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SECTION : REVIEW

Gloriosa: A High Demanding Pharmaceutical Plant in Near Future

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Abstract

Gloriosa superba L. wavy-edged mostly red flowers is an important indigenous medicinal plant growing in different region of India. Different phyto chemicals have been extracted and identified from the various plant parts mainly tubers and seeds, viz., colchicine, colchicoside, 3-demethyl-N-deformyl-N-deacetylcolchicine etc. Colchicine, the main alkaloid of *G. superba*, is a useful agent chiefly in the treatment of acute attacks of gout but is also valuable in other inflammatory diseases such as familial Mediterranean fever. Apart from gout it is also used for cancer, leprosy, swelling, piles, chronic ulcers and act as antipyretic, antidote in snake bite, anti helmintic, purgative and anti abortive. Other than inhibiting the assembly of microtubules, the major biological effects of colchicine include leukocyte diapedesis, lysosomal degranulation, and inhibition of proliferation of fibroblasts as well as collagen transport to the extracellular space. In this way it relieves the pain associated with acute gout, decreases interleukin-1 production in patients with primary biliary cirrhosis, and is used in the prevention or treatment of amyloidosis, scleroderma, and chronic cutaneous leukocytoclastic vasculitis. Colchicine is available as tablets and, in some countries, as injectable solutions. Tablets contain mostly 0.5–0.65 mg colchicine. Due to excessive use of the plants for diverse medicinal purposes, the species is on the edges of extinction and included in Red Data Book. The overall aim of this study was to review the genus Gloriosa over its documentation of the origin and distribution, botanical description, genetic resource, pharmaceutical importance, phytochemical constituents, cultivation practices, horticultural potentialities and also future prospect of *G. superba*.

1. Introduction

Medicine and health are central concerns for people everywhere. Since the beginning of human civilization, medicinal plants have been used by mankind for its therapeutic value. Nature has been a source of medicinal agents for thousands of years and an impressive number of modern drugs have been isolated from natural sources. Medicinal plants constitute an important natural wealth of a country. They play a significant role in providing primary health care services to rural people. Herbal resources serve as therapeutic agents as well as important raw materials for the manufacture of traditional and modern medicine. Substantial amount of foreign exchange can be earned by exporting medicinal plants to other countries. In this way indigenous medicinal plants play a significant role of an economy of a country.

India has several traditional medical systems, such as Ayurveda and Unani, which has continued more than 3000 years, mainly using plant-based drugs. The *materia medica* of these systems contains a rich heritage of indigenous herbal practices that have helped to sustain the health of most rural people of India. The ancient texts like the Rig Veda (4500–1600 BC) and the Atharva Veda mention the use of several plants as medicine. The books on ayurvedic medicine such as *Charaka Samhita* and *Susruta Samhita* refer to the use of more than 700 herbs (Jain, 1991).

The blind dependence on synthetic drug is now over and people are returning to the naturals with hope of safety and security. As more people become aware of the potency and side effects of synthetic drugs, there is increasing interest in natural product remedies with diverse chemical structures and bioactivities against different diseases. Medicinal plants represent an important asset to the livelihoods of many people in developing countries. A large number of plants have been used by man from ancient times as a medicine for curing

various ailments.

Growing global demand for herbal, medicinal, and aromatic plants have created a new niche market for these products valued at $60 billion US year^{-1}, with an average annual growth rate of about 7%. In recent years, medicinal plants have also been recognized as a significant source of livelihood opportunities for the rural poor, especially women, the landless poor, and marginalized farmers, and also constitute an important source of revenue for governments. More important, they represent a promising opportunity for reducing rural poverty and achieving economic development in relatively higher economic return per unit area compared to traditional crops, and the potential to add value through processing and marketing.

Gloriosa superba (Glory lily) is an important species of the family Colchicaceae is a perennial tuberous climbing herb having attractive wavy edged and the flowers are pendulous and yellow, red, purplish, or variously bicoloured in colour (Amano et al., 2008). It is one of the seven upavishas in the Indian medicine, which cure many ailments, but may prove fatal on misuse (Joshi, 1993). It is widely scattered in tropical and sub-tropical parts of Africa and Southeast Asia. In India, it is usually found in the Himalayan foot-hills, Tamil Nadu, Andhra Pradesh and West Bengal. Its flower is the national flower of Zimbabwe and also the state flower of Tamil Nadu in India due to its high ornamental value. The tubers and seeds of this plant species contain an important alkaloid i.e. colchicines which are highly in demand due to its uses for treating cancer, arthritis, Mediterranean fever, gout, rheumatism, inflammation, ulcers, bleeding piles, skin diseases, leprosy, impotency and snakebites (Gupta, 1982; Jana and Shekhawat, 2011). The conventional method of propagation of this plant is through tubers which is slow with poor multiplication ratio. Its production is seasonal having susceptibility to many pests (Kavina et al., 2011).

This plant species has great demand in herbal industry and the market demand has led to an increased pressure on the natural resources that lend to the production of this plant. The most serious proximate threats when extracting medicinal plants generally are habitat loss, habitat degradation, and over harvesting. Absence of commercial cultivation of these species, results in increased dependence on the wildest collections, which has further aggravated the situation (Badola, 2002). Today, a large number of medicinal plant species are considered threatened due to such high demand and destructive collection practices. Thus, the conservation efforts are of immediate need to save these species in the wild by maintaining their wild populations, and more cultivation practices in different countries, without which the species may be wiped out (Badola, 2002). The poor propagation coupled with over exploitation by the local population as well as pharmaceutical companies are the main factors responsible for its diminishing population size. So, it has been affirmed as endangered plant by the IUCN Red Data Book (Lal and Mishra, 2011).

