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INTEGRATING PHARMACOLOGICAL INSIGHTS, PHARMACOGNOSTICAL APPLICATIONS, AND PHYTOCHEMICAL ANALYSIS OF *CROSSANDRA INFUNDIBULIFORMIS*: A COMPREHENSIVE REVIEW

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Abstract: This review examines the medicinal properties and phytochemical composition of *Crossandra infundibuliformis*, commonly known as the firecracker flower. Widely used in traditional medical practices like Ayurveda and Siddha. *C. infundibuliformis* is known for its antimicrobial, anti-cancer, anti-diabetic, and wound-healing properties. The plant is mainly grown in tropical regions like Southern India, Malaysia, and Sri Lanka. It's valuable for floriculture and medicine. Phytochemical studies have identified numerous bioactive compounds in the plant, including alkaloids, flavonoids, phenolic acids, glycosides, tannins, phytosterols, and terpenoids, which contribute to its medicinal benefits. Traditionally, *C. infundibuliformis* has been used to treat diabetes, leprosy, ulcers, conjunctivitis, and skin conditions, underscoring its role in traditional healing systems.

Research supports its significant anti-arthritic, antimicrobial, anti-cancer, anti-diabetic, and antioxidant effects. For example, leaf extracts have been shown to possess strong antibacterial properties against several bacterial strains, and flower extracts have been effective against pathogens causing urinary tract infections. Additionally, ethanolic extracts from the leaves and stems have demonstrated notable anti-diabetic effects in diabetic rats, indicating its potential in managing diabetes.

The plant also shows aphrodisiac, hepatoprotective, neuropharmacological, and wound-healing capabilities. The review highlights the potential of *C. infundibuliformis* for drug development and calls for more research to confirm and extend its therapeutic applications. By bridging traditional uses with scientific research, this review aims to emphasize the medicinal potential of *C. infundibuliformis*, setting the stage for future studies and pharmaceutical innovations.

Keywords- *Acanthaceae, Crossandra infundibuliformis,* Pharmacological activity, Phytoconstituents.

I. INTRODUCTION

Traditional Chinese Medicine, Ayurveda, Kampo, traditional Korean medicine, and Unani have been practised in various regions globally and have evolved into well-regulated healthcare systems. Each of these traditions reflects the cultural and historical contexts of their origins, offering unique approaches to health and wellness that continue to be valued and refined in contemporary medical practice [1]. The increasingly widespread use of alternative medicine has prompted the WHO to promote the global integration of traditional and complementary medicine into the national healthcare systems and to encourage the development of national policies and regulations [2]. The global adoption of herbal medicines and phytonutrients, also known as nutraceuticals, is rapidly increasing. Many people are now choosing these products to manage a variety of health issues within different national healthcare systems, showing a shift towards natural and alternative treatment options [3].

Herbal medicines are substances one can eat or drink and maybe vitamins, minerals, or herbs or parts of these substances. It can be defined as ‘plants or their parts used for their scent, flavour, or therapeutic properties' [4]. Herbal remedies are commonly utilized either as an alternative to or in conjunction with conventional medicine [5]. Many individuals opt for a more holistic approach to

treatment, particularly those with persistent physical health conditions who frequently experience dissatisfaction with the perceived lack of efficacy of mainstream therapies [6].

Crossandra infundibuliformis is also called a butterfly plant because it is a heat-loving tropical plant that will bring colour to your garden during warm months. The plant is a member of the *Acanthaceae* family [7]. This plant is known for its tropical flower, often called "Firecracker," due to the tendency of the seed pods formed after flowering to burst open under high humidity conditions [8]. This particular plant provides numerous health benefits and has economic value. It is well known for its therapeutic properties in Indian systems of medicine, including Ayurveda and Siddha, as well as in traditional medicine around the globe. It thrives in tropical climates and cannot withstand low temperatures or frost. It flourishes in areas where the temperature hovers around 30 degrees celsius. Hence, this plant is commonly found in tropical regions such as Southern India, Malaysia, and Sri Lanka [9]. In India, *C. infundibuliformis* is widely distributed and commonly planted in gardens and temples for its colourful flowers. It is grown in various regions such as Mysore, Chennai, Delhi, Nasik, Assam, Kerala, Pune, Mumbai, and other parts of the country [10].

The *C. infundibuliformis* plant is important to the floriculture sector economically. *Crossandra* is also a significant traditional flower crop cultivated commercially in the country and is well-recognized in South India. The flowers, however not fragrant are very popular due to their attractive bright colour and light weight. It is well known for its vibrant blossoms, which are used to create garlands, gajras, and venis, among other decorative items. Because of its minimal maintenance needs and resistance to pests and diseases, the plant's economic worth is enhanced by lower production costs and a consistent supply of blooms for commercial use [11].

