CHAPTER 3

LITERATURE REVIEW
3. CHAPTER 3: LITERATURE REVIEW

3.1. Selection of plants for the present study

Nature is a great treasure of resources for humankind. The plant kingdom is one of the well explored and cost effective resources available in the form of plants, trees, shrubs and herbs that are well recommended in the traditional and alternate medicine systems in India and many countries worldwide. Plants offer the biggest advantage of being source of the medicinal remedies that is easily available in the local surroundings; having no side effects; cost effective and easy to use.

The present study was undertaken to provide a scientific rationale for the effectiveness of traditional use of selected plants in the management of the wounds. The basic criterion for the selection of these plants for the present study was that several references are available in the traditional Ayurveda texts for their use or these plants have been recommended to be used in traditional or folklore medicines. Most importantly, a large number of these plants are being used by the tribal communities for the treatment of wounds, cuts, skin diseases but scientifically validated study reports in support to substantiate their use for wound healing are lacking.

For the present study, four of such plants were selected and screened for evaluating their in vitro and in vivo wound healing potential.

Selected plants for the present study

On the basis of a detailed literature review, following plants were selected for the present study.

1. *Epipremnum aureum* (Linden & Andre) G. S. Bunting
2. *Hibiscus rosa-sinensis* L.
3. *Tabernaemontana divaricata* L.
4. *Polyalthia longifolia* var. pendula
Figure 3.1: Selected plants for the present study

Representative images of the selected plant species

A, B: *Epipremnum aureum*; C: *Hibiscus rosa-sinensis*; D: *Tabernaemontana divaricata*; E: *Polyalthia longifolia*.

Image courtesy:

*E. aureum*: http://www.exoticrainforest.com/Epipremnum%20aureum%20pc.html  
*T. divaricata*: http://florida.plantatlas.usf.edu/Plant.aspx?id=1924  
*P. longifolia*: http://www.medicinalplantsinnigeria.com
3.1.1. *Epipremnum aureum*

3.1.1.1. Profile of *E. aureum*

*Epipremnum aureum* is commonly found on many Pacific islands as well as Malaysia, in Hawaii, Central and South America, Southern Florida, the Caribbean island, Asia and India ([http://www.exoticrainforest.com/](http://www.exoticrainforest.com/)).

**A. Taxonomical classification of *E. aureum***

Classification of *E. aureum* (Table 3.1) is as per Bentham and Hooker system of classification (Sambamurthy, 2005).

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**B. Synonyms and common names of *E. aureum***

The synonyms for the plant *E. aureum* are *Pothos aurea*, *Scindapsus aureus*, *Epipremnum oreens*, *Rhaphidophora aurea*, whereas the plant is commonly known as Money plant, Devil’s Ivy, Golden pothos, Marble Queen ([http://www.tropicos.org](http://www.tropicos.org)).

**C. Morphology and botanical description of *E. aureum***

*E. aureum* is a monocot that grows vigorously and rapidly covering a wide area. It is a climber, climbing by means of aerial roots which hook over tree branches. This evergreen plant comprises of simple, alternate, cordate, glabrous, entire leaves with acute to acuminate tips and pinnate venation. The leaf surface is waxy. Leaves are small, generally varying in size between 8-20 cm in length, but if they are grown
along the ground or under favorable conditions they are longer and big in size. The leaves are beautifully variegated with white, cream, yellow and various shades of green in different cultivars. Colors, variegation and size of foliage are extremely variable, changing according to the lighting conditions and other cultural factors. The plant has a very peculiar growth pattern; when it is grown on the ground and if unrestricted in the wild, this liana can grow up on trunks of huge trees by attaching its aerial roots to their surfaces, reaching 10-20 meters. The majority of specimens of \textit{E. aureum} still possess either an oval or ovate leaves when fully grown but only in the extreme adult stages do the leaves become pinnatifed. Cultivated varieties of \textit{E. aureum} seldom show presence of inflorescences. Stem is thick, stiff, and slightly ridged; succulent with green or green streaked yellow; stout aerial rootlets, green to brown, are produced most frequently at the nodes, but also from the internodes. Aerial roots grow out of the main stem, and attach themselves to the host tree, or to any other support. They often root often reaching the ground, especially in a good wet season. Terminal buds are foliose, composed of immature leaves, which are light green to yellow-green in color; lateral buds are encased within the stem and not readily visible at the nodes; stems become very stout, or thicken with time, mostly remaining green or streaked with yellow. Figures 3.1.A and B show representative images for the plant \textit{E.aureum}.