2. The Genus *Gloriosa*

The generic name *Gloriosa* means 'full of glory' and the specific epithet *superba* means 'superb', alluding to the striking red and yellow flowers. In 1737, Linnaeus established the genus *Gloriosa* based on a specimen collected in south west India (Malabar, present-day Kerala). During the next 260 years, a further 40 species of *Gloriosa* were described (IPNI, 2012), although the majority was subsequently reduced to synonymy. A taxonomic revision of the genus *Gloriosa*, which also started with examination of material in the National Herbarium of Zimbabwe (SRGH) (Maroyi and Maesen., 2012). The Plant List is a working list of all known plant species. Collaboration between the Royal Botanic Gardens, Kew and Missouri Botanical Garden enabled the creation of The Plant List by combining multiple checklist data sets held by these institutions and other collaborators. Preliminary The plant list includes 36 scientific plant names of species rank for the genus *Gloriosa*. of these 10 are accepted species names-
Gloriosa aurea Chiov., *Gloriosa baudii* (A.Terracc.) Chiov.,*Gloriosa flavovirens* (Dammer) J.C. Manning and Vinn., *Gloriosa lindenii* (Baker) J.C. Manning and Vinn.,*Gloriosa littonioides* (Welw. ex Baker) J.C. Manning and Vinn., *Gloriosa modesta* (Hook.) J.C. Manning and Vinn., *Gloriosa revoilii* (Franch.) J.C. Manning and Vinn., *Gloriosa rigidifolia* (Bredell) J.C. Manning and Vinn., *Gloriosa sessiliflora* Nordal and Bingham, *Gloriosa superba* L.

3. Vernacular Names

The English name of *G. superba* is Climbing-lily, Creeping-lily, Flamelily, Glory-lily, Gloriosa lily, Tiger claw. In Sanskrit, *G. superba* are known as Langli, Kalikari, Ailni, Agnisikha, Garbhaghatini, Agnimukhi. The local names in the different states of India are Kalihari, Kathari, Kulhari, Languli (Hindi); Bishalanguli, Ulatchandal (Bengali); Dudhio, Vacchonag (Gujarati); Indai, Karianag, Khadyanag (Marathi); Karadi, Kanninagadde (Kannada); Adavi-nabhi, Kalappagadda, Ganjeri (Telugu); Mettoni, Kithonni (Malayalam); Kalappai-Kizhangu, Kannoru (Tamil); Ognisikha, Garbhhoghhatono, Panjangulia, Meheriaphulo (Oriya); Kariari, Mulim (Punjabi) (CSIR,1948-1976). The common names in world are Glory lily, Flame lily, Isimiselo, Vlamlelie, Riri vavai-moa. (Kavina et al., 2011, Nordal and Bingham 1998).

4. Origin, Geographic Distribution and Occurrences

Gloriosa is a native of tropical Asia and Africa. It is nowadays distributed throughout tropical India, from the North-West

Himalayas to Assam and the Deccan peninsula, extending up to an elevation of 2120 M and worldwide as a pot plant (Ade and Rai, 2009). In Karnataka, it is commonly found growing all along the Western Ghats; it is also found growing in Madagascar, Srilanka, Bangladesh, Indo-China and on the adjacent island (Neuwinger, 1994; Berkill, 1995; Faroogi and Sreeramu, 2001). In Australia, scattered naturalized populations exist in the understory of coastal dry sclerophyll forest and sand dune vegetation throughout South-East Queensland and New South Wales. The plant grows in sandy-loam soil in the mixed deciduous forests in sunny positions. It is very tolerant of nutrient-poor soils. It occurs in thickets, forest edges and boundaries of cultivated areas in warm countries up to a height of 2530 m. It is also widely grown as an ornamental plant in cool temperate countries under glass or in conservatories (Acharya et al., 2006).

5. Botanical Description

G. superba belongs to kingdom plantae, subkingdom tracheobionta, division-Spermatophyta class liliopsida, subclass liliidae, super order lilianae, order liliales, family colchicaceae and genus *Gloriosa* (Backlund and Bremer, 1998; Singh et al., 2013; Rajamani et al., 2009). *G. superba* is erect perennial, tuberous, scandent or climbing herbs (Figure 1A). Leaves are alternate, opposite or whorled, sessile or nearly so, ovate-lanceolate, with acuminate tips spirally twisted to serve as tendrils. Stems are slender, annual, up to 20 ft long, arising from a perennial, fleshy tuberous, cylindrical, bifurcated rhizome, usally V-shaped with the two limbs equal or unequal in length, pointed at the ends, up to 12 inches long and 1.5 inches in diameter (Anonymous, 1956). Flowers are axillary, solitary or may form a lax corymbose, bisexual, regular, 6-merous, 4.5–7 cm in diameter, showy, pendulous, perianth segment free, lanceolate or oblanceolate, often with undulated margins, strongly reflexed when mature, persistent, usually yellow and red (Prain, 1903; Smith, 1979; Floridata, 2004). The flowers were born on the long pedicel. The scarlet red coloured tepal was about 6.80×1.31 cm^2 in dimension (Figure 1B). The six radiating anthers were about 3.34 cm long and the style was nearly 6.40 cm. The stamen displayed profuse orange-yellow pollen. The pistil possessed three loculed ovaries which formed an ellipsoidal capsule. The fruit is oblong containing globose red colored seeds in each valve (Huxley, 1992; Burkill, 1995). The fruits are capsules that split open to release several smooth red seeds with a spongy test. Seeds are ovoid, about 4−5 mm in diameter, surrounded by a fleshy red sarcotesta (Maroyi et al., 2011).

6. Biology of *G. superba*

G. superba is a typical geophyte whose aerial stems die down in the dry season and the tuber is dormant during this period and sprouts with the rains. The life cycle of this plant is 170–180 days). Two or more tubers develop during each growing season, while the previous season's tuber starts to shrivel. It is propagated vegetatively (but the rate is very slow, as only two tubers are produced per year) or from seeds (which can remain dormant for 6–9 months). Plants propagated from seeds take 3–4 years to bloom. Plants arise from tubers develop about 3–6 stems, which start flowering after 5–8 weeks and continue flowering for about another 7 weeks, after which the stems die. Flower colour and shape seem to favour cross pollination and is accomplished by butterflies and 14 sunbirds. Fruits are mature after 6–10 weeks of pollination. The red sarcotesta of seeds helps their dispersal by animals. The dimensions and branching pattern of the plants are strongly correlated with tuber weight. Chemical research has shown that all parts of the plant are extremely poisonous and ingestion could be fatal. The species is believed to have magical properties (Anonymous, 1976; Davis, 1964; Maroyi, 1999).

