

Phytochemical, Morphological, Botanical and Pharmacological Aspects of a Medicinal Plant: *Kalanchoe pinnata* – A Review Article

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Abstract

Kalanchoe pinnata is a perennial plant of family Crassulaceae having worldwide distribution but mostly found in Caribbean, Central America, North America and some regions of Africa and Asia. *Kalanchoe pinnata* is found native to Madagascar where it grows in appreciable amount in sandy and granitic soil under subhumid to temperate humid climatic conditions with mean annual rainfall of about 1000 to 2000 mm. This aromatic plant is of extreme therapeutic potential and high medicinal importance owing to the presence of distinctive chemical constituents such as essential oils having alkaloids, lipids, triterpenes, bufadienolides, glycosides, steroids, flavonoids and cardenolides. Leaves of *Kalanchoe pinnata* contain a biologically active group of chemicals called "bufadienolides" including bryotoxin-A, bryotoxin-B, bryotoxin-C, cardiac glycoside, digitoxin and digoxin that possesses insecticidal, chemo-preventive, anti-tumor and anti-bacterial potentials. Its leaves are known to have numerous anti-ulcer compounds such as triacontane, taraxerol, syringic acid, succinic acid, stigmaterol, steroids, quercetin, pyruvate, peposterol, pseudotaraxasterol, protocatechuic acid, phosphoenolpyruvate, patuletin, palmitic acid, oxalic acid, oxaloacetate, kaempferol, isofucosterol, hentriacontane, glutinol, friedelin, flavonoids, ferulic acid, epigallocatechin, coumaric acid, codisterol, clionasterol, clerosterol, cinnamic acid, cardenolides, campesterol, caffeic acid, bufadienolides, bryotoxin-C, bryophynol, bryophyllol, bryophyllin-A and bryophyllin-C, bryophyllin, bryophollone, bryophollenone, β -sitosterol, β -amyrin, benzenoids, behenic acid, astragalol, arachidic acid and many more. *Kalanchoe pinnata* is known to exhibit wound healing, insecticidal, anti-inflammatory, anti-allergic, anti-microbial, anti-tumor and CNS depressant activities along with anti-oxidant and anti-diabetic potentials.

Keywords: *Kalanchoe pinnata*, bufadienolides, cardenolides, digitoxin, digoxin, triacontane, stigmaterol, phosphoenolpyruvate, insecticidal, anti-tumor, anti-diabetic

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1. Botanical Description and Physical Attributes

Kalanchoe pinnata (Bryophyllum) is perennial plant belonging to family (Crassulaceae). It has been used for thousands of years and has become essential ingredient in many medicines [1]. The uncertainty in the exact number of species within the genus is largely distributed in the region of Asia, Africa, North America, central America and Caribbean. It is also found in south America and Europe [2]. Variability is prevalent in morphology, growth habit, flower colour, leaves and stem and chemical composition. *Kalanchoe pinnata* pollinate very easily. *Kalanchoe pinnata* is known by different names depending where you are in the world. In English, it is typically called "air plant", "good luck leaf", "Hawaiian air plant", "life plant", "American life plant" and "flopers". In India, specifically in Hindi, it called as "Patharchattam", "Patharchur", "Pather Chat" and

"Paan-futti". In Bengali, it is called "Koppat", "Patharkuchi", "Gatrapuri", "Kaphpata", "Koppata" and "Pathorkuchiand" and in Unani it is called "Zakhm-e-Hayaat", "Pattharchoor" and "Pattharchat". The plant is herbaceous, varying in size. It usually grows 30-120 cm tall, but can sometimes reach upto 2m in height. The upright stem is hairless and fleshy. The leaves are also fleshy (i.e. succulent) and are either simple (particularly on seedlings) or compound (i.e. trifoliate or pinnate). They are oppositely set and flattened. Flower's colour is either green or yellow. *Kalanchoe pinnata* is ornamental plant. Analysis of various fraction of *Kalanchoe pinnata* indicated the incidence of alkaloid, diterpenoidal lactones, glycosides, steroids, phenolics and aliphatic compounds. The notable pharmacological properties included anti-diabetic, anti-

neoplastic, anti-oxidant, anti-allergic and many more events that are controlled by these chemicals [1].