D. Traditional uses of \textit{E. aureum}

An extensive literature search revealed that information pertaining to the traditional uses of the plant \textit{E. aureum} is lacking.

E. Phytochemistry of \textit{E. aureum}

Phytochemical screening of the methanolic extract and the aqueous extract of the leaves of \textit{E. aureum} showed presence of alkaloids, flavonoids, tannins, terpenoids, whereas anthraquinones, cardiac glycosides, sterols and phenols were detected only in the aqueous extract (Sonawane \textit{et al.}, 2011; Srivastava \textit{et al.}, 2011). The alcoholic extract of aerial roots of \textit{E. aureum} showed the presence of tannins, cardiac glycosides, steroidal terpenoids, saponins, anthraquinones, alkaloids (Srivastava \textit{et al.}, 2011).
F. Pharmacology of *E. aureum*

A study by Wolverton, (1984) reported that the use of golden pothos (*E. aureum*), grown on an activated carbon filter system reduced the air levels of benzene and trichloroethylene. Some of the earlier studies have noted that foliage plants, including golden pothos (*E. aureum*) can purify the air of various atmospheric chemicals, including formaldehyde (Sawada, 2008). A study made by Pahapur Business Centre and Software Technology Park, in New Delhi, India, and a trial conducted over 15 years by the Chittaranjan National Cancer Institute, Kolkata and the Central Pollution Control Board (CPCB), has concluded that *E. aureum*, apart from other two plants improved the indoor air quality at the same time induced healthy changes in the quality of the indoor environment (CPCB, 2008). According to another study by NASA on the use of common indoor plants for indoor air purification, Golden Pothos is one of the top three plants besides Philodendron and the Spider Plant, and is the most effective in removing formaldehyde (NASA). The plant has been found to be effective in removing benzene and carbon monoxide too (Yang, 2009). Further Srivasatava *et al.*, (2011) have reported antibacterial, antioxidant and antitermite activity of the ethanolic extract of the explant of *E. aureum*. Sonawane *et al.*, (2011) have reported antibacterial efficacy of the aqueous extract against *S. aureus* and *E. coli* and ineffectiveness of the methanolic extract of the plant against *S. aureus* and *E. coli*. Arulpriya *et al.*, (2012) have reported that different extracts of the aerial roots of *Pothos aurea* (Linden ex Andre) climbed over the plants, *Lawsonia inermis* and *Areca catechu* showed *in vitro* antioxidant activity and free radical scavenging activity, which is in accordance to the report by Roy S. *et al.*, (2013) who have reported that the crude extracts of many of the plants of the family Araceae exhibited strong antibacterial activity.

From all these results of the scientific reports available for the plant *E. aureum*, it is well noticeable that hardly any significant and validated studies have been done so far on this plant. Also it is obvious that this plant has not been explored and studied for its pharmacological activities. Hence it is a well deserving candidate for the present study to be studied in detail.
3.1.2. *Hibiscus rosa-sinensis*

### 3.1.2.1. Profile of *H. rosa-sinensis*

*Hibiscus rosa-sinensis* is an evergreen flowering shrub belonging to the family Malvaceae. It is widely grown as an ornamental plant throughout the tropics and subtropics. Sometimes it is also planted along the fence or as a hedge plant. It is colloquially known as the shoe flower or red hibiscus, and is native to China and East Asia but now widely cultivated and grown in India and Philippines. The potential of *H. rosa-sinensis* plant as a source of edible flowers and natural food colourants has been recognized on an industrial basis very recently (Devipriya, 2005).

#### A. Plant classification

Classification of the plant *H. rosa-sinensis* as per Bentham and Hooker system is given in Table 3.2 ([http://www.textbooksonline.tn.nic.in/books/12/std12-botany-em.pdf](http://www.textbooksonline.tn.nic.in/books/12/std12-botany-em.pdf)).