7. Genetic Resource of *G. superba*

Gloriosa superba has a wide natural distribution, and many selections are cultivated. Local depletion of the resource does occur, in India particularly, where the species has become endangered due to over- collection of the tubers. Although in its natural habitat, seed set and germination is poor. The diversity of *Gloriosa superba* still offers opportunities for further selection either for chemical constituents or as an ornamental. Investment analysis shows that *Gloriosa superba* cultivation is profitable under both irrigated and rainfed conditions. There are no known germplasm collections of *Gloriosa superba* (Raina and Gupta, 1999).

8. Economic Importance

G. superba L. is also known as the national flower of Zimbabwe and it is also the state flower of Tamil Nadu, except miscellaneous pharmaceutical product and other therapeutic preparations, it is also a popular plant for providing color in greenhouses and conservatories even immature flowers are beautiful to be hold. All parts of the plant, especially the tubers, are extremely poisonous. The tubers may be mistakenly eaten in place of Sweet Potatoes (*Ipomoea batata*) since the tubers resemble those of sweet potatoes (Kirti, 2007). The juice of the leaves is used as an ingredient in arrow poisons. The flowers are used in religious ceremonies. *G. superba* is believed as most important herb that is exported, and collection of seeds and roots for the foreign market is causing a shortage of raw material for local drug industries in India. If endangered plants like *G. superba* are allowed to become damaged through excessive collection, a whole series of traditional medicines

Figure 1: a. *G. superba* growing in experimental garden; b. Flowering stage of *G superba.*

and plants which have been in use for thousands of years will be threatened (Jana and Shekhawat, 2011).

The market rate of the seed internationally is around $45–$55/kg. In India the seeds are being officially exported through Basic Chemicals, Pharmaceuticals and Cosmetics Promotion Council, Mumbai, set up by the Ministry of Commerce, Government of India. In Indian market the annual trade estimated is 100–200 mt and the price range is ₹ 600–750/kg (Ved 2007, Jana and Shekhawat 2011). It was found that purified seed extract of *Gloriosa superba* exported ₹ 69,331,977 to Italy (April–June 2015) from India

9. Ethnobotanical Value

Ethnobotany is a multidisciplinary science defined as the interaction between plants and people. The relationship between plants and human cultures is not limited to the use of plants for food, clothing and shelter but also includes their use for religious ceremonies, ornamentation and health care (Schultes, 1992; Schultes and Reis, 1995). In the last two decade, many ethnobotanical studies were conducted among the rural population throughout the world. *Gloriosa* has a long history of ethnobotanical use and has received growing attention from ethnobotanical research because of its wide application in traditional medicine. Five different plant parts of *G. superba* are cited as important in ethnobotanical applications: leaves, seeds, unripe fruit, the root stock or tuber and the whole plant (Maroyi, 2012). Different parts of *Gloriosa superba* plant have wide variety of uses especially within traditional medicine practiced in tropical Africa and Asia. The urbanization and reach of modern health system to remote places and villages have led to negligence towards traditional knowledge related to plant based medicine. The sap from the leaf tip is used for pimples and skin eruptions. Tribals of Patalkot apply the powder of rhizome with coconut oil in skin eruptions and related diseases for 5 days. This combination is said to be effective in snake and scorpion bites too. Tribals crush roots of the plant in water and apply on head for curing baldness. To avoid painful delivery, Gonds and Bharias of Patalkot, apply rhizome extract over the navel and vagina. It induces labour pain and performs normal delivery. Bhumkas (local healers) generally prescribe 250 to 500 mg of the rhizome as dosage. This dose may lead to abortion if given to a lady with pregnancy of 1 or 2 months. Since the rhizome is having abortive action, this is prescribed for normal delivery. Duke (1985) has also reported the abortifacient action of the plant rhizome. It is widely used in the treatment of ulcers, leprosy, piles, inflammations, abdominal pains, intestinal worms, thirst, bruises, infertility and skin problem (Neuwinger, 1996**)**. Tubers are administrated to cattle to expel worms. When necessary one to two roots are effective as an antidote on cobra bite, scorpion sting and centipede sting. Tubers are mixed in fodder to increase lactation. Symbolically stem pieces are tied on arm of women to facilitate delivery (Jain, 1991). *G. superba* also used in wounds, skin related problems, fever, Inflammation, piles, blood disorders, uterine contractions, general body toner, poisoning (Haroon et al., 2008; Khandel et al., 2012).

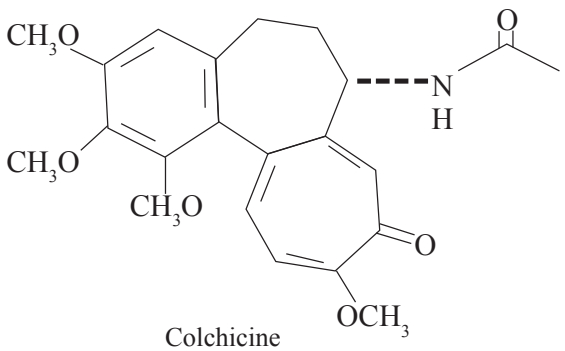
Leaves are used to treat ulcers, piles and expel placenta and seeds are used to cure cancer related diseases. Peoples burn the herb and apply ash on wounds to promote healing. They also drink plant juice as an antimalarial drug. The tuber is used as arbortifacient and as a suicidal agent to commit homicide, because of its high toxicity. The paste of the rhizome is applied to the lower part of the belly for easing childbirth (Duke, 1992). The Marakwet people of Kenya take a tuber decoction against abdominal disorders and to induce abortion. Macerated tuber is also used by them against smallpox, leprosy, eczema, itch and ringworm. In Congo, it is used externally to treat venereal

diseases and stomach ache. A paste made from the tuber is applied externally to facilitate parturition. Juice is used as ear drops to treat earache, and also against teeth pain. In coastal Kenya and Tanzania, powdered tuber is commonly used as a suicidal agent and to commit homicide. In Gaildubba, juice of the leaves is given to kill the lice. Leaf decoction applied as a liniment eases against cough and general pain and also for treating dropsy of the scrotum. In traditional medicine system, tuber is used for the treatment of bruises and sprains (Neuwinger, 1994), colic, chronic ulcers, hemorrhoids, cancer, impotence (Burkill, 1995), nocturnal seminal emissions and leprosy. Many cultures believe the species to have various magical properties (Watt and Breyer-Brandwijk, 1962). The plump roots of the plant have been used in the treatment of parasitic skin infections, leprosy, and internal worms (Jain and Suryavanshi, 2010).