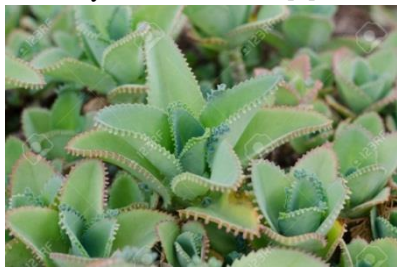


Fig 1 *Kalanchoe pinnata* plant

2. Historical Perspective

Kalanchoe pinnata is widely distributed in all tropical regions with various species having structural and botanical variations and unique chemical composition which make it an attractive option to be used as potential medicinal remedy in ayurvedic system of medicines. This plant was navigated by Malayo-Polynesian speaking navigators of Indo-Malay archipelago who visited to colonize the Madagascar after first century. *Kalanchoe pinnata* was evident to be transferred to other adjoining islands of India through Indian Oceans. Similarly, movement of *Kalanchoe pinnata* towards South America and Caribbean regions may have occurred after early arrival of European traders in Indian Ocean or more possibly during slave trade of West Africa in that region.

3. Demographic Locations

Kalanchoe pinnata is a plant most commonly found in temperate regions of Hawaii, Polynesia, Melanesia, Galapagos, Mascarenes, Macaronesia, West Indies, New Zealand, Asia and Australia. In Hawaii, this specie is regarded to be an invasive species as it is abundantly found in Philippines and commonly called kataka-taka and katakataka which means remarkable and astonishing. *Kalanchoe pinnata* is also evident to be native to Madagascar where it is found abundantly all along the coastal areas growing in sandy and granitic soils. It is a plant of sub-humid to temperate humid climate of central highlands of Madagascar with approximate rainfall of about 1000 to 2000 millimeters. In USA and Hawaii, it is sometimes found at low elevations of dry to mesic areas [3].

4. Morphological and Ecological Specifications

Kalanchoe pinnata is an erect/upright, succulent, fleshy and hairless stem whose leaves are also succulent and flashy having simple or compound type such as pinnate leaves or trifoliate leaves. These leaves are often found oppositely arranged having variable number of leaflets with approximate length of 5 to 25 cm and approximate diameter of 2 to 12.5 cm. They are green to yellowish green in colour with glabrous hairless structure and are borne on 2 to 10 cm long stalk. Leaflets of *Kalanchoe pinnata* are oval to elliptical in shape having obtuse rounded tips that are often found at the terminal of leaflets. Furthermore, smaller plantlets may also be occasionally formed in scalloped margins of leaflets in case if actual leaves get detached from

stem. Tubular, bell shaped pendulous and drooping flowers of about 7 cm lengths are evident to found arranged in branched clusters at the tip of terminal inflorescence. Every flower is borne on stalk with average length of about 10 to 25 mm having inflated, prominent, yellowish green to pale green sepals that partially fused to tube and often found streaked with red or pinkish colour blotches. Yellowish green to dark reddish coloured petals of about 3 to 6 cm length are often attached into a tube which further divides into four corolla lobes just near the tip. Flowers of *Kalanchoe pinnata* are mostly produced in spring and winter while its fruit is membranous and papery in appearance having four cylindrical carpels that usually remain enclosed within older parts of flowers and known to contain large number of brownish coloured seeds.

5. Major Chemical Constituents

Kalanchoe pinnata is an aromatic plant that is used as an herb having sweet and sour smell. Large number of *Kalanchoe pinnata* has been described on the basis of their taste. Plant grows from 1-1.5 m in height. Sweet *Kalanchoe pinnata* is sour in taste and plant colour is green. The distinctiveness of fragrance and aroma in many *Kalanchoe pinnata* species/cultivars is due to the presence of essential oil in leaves and other part of plant. This plant is a major source of lipids, alkaloids, bufadienolides, triterpenes, steroids, glycosides, cardienolides and flavonoids. Its leaves are rich in "bufadienolides" that constitutes bryotoxin-C, bryotoxin-B, bryotoxin-A, digitoxin and digoxin that shows strong chemo-preventive, anti-tumour and anti-bacterial effects and insecticidal potentials [4]. The leaves and bark of this plant are bitter in taste that is used in vomiting and diarrhea owing to carminative, analgesic and astringent to bowels.