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<td><em>Hibiscus rosa-sinensis</em></td>
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#### B. Plant synonyms of *H. rosa-sinensis*

*H. rosa-sinensis* is known by different vernacular names in India, *viz.* China rose or Shoe flower in English; Arkapriya, Japapushpa, Japa in Sanskrit; Jasund, Jasun, Jasoon in Hindi; Jasud, Jaswanti in Gujarati; Jassavandi, Jassavanda in Marathi; Joba, jaba, Juba in Bengali (Devipriya, 2005).
C. Botanical description of *H. rosa-sinensis*

This plant has a variable stature and may be upright or broad and spreading. The leaves are arranged alternately on the branches and are ovate in shape and grow from 5 to 15 cm long. The leaves may be dark green or variegated with lighter patches and the margins of the leaves are toothed. The flowers are large, generally red in the original varieties, and firm, but generally lack fragrance. Like all Hibiscus flowers, the stalks of the stamens and the style are fused into a long column that is exerted from the center of the widely spreading petals. In cultivated varieties the petals may be single or double, smooth or scalloped. Many anthers can be seen part-way up the column and five round stigma lobes are visible at the tip of the column. The fruit of red hibiscus is a dry, five parted capsule that contains up to three seeds, each of which is kidney-shaped and 2.5 cm long (Devipriya, 2005). Figure 3.1.C shows the representative image of plant *H. rosa-sinensis*.

D. Traditional uses of *H. rosa-sinensis*

The medicinal and emollient properties of the plant *H. rosa-sinensis* is well known from very early days (Devipriya, 2005). In *Ayurveda*, the flowers have been recommended for use to color hair, eyebrows, food and liquors. In the system of Siddha Medicine, the young leaves and flowers are used for inducing abortion, and as a cure for headache. The plant is useful in menorrhagia, strangury, cystitis and other conditions of the genitourinary tract (Kirtikar and Basu, 2005). The leaves and flowers are useful in healing of ulcers, whereas the flowers have beneficial effect in heart diseases (Kurup, 1979; Nadkarni, 1989; Ali *et al*., 1997). The leaves and flowers are beaten into paste and poultice onto cancerous swellings and mumps (Quisumbing, 1951; Duke and Ayensu, 1985). An infusion of petals is widely used in *Ayurvedic* medicine in India as a refrigerant drink in fever (Chatterjee and Prakashi, 1992). Its decoction is given in bronchial catarrh (Chopra *et al*., 1969). The seeds can be pounded into pulp and mixed with water for curing gonorrhea (Nadkarni, 1989). The flowers ground into a paste are boiled in coconut oil and applied externally to heal wounds, bruises, and dermatitis. The leaves and flowers are also used as an antiseptic for boils and ulcers (Wong *et al*., 2010). The plant flowers are also used in folklore medicine as demulcent, refrigerant, aphrodisiac, brain tonic and cardiotonic (Kasture
et al., 2000). In India, flowers are used by the natives to blacken shoes. Sankaranarayanan et al., (2010) have reported the ethanobotanical uses of petals of *H. rosa-sinensis* along with coconut oil and applied externally for alopecia. Decoction of roots is used for fever in children (Dixit, 2011). The plant is laxative, aphrodisiac, emmenagogue, refrigerant. The crushed tender leaves mixed with fresh butter are placed over boils to heal them. The red flowered variety of the plant species is preferred (Adhirajan et al., 2003). In Unani medicine, *Hibiscus* sharbat has been prescribed as a refrigerant and vitaliser in palpitation, cough, fever and burning sensation of the body. It is considered a cardiotonic and brain tonic and is also good for the treatment of schizophrenia and bleeding. In *Ayurveda*, the flowers are ground in paste and concentrated with raw rice and sugar and consumed for purifying blood. Also, *H. rosa-sinensis* has been prescribed for the treatment of *raktha pitha* which is nothing but changed and altered metabolic activities of blood (Devipriya, 2005). The fresh root extract of the plant is useful for veneral diseases (Chopra et al., 1974; The Wealth of India, 1959). The powdered root is taken as such (The wealth of India, 1959; Chopra et al., 1974) or the crushed roots may be mixed with oil and administered to control menstrual bleeding. Alternatively, equal quantities of the powdered roots of *Hibiscus* and lotus are mixed with the bark of *Eriodendron anfractuosum* and administered for menorrhagia (Nadkarni, 1989). The decoction of root is used in the treatment of piles. Medicated oil may be prepared from the expressed juice of the fresh root bark of *Hibiscus* or a decoction of the dried root bark as an ingredient can be used for the treatment of alopecia (Devipriya, 2005).