Table 1 : Morphological Classification of the *Crossandra infundibuliformis*

Kingdom	Plantae
Division	Tracheophyta
Class	Angiospermae
Order	Lamiales
Family	*Acanthaceae*
Genus	*Crossandra*
Species	*Crossandra infundibuliformis* (L.) Nees

Table 2 : Synonyms /Vernacular names of the *Crossandra infundibuliformis*

English	Firecracker flower, Unarmed orange nail dye
Kannada	Abbolige
Gujarati	Aboli
Bengali	Krasandra
Hindi	Krosendra
Marathi	Aboli
Telugu	Krassandra
Malayalam	Priyadarshini

II. PHARMACOGNOSTICAL STUDIES:

The evergreen subshrub *C. infundibuliformis* stands erect, reaching approximately 3 feet. It produces fan-shaped flowers that can bloom at any time of the year [8]. The characterisation of various genotypes within *C. infundibuliformis*, such as Arka Ambara, Arka Chenna, Arka Kanaka, Arka Shravya, Arka Shreeya, ACC-1, ACC-2, PCC-1, PCC-2, and *Crossandra nilotica*, encompasses features such as plant growth habit, stem hairiness, stem colour, leaf lamina margin, leaf venation, inflorescence peduncle colour, flower petal margin, flower arrangement, and flower colour [12].

Fruits are oblong capsules, seeds 4-orbicular with fimbriate scales. The leaves display either a smooth or wavy texture, are subdentate, and grow in a whorled pattern. They have a glossy, deep green colour, an upright oval shape, and cluster densely near the inflorescence. Their elliptical form features a sharp apex and base, with margins that are undivided. These leaves are simple in type and can also be oppositely arranged. Blossoms commonly have 3-5 asymmetric petals, emerging from 4-sided stalked spikes with tube-like 2 cm long stems in apricot or coral red hues, set in dense sessile spikes of either red or yellow. The calyx features 5 ovate and acute segments, with the inner pair notably smaller. It has an impressive range of colours varying from orange, pink, red, yellow and double-coloured blue types with a white throat. *Crossandra's* blooms arise from a hairy inflorescence featuring spikes with four sides and stalks, adorned by prominent linear-oblong bracts that overlap gracefully. The corolla of the plant is cylindrical and somewhat curved, while the stamens appear fringed and occur in pairs of four. Seeds are enveloped in scales that spread and become sticky when moistened. Each seedpod holds four seeds [13].

III. PHYTOCHEMICAL ANALYSIS:

Crossandra infundibuliformis contains various bioactive compounds across its leaves, flowers, stems, and roots. These compounds include alkaloids, flavonoids, phenolic acids, glycosides, tannins, phytosterols, and terpenoids. The plant parts contain minerals like potassium, calcium, and phosphorus also other nutrients like sugars, nitrogen, crude protein and total free amino acid. Moisture is

present in all parts, with the leaves having the highest moisture content [14]. Furthermore, pigment analysis reveals the presence of Chlorophyll A, Chlorophyll B, Lutein, Violoxanthin, and Neoxanthin [15].

IV. ETHNOBOTANICAL APPLICATIONS:

Crossandra infundibuliformis, a vibrant plant, is frequently selected for its medicinal uses in traditional practices. The plant parts have been used since old times in treating different sorts of turmoil like aggravation and it is likewise known for its injury-mending action. The plant was often used as a remedy for diabetes, leprosy, ulcers, conjunctivitis and skin problems. The plant was additionally notable for its sexual enhancer action [16]. Flower extract is utilized for a variety of ailments such as fever, headache, and pain [9]. Due to its therapeutic value, the many parts of this plant are used for many treatments. Paliyar tribes of Shenbangathope in Virudhanagar district of Tamil Nadu use flowers of *C. infundibuliformis* in combination with pepper in wound healing [17].

V. PHARMACOLOGICAL PROFILE OF *Crossandra infundibuliformis*:

Anti-arthritic activity

In-vitro Anti-Arthritic activity of plant extract of *C. infundibuliformis* leaves was studied here. Measuring the inhibition of protein denaturation by the Egg-Albumin method was used. The percentage inhibition of protein denaturation by petroleum ether and methanolic extracts at three different doses of 100, 250, and 500 µg/ml was evaluated. The standard diclofenac sodium was used. At the end of the study, it was found that petroleum ether extract was more effective than methanolic extract [18].

Anti-bacterial activity

Various foliar extracts of *C. infundibuliformis* were investigated for their anti-bacterial activity. The anti-bacterial activity was done by agar well diffusion technique assessing against 23 bacterial strains. Rifampicin was used as a standard drug. The findings demonstrated that the foliar extracts of *C. infundibuliformis* present to have great potential as a natural source of healthcare products [19].