Some major anti-ulcer chemical constituents in different parts of this plant are arachidic acid, astragalín, behenic acid, β -amyrin, benzenoids, β -sitosterol, bryophollenone, bryophollone, bryophyllin, bryophyllin-A-C, bryophyllol, bryophynol, bryotoxin-C, bufadienolides, caffeic acid, campesterol, cardenolides, cinnamic acid, clerosterol, clionasterol, codisterol, coumaric acid, epigallocatechin, ferulic acid, flavonoids, friedelin, glutinol, hentriacontane, isofucosterol, kaempferol, oxalic acid, oxaloacetate, palmitic acid, patuletin, peposterol, phosphoenolpyruvate, protocatechuic acid, pseudotaraxasterol, pyruvate, quercetin, steroids, stigmasterol, succinic acid, syringic acid, taraxerol and triacontane. Some essential fatty acids of this plant include behenic acid, arachidic acid, stearic acid and palmitic acid. In addition to that, this plant also contain HCN, succinic acid, oxalic acid, malic acid, citric acid, oxaloacetate and isocitric acid.

Table 1 Minerals of *Kalanchoe pinnata*

Parameters	Minerals
Calcium	96.5 $\mu\text{g/g}$

Potassium	76.40 µg/g
Phosphorus	26.42mg/100
Sodium	-
Magnesium	-
Iron	-
Zinc	-
Ascorbic Acid	44.03 mg/100
Riboflavin	0.20 to 0.42 mg/100 g
Thiamine	0.11 to 0.18 mg/100 g
Niacin	0.02 to 0.09 mg/100 g
Total ash	5.1%

This plant is rich in methionine, protein hydrolysate, vitamins, glutamic acid, casein hydrolysate, ascorbic acid, cysteine, riboflavin, glycine, thiamine, pyridoxine and niacin. This medicinal plant also contain appreciable concentration of calcium, potassium, ascorbic acid, zinc, iron, sodium, magnesium, phosphorous, riboflavin, thiamine, niacin, nicotinamide and casein hydrolysate. Few essential phytochemical constituents of *Kalanchoe pinnata* include flavanoids, alkaloids, tannins, phenolics and other mineral elements like zinc, iron, sodium, phosphorous, potassium, calcium and magnesium along with set of vitamins including phosphoenolpyruvate, protocatechuic acid, ferulic acid, p-coumaric acid, phydroxycinnamic acid, 4-hydroxybenzoic acid and uhydroxy-3-methoxycinnamic acid. Its leaves are known to contain kaempferol-3-glucoside, quercetin-3-O-diarbinoside, quercetin-3L-rhamonsido-L-arabino furanoside, astragalin, rutin, 3,8-dimethoxy-4,5,7-trihydroxyflavone, quercetin, kaempferol, friedelin and epigallocatechin-3-osyrgate [5].

6. Post Harvesting and Valuable Products

Kalanchoe pinnata is a plant that is easy to grow in variety of environmental conditions to be used in number of valuable market products and medicinal formulations [6]. *Kalanchoe pinnata* like other plants is consumed in a variety of ways for various purposes. The leaves of *Kalanchoe pinnata* is collected by local procedure. They were fresh and free from fungal infections. The leaves were washed with tap water and dried in a shade in a room away from direct sunlight. A fine powder was prepared by grinding the dry leaves in a blender. Fine powder is dissolved in ethanol and kept at room temperature at 28°C to minimize volatize compounds. Single or multiple leaves can be removed and used once needed for fresh/culinary purposes. *Kalanchoe pinnata* can also be maintained for some time by layering in salt alone [7]. Complete chemical characterization of solvent extract of *Kalanchoe pinnata* has shown that it constitutes sitosterol, β-amyrin, α-amyrin, n-alkanol and n-alkane. Furthermore, leaf of *Kalanchoe pinnata* contain phenolic components, bryophyllin B, fumaric acid, kaempferol, glycosides of quercetin, citric acid, isocitric acid, malic acid, wax alcohols and wax hydrocarbons [8].