E. Phytochemistry of *H. rosa-sinensis*

A large number of phytoconstituents have been identified from various parts of the plant *H. rosa-sinensis*. The plant contains calcium oxalate, flavonoids, campesterol, stigmasterol, ergosterol, lipids, phosphorus, thiamine, riboflavin, arachidic, gentisic, myristic, palmitic and oxalic acids, fructose, sucrose and glucose (Devipriya, 2005). Investigations by Mandade et al., (2011) have revealed the presence of sterols; carbohydrates and glycosides; tannins and phenolic compounds; proteins; triterpenoids and flavonoids in the hydroalcoholic extract of aerial parts, whereas Prajapati et al., (2003) have confirmed the presence of hibiscetin, cyaniidne, cyanin glycoside, taraxeryl acetate, β-sitosterol, campesterol, stigmasterol, ergosterol, citric
acid, tartaric acid, oxalic acid. Pattanaik, (1949) have revealed that the leaves and petals contain catalase while Srivastava et al., (1986) have identified presence of fatty acids, fatty alcohols, hydrocarbons in the leaves. Ghaffar and El-Elaimy, (2012) have established the presence of carbohydrates and/or glycosides, steroids, and/or triterpens, flavonoids, tannins and the same authors reported that alkaloids, saponins and coumarins were absent in the hydroalcoholic extract of leaves of *H. rosa-sinensis*. Mohan *et al.*, (2011) have shown the presence of flavonoids, tannins and glycosides in the anthocyanidin fraction of flowers of this plant. Siddiqui *et al.*, (2005) have isolated and identified five new compounds from the chloroform extract and ten new compounds from the hydroalcoholic extract of the flowers. Bhaskar *et al.*, (2011) have identified 2, 3-hexanediol, n-Hexadecanoic acid, 1, 2-enzenedicarboxylic acid and squalene as major components present in the flower extract by GC-MS analysis. Sikarwar Mukesh *et al.*, (2011) have confirmed the presence of apigenidin, citric acid, cyanidin diglucoside, cyanin, fructose, glucose, sucrose, gentisic acid, tartaric acid, pelargonidin, quercetin in the flowers. Sheng-Xiang *et al.*, (1998) have isolated Ethyl β-L-arabinopyranoside from the roots of the plant as a natural monoglycoside and Soni *et al.*, (2011) have showed presence of carbohydrates, proteins, glycosides, phytosterols in the aqueous root extract. Nade *et al.*, (2011) have reported the presence of flavonoids, glycosides, saponins, alkaloids, and sterols in the ethyl acetate soluble fraction of methanol extract of roots.