10. Phytochemical Constituents

A wide variety of phytochemicals are found in glory lily. In the world market glory lily considered as rich source of colchicines. A new alkaloid allied to colchicine, provisionally named gloriosine, has been isolated by chromatographic fractionation of the total alkaloids from fresh tubers. The other alkaloids reported to be present in the tubers are *N*-formyldesacetyl colchicine ($C_{21}H_{23}O_6N$; m.p. 258–260 °C); $C_{33}H_{38}O_9N_2$ (or $C_{15}H_{17}O_4N$) (m.p. 177–178 °C); $C_{23}H_{27}O_6N$ (probably methyl colchicines, m.p. 276 °C) and an alkaloid with m.p. 239–242 °C (Clewer et al., 1915; Subbaratnam, 1952; Subbaratnam, 1954). From tuber. Silosterol, its Glucoside and beta and Gamma Lumicolichicines. Beta silosterol, its Flucoside and 2-H-6-MeO benzoic acid. Flower's contain Luteolin, its Glucoside, its Glucoside and 2-de-Me-colchicine (Gupta et al., 2005; Jain and Suryavanshi, 2010).

Colchicine, the main alkaloid (Figure 2). of *Colchicum autumnale*, acute attacks of gout (Rueffer and Zenk, 1998) and it is also obtained from *Gloriosa superba* (Thakur et al., 1975; Sivakumar and Krishnamurthy, 2004). Besides *Gloriosa superba* and *Colchicum autumnale,* colchicine is also obtained



Colchicine

Figure: 2

from corms of *Colchicum luetum* and seeds of *Iphigenia stellata* (Subbaratnam, 1952). The terms *colchicine* is derived from area known as Colchis near Black Sea. Thomson was the first who proposed early idea of action of colchicine in gout treatment (Gupta et al., 2005). Colchicine is a tricyclic alkaloid, the main features of which include a trimethoxyphenyl ring, a seven membered ring with an acetamide at the seventh position, and a tropolonic ring. Chemically colchicines is (S)-N-5, 6, 7, 9-tetrahydro-1, 2, 3, 10-tetramethoxy-9-oxobenzo (a) heptalen-7-yl acetamide (Budavari, 1989) with the molecular formula $C_{22}H_{25}NO_6$ (molecular weight: 399.43; m.p. 151-152 °C). Colchicine consists of pale yellow scales or powder; it darkens on exposure to light due to photoisomerisation and formation of α-, β-and *y*-lumicochicines (Chapman et al., 1963). Colchicine is soluble in water, freely soluble in alcohol and in chloroform, slightly soluble in ether (Loudon and Speakman, 1950). Optimum storage temperature for colchicines is 15 °C to 25 °C, in dark coloured bottles.

Ghosh et al. (2002) studied the root culture of *G. superba* by using direct and indirect precursor of the biosynthetic pathway for the enhancement of colchicines production. Ghosh et al. (2006) reported that colchicine can also be applied in the lanolin paste or as a solution, for instance, on a cotton dot, placed in a leaf axil. Khan et al. (2007) evaluated the enzyme inhibition activities of *G. superba* rhizomes extract against lipoxygenase, actylcholinesterase, butyrycholinesterase and Urease in which wonderful inhibition was observed on lipoxygenease. Further, Khan et al. (2008) reported anti microbial potential of *G. superba* extracts in which excellent antifungal activity was confirmed against *Candida albicans, C. glabrate, Trichophyton longifusus, Microsporum canis* and *Staphylococcus aureus.*

Colchicine is a toxic alkaloid which needs careful use and disposal. It is very toxic and suspected to be carcinogenic (Murray et al., 2004). Overdose of colchicines leads to the delayed onset of multiorgan failure (Stern et al., 1997). Colchicine poisoning resembles arsenic poisoning; the symptoms include burning in the mouth and throat, diarrhea, stomach pain, vomiting and kidney failure (Maroyi and Maesen, 2012).

Colchicine has some biological effects. An early experiment with plants and colchicines was Charles Darwin (1875) who applied the drug to insectivorous and sensitive plants. The reactions in leaf movements were tested but no conclusive results were obtained for colchicine (Eigsti and Dustin, 1995). Later Pernice in 1889 described the action of colchicines on mitosis. According to many references Malden was first scientist to observe the effects of colchicines on mitosis because he reported that the drug appeared to excite karyokinesis in

white blood cells. The major biological effects of colchicine are it interferes with most leukocyte function (Famaey, 1988); it inhibits lysosomal degranulation and increases the level of cyclic AMP (Greenberg, 2000); it binds to inhibits the assembly of microtubules (Kovaces and Csaba, 2005); colchicine reduces the inflammation and relives the pain associated with acute gout (Insel, 1996); colchicine prevents recurrences of acute pericarditis in adults children (Rodriguez et al., 1987).

Colchicine is available as tablets and in some countries, as injectable solutions. Tablets contain mostly 0.5 to 0.65 mg colchicine. Colchicine is sold under different trade names in different countries as medicine for gout (Ben-Chitrit and Levy, 1998; The Drug Monitor, 1972), like-in Australia it sold as Colgout (Protea); Colchicine (Medical Research); Colcin (Knoll); Coluric (Nelson). In Canada it sold as the name of Colchicine (Abbott), in France, Colchicine (House ISH); Colchineous (Houde ISH); in Germany it sold as Colchicum-Dispert (Kali- Chemi); in South Africa, Colchicine Houdse (Roussel) and in USA, it sold as the name of Colchicine (Abbott, Barr Lab, Danbury, Lilly, Rugby, Towne, United Research Laboratories). In India, there are so many medicine tablets are available in market, which are manufactured by Zydus Alidac (Zydus Codila Health. Care Ltd,) i.e., Colchicine (0.5 mg) tablet, Gountnil (0.5 mg) tablet, Coljoy (0.5 mg) tablet and Zycolchicin (0.5 mg).