Kalanchoe pinnata is known to be used in number of medicinal remedies in conventional and advanced system

of medicines owing to its excellent therapeutic potentials as its aqueous extract contains appreciable amount of bryophyllin-B that is effective against in-vitro growth of tissue culture while methanolic extract has potential against cytotoxicity of tumour cell culture. Methanolic leave extract also acts as strong anti-inflammatory, anti-pyretic and analgesic agents that significantly reduce carrageenan-induced paw oedema, yeast-induced pyrexia, acetic acid induced writhing and cotton pellet granuloma. Leaf juice of *Kalanchoe pinnata* has found to be effective for *Pseudomonas aeruginosa*, *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus* while extract prepared from ethyl acetate has shown anti-mutagenic effects [4]. Fresh leaf juice has proved to be an effective remedy for jaundice in folk system of medicine in India. In Africa, leaf juice is generally given to newborn infant while its infusion is taken by adults and mother of infants. Different parts of this plant are used for various clinical symptoms such as kidney stone, urinary stones, hypertension, inflammation, arthritis, ureterolithiasis, tuberculosis, respiratory troubles, pneumonia, painful micturition, nephrolithiasis, jaundice and hoping cough, gout, epilepsy, dysuria, insect bites, diabetes, bronchial infections, boils, dysentery and asthma.

7. General Uses and Pharmacological Applications

Kalanchoe pinnata has long been used to treat the hemorrhage and various bleeding disorders because of astringent activities and hemostatic potentials [9]. Its juice is also used as febrifuge in Singapore while the soup prepared from its leaves is also given as tonic to treat kidney and stomach disorders. In Brazil, various parts of this plant are considered as cough suppressant, anti-inflammatory agent, diuretic medicine, wound healing remedy and sedative drug. It is also been used for respiratory disorders starting from simple cough to bronchitis and from severe bronchitis to asthma. It helps to treat edema of legs, skin disorders, gastric ulcers and kidney stones. Some external applications are found to be effective for insect bites, severe burns, painful boils, chronic ulcers, deep wounds, severe infections, earache, toothache and headache. It also helps to promote menstruation and assist the childbirth during labor. It is useful medicinal remedy for preventing toxic liver damages, intense viral infections and catastrophic alcoholic symptoms. Aqueous extract has proved to be potential anti-tumour, anti-diabetic and anti-inflammatory agent along with cutaneous leishmanicidal activities and neuro-protective effects. It has proved to be effective against necrosis of kidneys, accumulation of inflammatory cells, epithelial desquamation, blood vessel congestion and gentamicin induced glomerular congestion. It normalizes the level of nitrogen in urea [10].

Various extracts of *Kalanchoe pinnata* are known to contain quercitrin flavanoids that are very effective against fatal anaphylactic shocks [11]. Its leaves are used for wounds, ulcers, tuberculosis, swellings, plegmon, polyuria, impetigo, dysentery, diarrhea, ophthalmia dysuria, congestion,

insect bites, boils and burns. The combination of its leaf juice, jeera and banaspati ghee are used to treat bloody diarrhea. Leaf poultices are applied for inflammations, swellings, sprains and wounds. Its leaf juice is used for cholera and when mixed with Kali Mirch proved to be effective for hemorrhoids and blood oozing piles. Leaf powder of this plant is used for leprosy, blocked urination, burning urination and inflammations when taken with black pepper. The leaves roasted on fire when applied on surgical sutures and wounds of skin helps to prevent discoloration and visible scars. Roots of *Kalanchoe pinnata* are used to maintain and reduce high blood pressure along with cardiac problems. Different species of this genus and different parts of this plant are used to treat fever, constipation, boils, wounds, cuts, soars, round worms, pyretic symptoms, ear pains, diabetes, liver disorders, hepatitis, excessive urination, hemorrhoid, bloody piles, stomach ache, intestinal disorders, severe inflammations, mixed diarrhea, leucorrhoea, jaundice, cancer, kidney disorders, gallbladder stones, cardiac poisoning and many more [12].