Three different leaves extract of *Crossandra* were extracted to identify the antimicrobial effect on mainly three microbial strains namely *E. coli*, *B. subtilis* and *S. aureus*. This activity was measured by the agar well diffusion method. Ethyl acetate extract showed the maximum zone of inhibition [20].

Various flower extracts of *Crossandra* were evaluated against the pathogens which cause Urinary tract infections. UTI pathogens were *Klebsiella pneumoniae, Pseudomonas aeruginosa, Enterococcus faecalis, Proteus vulgaris*. The disk diffusion technique was utilised with the Muller Hinton agar media. The acetonic extract of the showed prominent antibacterial activity [21].

Anti-candidal and anti-fungal activities

The different leaf extracts of *C. infundibuliformis* were evaluated for anti-fungal activity against 4 fungal organisms and anti-candidal activity against 2 candidal strains using agar diffusion method with Saburoud's dextrose agar (Hi-Media). Amphotericin B served as the reference standard. The MIC values were assessed in the case of anti-fungal and anti-candidal activities. Petroleum ether extract from the leaf showed good antifungal activity and ethyl acetate extract from the leaf showed good anticandidal activity among other extracts [19].

Anti-cancer and insecticidal activity

The ethanolic extracts of the leaves of *Crossandra infundibuliformis* possess significant *in-vitro* anticancer and insecticidal effects with increasing concentrations. The MTT assay method was used to assess the anti-cancer activity against the human breast cancer cell line (MCF-7), while the insecticidal activity was tested against the Wheat weevil (*Sitophilus oryzae*). Maximum insecticidal activity (100%) was identified at the strength of 0.16% and 0.2% of ethanolic leaf extract of the respective plant [22].

Anti-diabetic activity

The study used the ethanolic extracts from the leaves and stems of *C. infundibuliformis* to study their effects on diabetes and antioxidants in diabetic rats. The rats were induced with diabetes using alloxan and were treated over 30 days. Blood glucose levels were monitored using a standard blood glucometer. The study also looked at various biochemical and in-vivo antioxidant parameters like lipid peroxidation, reduced glutathione, and catalase. Additionally, histopathological studies were conducted on the liver and kidney of the rats. The rats treated with ECILS alongside diabetes showed significant reductions in glucose, total cholesterol, and triglycerides, as well as an increase in high-density lipoproteins compared to the rats in the disease control group [23].

Anthelmintic activity

Different root extracts of *C. infundibuliformis* were investigated for their phytochemical analysis and anthelmintic activity. The Paralysis time and death time of worms were determined to evaluate the activity. Three different concentrations 20mg/kg, 50mg/kg, and 100mg/kg were used. Albendazole(10mg/kg) served as reference standard. The phytochemical screening was performed. the root extract showed a promising effect at 100 mg/kg [24].

Antihyperlipidemic activity

The study was conducted to assess the hypolipidemic activity of ethanolic extract of *Crossandra* leaves and stems (ECILS) in the high-fat diet rat. The rats are fed with a high-fat diet for 1 month. Then they were tested for various blood parameters levels like TC, TGs, low-density lipoproteins (LDL), very-low-density lipoprotein (VLDL), and low-density lipoproteins (HDL). The ethanolic extracts of stem and leaves showed improved serum lipid profile in rats by decreasing the serum TC, TG LDL-C, and increasing serum HDL-C [25].

Anti-inflammatory activity

Methanolic extract of *C. infundibuliformis* flower was investigated for the temporary and persistent inflammation study and also its effects on levels of biochemicals and various hematological parameters were analysed. Formaldehyde and Carrageenan were used

to induce the Paw oedema in this experiment. Nitric oxide (NO) level, haemoglobin (Hb) level, C-reactive protein (CRP) level, RBC, WBC & platelet count, and erythrocyte sedimentation rate (ESR) were also estimated. The extract showed significant anti-inflammatory results when observed at and after 2 hours of administration at all the given concentrations (75, 150 and 300 mg kg^{-1}). Extract at 300 mg kg^{-1} showed an effect comparable to that of standard i.e. diclofenac sodium (10 mg kg^{-1}) in both temporary and persistent inflammation studies [26].

Antioxidant activity

The research aimed to assess the antioxidant characteristics of various extracts obtained from the leaf of *C. infundibuliformis*. Various *in-vitro* antioxidant assays like 1, 1'-diphenyl-2-picrylhydrazyl (DPPH), lipid peroxidation (LPO), nitric oxide, hydrogen peroxide radical scavenging, reducing power and total antioxidant capacity assays are utilised to identify the antioxidant property of the extracts. The antioxidant property of ethyl acetate extract was higher than other extracts in the DPPH method. Moreover, methanol extract has significantly higher antioxidant activity in LPO inhibition, hydrogen peroxide and reducing the capacity of the extract than other chloroform and ethyl acetate extracts. The results show that *C. infundibuliformis* leaves possess anti-oxidant activity [27].