11. Pharmaceutical Importance of *Gloriosa*

The therapeutic potential of plants and plant based product are recognized throughout the world. Plants are excellent organic chemists and constantly respond to environmental challenges by adjusting their capacity to produce natural products. Natural products have continued over the centuries to be significant sources of drugs and lead compounds (Neuman and Cragg 2012). According to the WHO 11% of the current 252 drugs considered essential for humans are exclusively derived from flowering plants (Raskin et al., 2002). In industrialized countries ca. 25% of prescription medicines contain at least one compound that is directly or indirectly derived from natural origin.

Gloriosa superba L. is an important medicinal plant and is a source of important pharmaceutical compound known as colchicine. Colchicine has been used in medicine for a long time. Colchicine has been effectively used in the treatment of several inflammatory conditions, such as gouty attacks, serositis related to familial Mediterranean fever, Behcet syndrome, and more recently also in acute and recurrent pericarditis. Growing evidence has shown that the drug may be useful to treat an acute attack and may be a way to cope with the prevention of pericarditis in acute and recurrent cases and after cardiac surgery (Imazio et al., 2009).

In acute gout, colchicine is effective in alleviating the acute attack and as a prophylactic medication. Colchicine is used to prevent or treat attacks of gout (also called gouty arthritis). This condition is caused by too much uric acid in the blood. An attack of gout occurs when uric acid causes inflammation (pain, redness, swelling, and heat) in a joint. The exact mechanism of action by which colchicines exerts its effect has not been completely established. Colchicine binds to tubulin, thereby interfering with the polymerization of tubulin, interrupting microtubule dynamics, and disrupting mitosis. This leads to an inhibition of migration of leukocytes and other inflammatory cells, thereby reducing the inflammatory response to deposited urate crystals. Colchicine may also interrupt the cycle of monosodium urate crystal deposition in joint tissues, thereby also preventing the resultant inflammatory response. Overall, colchicine decreases leukocyte chemotaxis/ migration and phagocytosis to inflamed areas, and inhibits the formation and release of a chemotactic glycoprotein that is produced during phagocytosis of urate crystals. Familial Mediterranean fever (FMF) is an autosomal recessive disease characterized by recurrent irregular self-limited attacks of fever and polyserositis accompanied by an increase in acute phase reactants. Colchicine response is excellent in the majority of FMF patients. Colchicine prevents recurrences of acute pericarditis in adults and children. Recent studies suggest that colchicine may prove to be useful in a much wider spectrum of cardiovascular diseases than previously suspected, rekindling the interest in this old drug. Low-dose of colchicine is useful for secondary prevention of cardiovascular disease (Nidorf et al., 2013, 2014). Colchicine also prevent cancer disease that affects the microtubule dynamics constitute one of the most important classes of chemotherapeutic agents. This agent triggers a checkpoint, the spindle checkpoint, which monitors the attachment of chromosomes to the spindle, and elicits arrest in mitosis generally followed by apoptosis.

Some commercially available colchicine based drug available in market which are very much useful for patients, few of them are Colcrys; Mitigare (US brand), Colchicindon, Coljoy, Colchiondonen, Gountnil, Zycolchin etc (Indian brand).

12. Cultivation Practices

12.1. Soil, climate and land preparation

G. superba cultivation economically viable as for any other crop. *G. superba* thrives in tropical and subtropical climates and clay loam textured moist soil in the mixed deciduous forests in sunny positions. A well drained red loamy soil is good for cultivation. Water logged soils are not suitable. High amounts of organic matter and mild acidity is favourable for the growth of this plant. It is extremely tolerant to nutrient-poor soils (Inchem, 2004). Water logged soils are not suitable.

Climatic conditions play a very important role in making *Gloriosa* needs a well drained soil and grows well in sandy (Lal and Mishra, 2011). It occurs in thickets, forest edges and boundaries of cultivated areas in warm countries up to 2530 m amsl (Neuwinger, 1994).

Planting can be done during the rainy seasons and required the seed rate of nearly 1800–2000 kg of tubers ha^{-1}. Planting is distributed from June–July. The ideal pH should be 6.0–7.0. This can be cultivated up to 600 m amsl with an annual rainfall of 70 cm. Land should be ploughed many times and soil should be in fine tilth and incorporate 10 tonnes of Farm Yard Manure (FYM) during last ploughing. Furrows of 20 cm depth and 120 to 140 cm between the furrows are formed and tubers are planted at 20–35 cm spacing. It is mainly propagated through tubers. Tubers are treated with 0.1% carbendazim for half an hour for controlling tuber rot. Glory lily is cultivated in Tamil Nadu mainly in the western parts viz., Mulanur, Dharapuram of Tirupur district, Oddanchatram and Ambilikai of Dindigul district, Markampatty and Aravakurichi of Karur District, Attur of Salem district. The plant requires some support. Vines trained over support plants (*Commiphora beryii, Dedonea viscose*). Permanent structures like iron wires can also be formed for growing the vines (Kavithamani et al., 2013).

12.2. Irrigation

Irrigation is given immediately after planting. After flowering there is no need of irrigation. Nowadays drip irrigation is well suited with growers. During early stages frequent weeding is necessary (Kavithamani et al., 2013). Frequent irrigation is required during the sprouting time to keep the soil surface soft, so that there is no hard pan formation, which inhibits sprouting and emergence of growing tip outside the soil. Excess watering is harmful to the plant. An irrigation interval of 4–7 days during initial period and later on at an interval of 15 days is recommended. On an average basis, a plant requires 5 lt of water day^{-1}. No irrigation is required after flowering. Flood irrigation is in vogue in cultivated areas and off late drip irrigation is receiving popularity among growers (Manivel and Reddy, 2014).

12.3. Manuring

NPK (Nitrogen, Phosphorus and Potash) at 120:50:75 kg ha^{-1} is applied in two split doses. Half of N and the entire dose of P and K are applied as basal dressing. Remaining quantity of N is applied at one and two months after planting (Kavithamani et al., 2013). Though *Gloriosa* makes satisfactory progress with little manuring and fertilization, the addition of well decomposed manure, bone meal and fertilizers to the soil ensures a vigorous plant, strong rhizomes and better flowering. Ten tonnes of compost is required for one acre. A fertilizer dose of 60 kg N, 25 kg P_2O_5 and 40 kg K_2O ha^{-1} is recommended. Of the nutrients, the whole P_2O_5 and K_2O and one-third of Nitrogen is applied as a basal dose and the remaining two-third of Nitrogen is given in the first six to eight weeks after planting (Manivel and Reddy, 2014).