7.1 Therapeutic Potentials

Kalanchoe pinnata is known to have strong anti-oxidant properties. Many researches have shown that essential oil contains potential anti-cancer, anti-viral and anti-microbial properties. Anti-oxidants are an important part of maintaining a healthy and balanced lifestyle. *Kalanchoe pinnata* may be a very important source of these essential compounds. However, despite these reputed properties, it is important to be aware of that *Kalanchoe pinnata* contain methanol-soluble fractions that inhibit the development of a variety of acute ulcers intentionally induced. Some other highly valuable biological activities of this plant are anti-ulcer, hepato-protective, anti-diabetic, diuretic and wound healing, insecticidal and anti-cancer.

7.1.1 Wound Healing Activity

Wound healing activities of *Kalanchoe pinnata* are shown by ethanolic extracts as it significantly reduces the size of cuts and wounds as well as oedema at affected sites. However, some recent investigations have shown that this wound healing potentials may be due to the presence of phenolic anti-oxidants and steroidal glycosides. Some recent studies have shown that extracts prepared in alcohol, petroleum ether and water have potential wound healing effects. These experimental investigations demonstrated that aqueous extracts have more potential in comparison with alcoholic and etheric extracts [10].

7.1.2 Insecticidal Activity

In a recent scientific investigation, researchers have found that methanolic extracts of this plant contains bufadienolides that have strong insecticidal properties. These isolated compounds were reported to be strong insecticidal agents against three different silkworm larvae and basic reason was mainly associated with presence of 1,3,5-orthoacetate moiety among all compounds.

7.1.3 Anti-Inflammatory Activity

Leaf extracts of *Kalanchoe pinnata* were prepared in methanol, acetone, chloroform and petroleum ether to check its effects on formaldehyde induced oedema on experimental basis. Among all extracts, methanolic extract showed more pronounced effects in inhibiting the paw oedema in comparison with all other extracts. Furthermore, formaldehyde induced inflammations from damaged cells that possesses enough potential to produce endogenous mediators were tested for bradykinin, prostaglandins, serotonin and histamine. Hence, it was concluded by these experimental results that inhibition in oedema induced by formalin in rats was mainly attributed to the presence of bufadienolides and various other water soluble constituents of extract.

7.1.4 Anti-Allergic Activity

Some recent scientific investigations have revealed that oral treatments with quercitrin extracted and isolated from plants prevent fatal anaphylaxis in animals, upto 75 percent. These results shows that oral administration of various forms of *Kalanchoe pinnata* are effective to slow down the modules of pro-anaphylactic induced immune responses. Protection achieved by quercitrin suggested that flavonoid is the most critical component of *Kalanchoe pinnata* that is found effective against extreme allergic reactions [13].

7.1.5 Anti-Microbial Activity

Roots of *Kalanchoe pinnata* were mixed with methanol, chloroform, petroleum ether and water to prepare extracts of various polarities which showed number of potential activities upon oral administration owing to the presence of different types of flavanoids. These solvent extracts were evaluated in murine models of cutaneous leishmaniasis. Daily doses of free quercetin, 3O-L-arabinopyranosyl, quercetin 3-O-L-rhamnopyranoside and quercetin-L-rhamnopyranoside were administered to experimental animals. It was experimentally found that these chemicals were able to control the growth of lesions caused by *Leishmania amazonensis* and significantly reduced the parasitic load. These flavonoids were proved to be effective as the crude *Kalanchoe pinnata* aqueous extract was given at 320 mg/kg of body weight. HPLC-DAD-MS analysis of the plasma of extract-treated mice suggested that quercetin and quercetin glucuronides are the main metabolites of *Kalanchoe pinnata* quercetin glycosides. These results specify that quercetin glycosides are important active mechanisms of the aqueous extracts as they possess potent oral efficacy against cutaneous leishmaniasis.