Anti-solar activity

The study evaluates the ultraviolet absorption capacity of the aqueous extract of dry and fresh leaves of *Crossandra* Ultraviolet-visible spectrophotometer was utilized in the experiment. The results show that aqueous fresh leaf extract of *Crossandra* has better Anti-solar activity than dry leaf extract. As it contains natural flavonoids and polyphenols they were regarded as good sunscreen agents [7].

Antitubercular activity

The leaf and flower extracts of *C. infundibuliformis* were screened against tubercle bacillus using the Alamar blue TB assay method. The strain of bacteria was *Mycobacterium tuberculosis* (H37 RV strain). The minimum inhibitory concentration of methanolic extract from the flower and ethyl acetate extract from the leaf was sensitive at 3.12g/ml against the bacteria [15].

Anti-Ulcer activity

Methanolic extract of *Crossandra* flowers was investigated for its anti-ulcer properties. Gastric ulcer was induced by aspirin administration in the experimental rats. Ranitidine was the standard drug and 200mg/kg and 400mg/kg of the extract were employed to evaluate the experiment. Ulcer index and percentage of ulcer incidence are measured on the last day of the study. Both the dose of the extract showed similar action to that of the ranitidine [28].

Aphrodisiac activity

At the dose of 200mg/kg and 400mg/kg body weight, the petroleum ether extract derived from the leaves of *C. infundibuliformis* demonstrates notable aphrodisiac potential in ethanol-induced testicular toxicity in Albino Wistar rats. All the doses increased in mount frequency and intromission frequency, and they significantly prolonged the ejaculatory latency while reducing mount and intromission latency. Additionally, there was an increase in serum testosterone concentrations in all the groups in a manner suggestive of dose dependence. These findings suggest that it may be used to improve impaired sexual functions in animals and induce testicular toxicity in rats [29].

Cytotoxic activity

The ethanolic extract of *C. infundibuliformis* leaves was tested for cytotoxic testing by using Brine shrimp lethality assay and MTT assay. Ethanolic extract of the leaf was found to be non-cytotoxic [30].

Hepatoprotective activity

The petroleum ether extract of *C. infundibuliformis* impact on liver function biochemical parameters was evaluated to determine its hepatoprotective effect. Hepatotoxicity was induced by carbon tetrachloride. The activity levels of ALT, AST, ALP and bilirubin were taken as an index for hepatotoxicity induced by CCl4. The lipid profiles like total cholesterol, TGs, free fatty acids and phospholipids were also observed in CCl4 and plant-treated groups. The study found that the extract of *Crossandra* showed significant hepatoprotection compared to silymarin [31].

Neuropharmacological Assessment

The aqueous and ethanolic extract of leaves of the *Crossandra* was assessed for its CNS activity. The effect of the extract was analysed by rats with Rota rod, Elevated plus maze and Morris water maze methods for anxiolytic activity. Auto track Hot Plate Analgesiometer for analgesic activity and spontaneous behaviour, learning and memory for cognitive evaluation. 2% Tween 80 was utilised as the control. Diazepam (2 mg/kg) and Pentazocine (5 mg/kg) were used as standard drug. The rats which received the aqueous extract of 200 mg/kg showed an increase in the %OAE (open arm entries) and % TSOA (time spent in open arm) in elevated plus maze and restraint test. A dose of 400mg/kg of ethanolic extract statistically increase in the reaction time on the Hot plate analgesiometer. This would be due to the presence of various phytochemical constituents like flavonoids and tannins [30].

Wound healing Activity

The study uses *C. infundibuliformis* flower for ethanolic extract. The extract is evaluated against wound healing activity in rats using an excision wound model. The flower extract was formulated into ointment of 2 different concentrations (2 % and 4% w/w). Two concentrations of ointments showed a good response to wound healing as compared to the standard drug nitrofurazone ointment (0.2%) [32].

VI. CONCLUSION

This review article provides a comprehensive overview of *Crossandra infundibuliformis*, focusing on its pharmacological properties and phytochemical profile. It aims to catalogue and assess the plant's bioactive compounds, such as alkaloids and flavonoids, and summarize its therapeutical activities, including anti-cancer, antimicrobial, and antioxidant effects. Additionally, the review identifies research gaps and suggests areas for further investigation. Connecting traditional uses with scientific findings validates and expands the plant's ethnopharmacological applications. Ultimately, the article aims to lay the groundwork for new drug development and raise awareness of the plant's medicinal potential within the scientific community and the general public.

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