12.4. After cultivation practice

Commiphora must be trimmed annually. Care must be taken to avoid the damages to growing portions. Artificial pollination can be done between 8–11 am for getting higher yield. To eradicate leaf eating caterpillar we can Spray 0.2% Dichlorovas to control the caterpillar infestation. Proper drainage can be given during rainy season and drench 2 g of COC/1 lit of water (Kavithamani et al., 2013).

12.5. Propagation and planting

G. superba can be a commercially viable source of colchicines provided it can be propagated at a fast rate. Krause (1991) stated that in horticulture practice, vegetative propagation of *G. superba* is commonly used; the mother tuber produces two daughter tubers per year. *Gloriosa superba* is propagated mainly during the rainy season, by bulblets, division of the tubers or from seed. V- or L-shaped tubers should be divided every third year. The plants raised from seeds take nearly three to four years to flower. Hence, except for experimental purposes, seed propagation is not favoured by the growers. The tuber is delicate, and should be teased apart gently just before new growth begins, when the buds are easiest to spot (Kavithamani et al., 2013). Tubers should be handled carefully, as they are brittle and liable to break easily. Tuber dormancy can be overcome by soaking in continuously aerated water. Small tubers have been found to have a higher success rate than bigger ones. Tubers of 50–60 g are planted horizontally and 30−45 cm apart in well-tilled soil at a depth of 6−8 cm in furrows 45−60 cm apart. A closer spacing gives a higher percentage of cross-pollination resulting in improved fruit set. The best planting medium is a 1:1:2 mixtures of soil, sand and compost. If the growing bud is subjected to any kind of damage, the tuber will fail to sprout. Since the vigour of the vine and its flowering and fruiting ability depends on the size of the tubers, it should not weigh less than 50–60 g. Planting during the months of July and August have been found to favour good growth and yield. About 2.5 to 3.0 t ha^{-1} of tubers are required for planting. In order to avoid rotting of the tubers before sprouting, only healthy tubers should be selected for planting. Growing *Gloriosa superba* from seed requires more time (Raina Gupta, 1999). The seeds have to be soaked overnight in warm water, and then planted in a well-drained medium. Germination is erratic and may take from 3 weeks to 3 months. Seedlings grow rapidly and mostly produce tubers by their second year; flowering starts in the fourth year. Chemical scarification (e.g.

with 1% hypochlorite) or removal of the sarcotesta reduces seed dormancy from 6–9 months to about 4 months, and accelerates germination to 11–15 days. Germination rates as high as 97% have been reached for seeds incubated at 20−25 °C for a period of 31 days. Higher temperatures have adverse effects (Le Roux, and Robbertse, 1994).

G. superba being a rich alternative source of colchicines, a large majority of this plant raw material is still collected in wild to meet the increasing demand of the active principle. As natural population of this plant becoming endangered and environmental instabilities sometimes make it difficult to acquire, it has become critical to develop alternative source of plant-derived chemical. As seed germination is poor and vegetative propagation is slow, like many other medicinally important plants the potential of plant cell and tissue culture has been exploited as an alternative to traditional agriculture for this medicinally important plant species (Ghosh et al., 2007).

12.6. Time of flower bud opening

The flowering phase in *G. superba* extended from 18 to 23 days (mean of 21.10 days). In *G. superba*, maximum mean percentage of flower bud opening in a day was observed between 8.30 to 9.30 am (52.00%) followed by 7.30 to 8.30 am (30%) (Selvarasu and Kandhasamy, 2012).

12.7. Interspecific hybridization

The genetic variability also is low owing to the continued vegetative propagation through tubers which has reduced the vigour, tolerance to biotic and abiotic stress causing low yields. The growing demand for the seeds of *G. superba* in the international market and the wider popularity it has gained among the farmers necessitates attempts to induce new variability with high yield, high colchicine content, dwarf stature and leaf blight resistant of the plant as well. Traditional or conventional breeding has not been attempted so far as there is only one ecotype under cultivation and genetic wealth is limited. Introduction of new variability is the only option for the breeders at present to create new variability for selection of high yielding cultivars (Rajadurai, 2001). Although a lot of information is available on the growth and development of *Gloriosa*, limited attempt has been made to breed a new cultivar in *G. superba*. Hence there is an urgent need to explore the possibilities for developing variability in this species with varying flower colour, shelf life, high seed yield and improved colchicine content through interspecific hybridization. The germplasm of *G. superba* consisting of 18 ecotypes were evaluated for genetic diversity in two seasons (September, 2007 and September, 2008) at the Department of Medicinal and Aromatic Crops, Horticulture College and Research Institute, TNAU. Five entries which recorded high yield and quality among the 18 germplasm were selected and crossed with *Gloriosa rothschildiana*. Ten cross combinations were made from the selected parents (Cooper and Brink, 1940, Farooqi and Sreeramu, 2004; Nakamura et al., 2005; Junji et al., 2009).

12.8. Harvesting and storage

Gloriosa is a perennial plant. A single plant produces 75–100 flowers and a single fruit contains 70–100 seeds. The harvesting time is February (for crops planted in July). When planted in June, 55 days after planting of *Gloriosa*, flowering will start and continues to flower and fruit till October. The fruit requires about 105–110 days from the set to reach maturity. Artificial pollination is necessary for higher yields. It will take another 2–3 month period for the capsules to reach maturity stage after the pollination. The right stage of harvest is when this capsule starts turning light-green from dark-green and the skin of the fruit shows a shrunken appearance and becomes light in weight. At this stage, when pressed, the pod gives a crinkling sound. After harvesting the capsules are kept in open space for 7–10 days with proper ventilation to allow them to open naturally at ripen stage. It will take another 5–7 days, to bring the seeds into dry condition. The rhizomes, which are, buried beneath the soil again sprouts and the plant cycle continues with the advent of monsoon. The rhizomes are finally harvested after 5–6 years of plantation, cut into small pieces and dried in shade (Saravanan and Buvaneswaran, 2003).

