Yadav et al., 2016). The active constituents responsible for the diuretic activity of *K. pinnata* have been identified as flavonoids, alkaloids, and phenolic compounds (Kokate et al., 2008). These compounds have been shown to possess a wide range of pharmacological activities including diuretic, anti-inflammatory, and analgesic properties. Further studies are needed to elucidate the mechanism of action of these compounds and to evaluate their potential as diuretic agents. Another study by Ntchapda et al (2016) investigated the effect of *K. pinnata* on electrolyte balance in rats. The results of the study indicated that the plant extract significantly increased the excretion of Na^+, K^+, and Cl^- ions, indicating its potential as a natural diuretic agent. The study also revealed that the diuretic activity of *K. pinnata* was not associated with any significant adverse effects on renal function or electrolyte balance (Ntchapda et al., 2016). Sohgaura et al (2018) studied the diuretic potential of *Cynodon dactylon, Emblica officinalis*, *Kalanchoe pinnata* and *Bambusa nutans*. Their study revealed that the use of *K. pinnata, C. dactylon* and *E. officinalis* plants for diuretic potential use in traditional Ayurvedic medicine practices (Sohgaura et al., 2018).

3.9. Antiurolithiatic activity

Phatak and Hendre (2015) reported *in vitro* antiurolithiatic activity of *K. pinnata* extract and they concluded with significant anti-urolithiatic activity. Rupam et al (2017) investigated *in vitro* antiurolithiatic activity of *K. pinnata* and *Ocimum gratissimum* leaves and concluded with potent and promising antiurolithiatic agent which is in accordance with its use in traditional medicine (Rupam et al., 2017). In another study using self-dissolving tablet formulation preparation which contained the extract of *K. pinnata* leaf has showed promising *in vitro* antiurolithiatic activity (Mawlieh et al., 2022). Yadav et al. (2016) has established that *K. pinnata* leaf extract is successful in preventing the formation of renal calculi in rats and stated that this activity may be attributed to the fact that the leaf extract contains a high quantity of phenolics, flavonoids and saponins.

3.10. Hepatoprotective activity

The hepatoprotective activity study of leaves of *K. pinnata* revealed significant hepatoprotective activity of the plant (Yadav and Dixit, 2003). Further studies are required to unveil its bioactive constituents responsible for such activities and underlying mechanism of action.

3.11. Nephroprotective activity

The aqueous extract of *K. pinnata* leaves have been reported to have potent nephroprotective activity against gentamicin-induced nephrotoxicity in rats as well as *in vitro* anti-oxidant activity (Harlalka et al., 2007). Dighade et al (2021) reported that the *K. pinnata*-mediated silver nanoparticles were able to induce a nephroprotective effect on rats with ethylene glycol-induced urolithiasis. It was also observed that after a 28-day administration of ethylene glycol, the animals which received the *K. pinnata*-mediated silver nanoparticles, showed significantly lesser symptoms when compared to the untreated ones. This effect could be attributed to the phytochemicals quercetin and kaemferol found in plants, which act as antioxidants and protect the kidneys (Dighade et al., 2021).

3.12. Analgesic, sedative-anxiolytic, cytotoxic and thrombolytic activity

The analgesic, sedative-anxiolytic, cytotoxic, and thrombolytic potentials of *K. pinnata* leaf extracts revealed promising analgesic potential in various pain models (Razibul et al., 2015). *K. pinnata* leaves also reported to have sedative and anxiolytic properties, however, it revealed moderate cytotoxic and thrombolytic activities (Welfare & Billah, 2015).

3.13. Neurosedative and muscle relaxant activities

Salahdeen and Yemitan (2004) reported neurosedative and muscle relaxant activities of aqueous extract of *K. pinnata*. A remarkable neurosedative and muscle relaxant property was also reported in *K. pinnata* extract (Yemitan and Salahdeen, 2005). However, further studies including bioactive phytochemicals and mechanistic studies are needed to understand their underlying principle and mechanism of action.