7.1.6 Anti-Tumor Activity

Five different bufadienolides isolated from *Kalanchoe pinnata* leaves were examined for inhibitory effects on EBV-EA (Epstein-Barr virus early antigen) activation in Raji cells that were induced by tumor promoter named as 12-Otetradecanoylphorbol-13-acetate. So, bufadienolides showed potential inhibitory effects while bryophyllin-A exhibited marked inhibition among the tested

compounds, Bryophyllin-C that is a reduction analogue of type-1 and bersaldeenin-3-acetate lacking orthoacetate moiety were found to be less active. These results suggested that bufadienolides are potential cancer protecting and chemo preventing agents [14].

7.1.7 CNS Depressant Activities

Methanolic fraction of the leaves of *Bryophyllum pinnatum* had produced significant alteration of behavioral pattern such as it caused dose-dependent potentiation of pentobarbitone sleeping time and had significant effects on analgesic activity. At other end, marked reduction of exploratory performance and loss of residual curiosity were also observed [15].

7.1.8 Anti-Oxidant Activity

Kalanchoe pinnata aqueous extract was evaluated for its potential protective effects on the gentamicin induced nephrotoxicity of rats. In-vitro investigations have revealed that leaf extract of *Kalanchoe pinnata* possesses strong anti-oxidant potential along with oxidative radical scavenging effects. Furthermore, water based leaf extracts of *Kalanchoe pinnata* might also have nephroprotective potentials in case of gentamicin-induced nephrotoxicity in testing animals.

7.1.9 Anti-Diabetic Activity

Presence of zinc in plants could mean that plants can play valuable roles in management of diabetes which result from insulin malfunction. The anti-nociceptive effect of herb's aqueous leaf extracts was evaluated by the 'hot-plate' and 'acetic acid' test models of pain in mice. The anti-inflammatory and anti-diabetic effects of the plant extract were investigated in rats, using fresh egg albumin-induced pedal oedema and streptozotocin-induced diabetes mellitus. The aqueous leaf extract produced significant ($P < 0.05-0.001$) anti-nociceptive effects against thermally and chemically induced nociceptive pain stimuli in mice. Similarly, plant extract also showed significantly ($P < 0.05-0.001$) inhibition of fresh egg albumin induced acute inflammation and caused significant hypoglycemia in rats. Different phyosterols, flavonoids, triterpenoids and polyphenols of this herb are speculated to account for observed anti-diabetic, anti-nociceptive and anti-inflammatory potentials of this plant. It exerted strong anti-inflammatory and anti-nociceptive effects probably by inhibiting the release, synthesis or production of inflammatory cytokines and mediators including polypeptide kinins, prostaglandins and histamines [4].

8. Summary

Kalanchoe pinnata is typically found in tropical and temperate regions of the world. It is commonly known to exhibit a wide range of potential pharmacological activities which involves the treatment of various serious disorders mainly related to mankind. *Kalanchoe pinnata* is widely used as heavenly herb. Modern pharmacological investigations have generally confirmed the traditional uses of *Kalanchoe pinnata* and their extracts in severe sicknesses, inflammations, painful ulcers, fungal infections, viral

diseases and microbial attacks, impaired immune system, diabetes mellitus, spasms and insecticidal properties. It is believed that detailed information as presented in this review on its phytochemical constituents and various biological properties of its extracts and the constituents might provide incentive for evaluation of the use of the plant in medicine and in agriculture. Extracts and fractions tested on mice and rats showed significant analgesic, anti-anaphylactic, anti-allergic, anti-inflammatory, anti-tumorous, anti-leishmanial, anti-ulcerous, anti-fungal, anti-bacterial, anti-histamine, CNS-depressant, anti-viral, febrifuge, immuno-suppressive, gastro-protective, immune-modulator, muscle-relaxant, insecticidal and sedative results without having adverse effects. Some small companies in India such as Amazon are using it as raw materials for phytochemicals. The pharmacological studies so far have mostly been performed in-vitro and in-vivo with animals. In future, the isolated principles of *Kalanchoe pinnata* needs to be evaluated in scientific manner using specific animal models and clinical studies as it is the dire need of hour. Furthermore, it is also urgently needed in order to confirm the worth of traditional wisdom in the light of a rational phytotherapy on the toxicity of plant and especially on bufadienolides and its usage during pregnancy and also to understand molecular mechanism of action in order to predict molecule's chemical structures and various biologically active byproducts alongside.

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