12.9. Yield

The yield of seeds differs greatly, depending upon the vigour and age of the plant which, in turn, depend on the size of the tuber. The expected yield (seed) 1000 kg year^{-1} ha^{1}. Selling price is ₹ 600000 mt^{-1}. The yield in the initial year will be low, but it gradually increases in the subsequent years. Around: 600 kg to 700 kg of seed ha^{-1}. The yield of pericarp (husk) is about 75% of the seeds (Raina and Gupta, 1999). In initial years, the yield is low and gradually increases year by year. First two years about 100 kg acre^{-1} but after 3 years 200–300 kg of dried seeds acre^{-1} can be achieved in well maintained fields. Artificial pollination is needed to get more yield. Market price is around ₹ 600 to 800 kg^{-1}. There are many companies (extractors of colchicine) purchasing seed material from farmers. It is being used as an abortifacient and disease management by its rich production of colchicine, is reported for its use in various clinical conditions leading to it's over exploitation. In South Africa the seed production of 'wild-type' plants is positively correlated with height of the plant, and is on average 258 seeds plant^{-1} for plants 60–65 cm tall compared with about 30 seeds plant^{-1} for plants 30–40 cm tall. In Tamil Nadu, India, small-scale plantings, raised from tubers, yield on average 250–300 kg seed ha^{-1} from the second year onwards (Raina and Gupta,

1999, Chitra and Rajamani, 2010).

1.10. Disease and pest management

Gloriosa has few pests and diseases. Major pests of *Gloriosa* are Lily Caterpillar and Green Caterpillar and spraying of Metacid at a concentration of 0.2% at fortnightly intervals controls these pests. Major diseases are leaf blight and tuber or basal stem rotting and wilting. The leaf blight incidence is higher during cloudy weather coupled with high humidity. This disease can be controlled by spraying Dithane M-45. Another disease is tuber rot which is a soil borne disease affecting the underground rhizomes causing the death of the plant. Drenching the soil with Bavistin @ 0.2% is recommended to control the disease. Some progressive farmers apply bio-pesticides and bio-control agents for controlling pests and diseases.

Yield loss due to defoliators and the major sucking pests (*Thrips tabaci*) was found to be 26.17% and 10.98%, respectively. Natural lactones (2 ml l^{-1}) and azadirachtin (1%) were found effective against sucking pests and defoliators. Spraying of tebuconazole (0.1%) twice on 30 and 60 DAP recorded the lowest leaf blight intensity of *Trichoderma viride* (2.5 kg ha^{-1}) along with Mahua cake (150 kg ha^{-1}) dipping the tubers in *P. fluorescens* (0.2%) followed by spraying (tebuconazole+trifloxystrobin) 0.2% twice at 30 and 60 DAP recorded the lowest root rot intensity. In the protected plots, azadirachtin (1%) 10,000 ppm @ 1 ml l^{-1} was sprayed twice at interval of 15 days. Yield losses due to defoliators (*Plusia signata* and *Spodoptera litura*) and the major sucking pest *Thrips tabaci* were found to be 26.17 and 10.98% respectively. The different biopesticides viz. NSKE (5%), azadirachtin (1%), Pungam oil (3 ml l^{-1}), natural lactones (2 ml l^{-1}) and *Beauveria bassiana* (2%) were evaluated against the thrips. Fipronil (1.5 ml l^{-1}) and spinosad (0.4 ml l^{-1}) were given as chemical checks. Two sprays were given and after spraying, the mean number of thrips $plant^{-1}$ was observed to be the lowest in fipronil (0.06 thrips $plant^{-1}$) followed by spinosad (0.12 thrips $plant^{-1}$) in treated plots. Among the biopesticides and natural lactones recorded the lowest mean population of 0.76 thrips $plant^{-1}$ followed by azadirachtin (1%) (0.96 thrips $plant^{-1}$), whereas the untreated plots recorded an average of 8.38 thrips $plant^{-1}$ (Vidyasekaran, 2000). A field experiment was conducted at farmer's field at Vellipalayam, Coimbatore district, Tamil Nadu to manage the leaf blight disease. Spraying of fungicides and bio-control agents were done at 30 and 60 DAP. The results revealed that spraying tebuconazole (0.1%) twice on 30 and 60 DAP was effective in managing the leaf blight disease which recorded sthe lowest disease intensity (16.3%) and highest yield (523 kg ha^{-1}). It was found to be at par with spraying *Pseudomonas fluorescens* (0.2%) on 30 DAP followed by lemongrass oil (0.2%) on 60 DAP which recorded a disease incidence 17.2%. In the control, the disease intensity had gone up to 29.4% and seed yield was 386 kg ha^{-1} (Maiti et al., 2007).

A field experiment was conducted at farmer's field at Vellipalayam, Coimbatore district, Tamil Nadu to manage the root rot disease caused by *Macrophomina phaseolina* in *G. superba*. The results revealed that soil application of *Trichoderma viridae* (2.5 kg ha^{-1}) along with Mahua cake (150 kg ha^{-1}) dipping the tubers in *P. fluorescens* (0.2%) followed by spraying (tebuconazole+trifloxystrobin) (0.2%) twice at 30 and 60 days after planting recorded the lowest disease intensity (11.0%) and recorded highest seed yield (553 kg ha^{-1}). Dipping the tubers in tebuconazole+trifloxystrobin (0.2%) followed by spraying with the same chemical and another treatment involving soil application of Mahua cake (150 kg ha^{-1}) followed by dipping the tubers with *P. fluorescens* (0.2%) were the other best management practices that recorded disease incidence of 14.0 and 14.7%, respectively. (Maiti and Geetha, 2013).

Arbuscular mycorrhizal (AM) fungi are known to play a pivotal role in the nutrition and growth of plants in many production-orientated agricultural systems, but little is known about their potential effect on secondary metabolites in medicinal and aromatic plants (Kapoor et al., 2002a, b, 2004; Khaosaad et al., 2006). *Gloriosa superba* is usually both mycorrhizal and responsive to the symbiosis. It has been carried out on the effect of AM in the production of colchicine in *G. superba* (Sailo and Bagyaraj, 2005).