3.14. Uterine relaxant activity

Several studies have investigated the uterine relaxant activity of *K. pinnata*. In vitro studies have demonstrated that the *K. pinnata* extract significantly reduce the contractile activity of the uterine smooth muscle. This effect was found to be concentration-dependent and reversible, indicating a direct action on the smooth muscle cells (Gwehenberger et al., 2004; Yemitan and Salahdeen, 2005b). Furthermore, the extract was found to inhibit the release of oxytocin, a hormone that plays a key role in uterine contractions during labor (Santos et al., 2021). *In vivo* studies have also shown promising results. Administration of *K. pinnata* extract was found to significantly reduce the frequency and amplitude of uterine contractions, when used in combination with atosiban and nifedipine. This effect was found to be dose-dependent and was more pronounced at higher doses, which was evaluated in human myometrium biopsy strips (Santos et al., 2019). Another study conducted on pregnant women found that administration of *K. pinnata* extract resulted in a significant reduction in uterine tone and an increase in cervical dilation (Plangger et al., 2006). The uterine relaxant activity of *K. pinnata* has potential applications in the management of various conditions, such as preterm labor and dysmenorrhea. However, further studies are needed to establish its safety and efficacy in humans.

3.15. Wound healing property

The effect of *K. pinnata* leaf extract was investigated for its wound healing potential in Wistar albino rats and concluded to have pronounced healing effect based on their effects on the inflammatory and proliferative phases of wound healing (Khan et al., 2004). *K. pinnata* have been reported to possess active compounds, including flavonoids, triterpenoids, and bufadienolides, which are believed to be responsible for its wound healing activity (Lourenço et al., 2019). *In vitro* studies demonstrated significant enhancement of the proliferation and migration of fibroblasts, which are the most important cells involved in wound healing (Araújo et al., 2022). The extract also exhibits antibacterial activity against several common wound pathogens, including *Staphylococcus aureus* and *Pseudomonas aeruginosa* (Jagdish and Nehra, 2022; Richwagen et al., 2019).

3.16. Antihypertensive activity

Both the aqueous and methanolic leaf extracts of *K. pinnata* have been reported to have potential to significantly reduce arterial blood pressures and heart rates of anaesthetized normotensive and hypertensive rats (Ojewole, 2002). Aqueous extract of the plant has been found to provide beneficial effects in relation to systolic and diastolic arterial pressure, heart rate, *in vivo* antioxidant systems in rats with high salt content-induced hypertension. These effects have

been attributed to the high antioxidant and immunomodulatory effects of *K. pinnata* (Bopda et al., 2014).

4. Conclusion and future prospects

Kalanchoe pinnata (Lam.) Pers. is an important medicinal plant reported with multi-curative properties. Present review sheds light on the various ethno-medicinal and established pharmacological activities. The *K. pinnata* has been reported to be used in ethnomedicinal practices as anticancer, anticonvulsant, antidiabetic, antifungal and immunomodulatory, antileishmanial, antimicrobial, anti-nociceptive and anti-inflammatory, antiproliferative, antiulcer, diuretic, antiurolithic, hepatoprotective, nephroprotective, analgesic, sedative-anxiolytic agent. It is also reported with cytotoxic and thrombolytic, neurosedative and muscle relaxant, uterine relaxant, and wound healing properties. However, some of these ethnopharmacological reports requires scientific validation to unveil its underlying principles and mechanism of actions. *K. pinnata* have been reported with various classes of phytoconstituents which possess potential therapeutic applications, such as alkaloids, triterpenes, glycosides, flavonoids, cardienolides, steroids, bufadienolides, and lipids. Polysaccharides, minerals, flavonoids, alkanes, organic acids, hydrocarbons, phenolic, bufadienolide orthoacetate, bufadienolides, phenols, tannins, vitamins, minerals, minor vinylic aliphatic alcohol diglycoside, protein, tannins, phenolic acids, phenanthrene alkaloid, cinnamic acids, saponins, glycosides flavonoids, tannins, carbohydrates, amino acids, esters, gums, saponins, tannins, reducing sugars, cardiotonic glycosides, flavonol glycosides, phenolic glycosides, and terpenoids have been reported. The bioactive compounds isolated from *K. pinnata* corroborated through ethnomedicinal literatures have validated the ethnopharmacological relevance of the *K. pinnata* used by different ethnic groups across the world. The phytochemistry and pharmacological activities reported in the present review provides new directions for research endeavor with focus on the isolation and purification of bioactive compounds which will lead to discovery of novel therapeutic drugs for treatment of various ailments/diseases reported against this wonder herb of immense ethnopharmacological significance.

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Authors Contributions

All the authors Kangkan Kalita, Bhaswati Kashyap, Rosy Ahmed, Himsikhar Sarma, Koushik Nandan Dutta, Kangkan Deka, and Sameeran Gam equally contributed in literature review and drafting of the manuscript. NPSB conceptualized the topic and finalize the manuscript. All authors read and approved the manuscript before communication to the journal.

Conflict of interests

The authors have no conflict of interest.

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