13. Pharmacological Activities

Gloriosa superba L. a liliaceous monocot plant, an important medicinal plant shows a number of important pharmacological activities. It is valued for colchicine and other tropolone alkaloids (Jain and Suryavanshi, 2010). The drug is reported to be used for a variety of medicinal purposes (Finnie and Staden, 1991). The medicinal importance of *Gloriosa superba* is due to the presence of alkaloids in all parts of the plant, mainly colchicines (superbine), an amino alkaloid derived from the amino acids phenylalanine and tyrosine (Evans et al., 1981). Every part of the plant was used in Siddha, Ayurveda and Unani system of medicine (Amudha and Shanthi, 2011). The tuber powder was effectively used against paralysis, snake bite, insect bites, against lice, intermittent fevers, wounds, anti-fertility, gonorrhea, leprosy, piles, debility, dyspepsia, atulence, haemorrhoids, helminthiasis and in ammations (Jana and Shekhawat, 2011). The tubers are used as adulterant aconite (Brukil, 1909). The drug is collected in Bengal and few other parts of India (Anonymous, 1956). It is sometimes used for promoting labour pains and also as abortifacient. Externally it is used as a local application for

parasitic skin diseases and as a cataplasm in neuralgic pains (Davies, 1964). The tuber is administered to cattle for the expulsion of worms. The leaf juice is used for killing lice in the hair. Very recently, *G. superba* leaf extract has been used for metal nanoparticle synthesis (Gopinath and Arumugam, 2012). Since 2000 B.C, it is being used as a traditional medicine by the tribes (Ade and Rai, 2009). Gloriosine and colchicines are two used phytochemicals for the treatment of gout and rheumatism. Methanolic aqueous extract of roots has displayed anticoagulant property which may be due to inhibition of thrombin induced clotting (Jain and Suryavanshi, 2010).

Gloriosine and colchicine are two commonly used phytochemicals that is present in whole part of plant. Due to the presence of these alkaloids *G. superba* show many pharmacological properties like anti inflammatory (Jomy et al., 2009), Antimicrobial (Hemaiswarya et al., 2009), Antithrombotic/Antcoagulent potential (Kee et al., 2008), Anticancer activity, Snake bite potential, Hapatoprotactive activity (Mohandass, 2011), Antioxidant activity and Anthelmintic Activity (Pawar et al., 2010) etc.

14. Horticultural Potential of *G. superba*

G. superba is an increasingly important species for its horticultural and floricultural uses. In recent years, a number of cultivars have been used as ornamentals in the USA and Europe (Bose et al., 2003). *G. superba* can be grown as a house or outdoor plant; but it is unlikely to flower outside in Europe. It dies down when the weather gets cold. *G. rothschildiana* is one of the prettiest cultivars of *G. superba*. In India, the herb is largely cultivated for horticultural use, from the Northwest Himalaysas to Assam. In Tamil Nadu and Karnataka, it is also cultivated for its horticultural potential beside medicinal properties (Field, 1972). This cultivar was named after Baron Z.W. Rothschild, an authority on birds, who bought the flower from Africa and entered it at an exhibition of the English Horticultural Society at the turn of the previous century (Bose et al. 2003). It was first cultivated in the United Kingdom in 1902, now mainly grown in Belgium, Denmark (O'Brien, 1903), the Netherlands and the United States of America (Lal and Mishra, 2011).

G. superba is characterised by poor seed germination, susceptibility towards many pests and excessive collection in habitats for both medicinal uses and pharmaceutical trade (Dounias, 2006). Therefore, in order to provide enough plant material for commercial exploitation, cultivation of the species at a large scale is necessary. In horticultural practice, vegetative propagation of *G. superba* is commonly used but the growth is very slow (Krause, 1995), multiplication rate is low as only two plants are produced per corm per year. It takes four or five vegetative cycles to complete a reproductive phase (Samarajeewa et al., 1993). The effect of different growth regulators on initiation and multiplication of *G. superba* shoots in tissue culture have been studied by many researchers (Finnie and Van Staden, 1991, 1994; Sivakumar and Krishnamurthy, 2004). The tissue culture production of resting organs such as tubers is very important as they adapt easily after they have been transplanted to soil (Kozak, 2002). *In-vitro* tubers have several advantages, they are hardier, easier to handle, can be transported dry and there is no dormancy period (Jha et al., 2005), thereby making year-round cultivation possible.

15. Current Status and Future Prospects

India's share (about 1%) in the world trade of medicinal plants is far less than that of China (about 33%). Given, the agro climatic suitability, variability, biodiversity richness, treasure of traditional knowledge and historical pattern of medicinal and aromatic plants in India, the prospects for intensifying and diversifying the country's medicinal and aromatic plants industry are tremendous. Therefore, it is extremely important to conserve the rich medicinal and aromatic plants biodiversity and extend their evaluation for utilization by the industries so as to sustainably meet their domestic and export demands besides maintaining desired quality standards. Shift from collection mode to cultivation will ensure purity, authenticity and availability of medicinal and aromatic plants for user industries (Manivel and Reddy, 2014).

G. superba is widely used as a medicinal plant, despite the fact that the whole plant is very poisonous. It is therefore recommended that protocols for safe use of the different plant parts be developed. It is a source of colchicines and colchicocides, which are very costly, being highly demanded by pharma industries and is commonly grown as a garden ornamental in the tropics. Due to excessive use of the plant for diverse medicinal purposes the species is on the verge of extinction and included in Red Data Book (Mishra and Kotwal, 2009). The strenuous efforts of botanists, biotechnologists, policy makers and conservationists are required. It is a matter of great concern to conserve this plant otherwise we will be losing it by 2020 (Ade and Rai, 2009). Thus, there might be good opportunities for planting the crop commercially for ornamental purposes, or for the production of colchicines (Duke, 1992).

16. Conclusion

G. superba produces two important alkaloid clochicine and gloriosine, which are present in seeds and tubers. *Gloriosa superba* is a commercially imperative medicinal plant which

has diverse medicinal applications and eventually due to over-exploitation this plant is facing local extinction. It has been affirmed as endangered plant by IUCN and hence there is a pressing need to conserve the plant by *in situ* and *ex situ* multiplication in general and micropropogation in particular so as to meet the ever increasing demand from the industries.

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