**F. Pharmacology of *H. rosa-sinensis***

A battery of different pharmacological efficacies has been reported for different parts of the plant *H. rosa-sinensis*. Some of these reported efficacies include antioxidant activity (Mandade *et al.*, 2011); anti-implantation and uterotrophic properties (Vasudeva and Sharma, 2007); hypolipidemic efficacy (Kumar *et al.*, 2009); in vivo antiulcer characteristics (Kumari *et al.*, 2010); antipyretic and analgesic potential (Soni and Gupta, 2011); antibacterial activity of the root methanolic extract (Rathod *et al.*, 2012); anti-spermatogenic and androgenic activities of flowers (Reddy *et al.*, 1997). Gilani *et al.*, (2005) have reported use of the plant in gastrointestinal disorders with spasmodic and spasmodytic constituents in aqueous ethanolic extract of aerial parts of *H. rosa-sinensis* The chemopreventive activity and the effect of gentisic acid in inhibition of tumor promotion and oxidative stress have been established by
Sharma et al., (2004). The plant exhibited a protective role against age, scopolamine-induced amnesia, a protective role in reserpine-induced orofacial dyskinesia and oxidative stress (Nade et al., 2009; 2011). Alam et al., (1990) have demonstrated the anti-diabetic efficacy of *H. rosa-sinensis* in diabetic rural population. The flowers have been found to be effective in the treatment of arterial hypertension (Dwivedi et al., 1977) and have significant antifertility effect whereas other parts of the plant had no antifertility effect (Singh et al. 1982; Sethi et al. 1986; Kholkute et al., 1997). Flower extract possessed blood glucose and insulin lowering effects (Sachdewa et al., 2003) while Siddiqui et al., (2006) have reported hypotensive activity for the hydroalcoholic extract of the flower at the same time also confirmed comparatively lowered hypotensive effect exhibited by the isolated active compounds from the crude extracts. The flowers augment endogenous antioxidant compounds of rat heart and also prevent myocardial injuries (Gauthaman et al., 2006). Anti-obesity and anti-atherogenic potential as well as the effect on carbohydrate metabolizing enzymes have been reported for the flowers by Gomathi et al., (2008; 2009). Red flowers of *H. rosa-sinensis* showed highest total anthocyanin content and also displayed high ferrous ion chelating ability and lipid peroxidation inhibition activity (Wong et al., 2009; 2010). The anthocyanidin fraction of flowers possessed antihypertensive and antioxidant properties (Mohan et al., 2011); whereas Yamasaki et al., (1996) have reported that the red pigment, anthocyanin, prepared from the petals can function as an antioxidant. Shewale et al., (2012) have shown potential antidepressant activity of the anthocyanidins present in the methanolic extract of the flowers. Anti-genotoxicity effect (Khatib et al., 2009); immunostimulatory action (Gaur et al., 2009) and a reversible suppressive effect on cholesterol level, glucose level and spermatogenesis of flowers have been established earlier (Mishra et al., 2009). The hair growth potential of oil formulations from the flowers of *H. rosa-sinensis* have been very well established by many researchers (Nema et al., 2009; Jadhav et al., 2009; whereas, Upadhyay et al., 2011) have found that the ethanolic extract of flowers exhibited hair growth retardation activity. Wound healing efficacy of the flower extracts have been reported earlier by Nayak, et al., (2007) as well as by Bhaskar and Nithya, (2012). In vivo safety, anti-inflammatory, analgesic and anti-pyretic effect of the flower extract have been shown by Birari et al., (2009). The leaf extract of *H. rosa-sinensis* did not possess antibacterial activity (Nair et al., 2005; Wong et al.,
2010), which was in accordance with studies carried out by Koday et al., (2010). The leaves of the plant improved glucose tolerance in rats (Sachdeva et al., 2001) while the insulin secreting activity of leaf extract in diabetic rats has been reported by Vimala et al., (2008). Moqbel et al., (2011) have reported the insulinotropic as well as protective effect in non-obese diabetic mice using fractions obtained from leaf ethanolic extract. The leaves possess hypoglycemic and hypolipidemic activities (Mamum et al., 2013); relatively weak radical scavenging activity but good metal chelating ability (Wong et al., 2010).

3.1.3. *Tabernaemontana divaricata*

### 3.1.3.1. Profile of *T. divaricata*

*Tabernaemontana divaricata* is a common garden plant in tropical countries and it has been used as a traditional medicine. It is found in dry regions of India, Sri Lanka. It is generally a choice of plant for use in shrubbery border and many times used for landscape and has ornamental features. Figures 3.1.D shows representative images for the plant *T. divaricata*.

**A. Plant classification**

Classification of the plant *T. divaricata* is shown in Table 3.3.

(www.flowersofindia.net; Integrated Taxonomic Information System; www.itis.gov)

**Table 3.3: Taxonomical classification of Tabernaemontana divaricata**

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</table>
B. Synonyms of *T. divaricata*

Some of the synonyms of the plant are *T. divaricata*, *T. coronaria*, *N. coronarium*, *N. divaricatum*; *E. microphylla*, *E. divaricata*, *E. coronaria*. Different vernacular names of the plant include, Crape Jasmine; Carnation of India; Moonbeam in English; Tagar; Tagari; Chandani in Hindi; Tagar; Sagar in Gujarati, Ananta; Tagar in Marathi; Nandeevriksha; Nandyavartha in Sanskrit; Nandiar vattai in Tamil just to name a few.

C. Botanical description of *T. divaricata*

This pretty blossom is a member of the Milkwood family. *T. divaricata*. Crape jasmine is an evergreen, well-branched shrub very common in India. It is glabrous shrub and generally grows to a height of six feet, however; it can also grow into a small tree with a thin, crooked stem. The plant belongs to the family Apocynaceae. The plant has large, glossy, dark green leaves and they are six or more inches in length and about two inches in width. The leaves are simple, entire, opposite and oblong having pinnate venation. The stem bleeds a white milky sap when injured. Crape jasmine blooms in spring but flowers appear sporadically all year. The waxy blossoms are white five-petaled pinwheels that are borne in small clusters on the stem tips and the plant is year-long flowering.

D. Traditional uses of *T. divaricata*

All plant parts are used in Ayurvedic, Chinese and Thai Traditional Medicine. In Ayurveda, it is described that the root is acrid; bitter with a flavor; digestible and useful in *kapha*, biliousness and diseases of the blood. The plant pacifies vitiated *vata*, *pitta*, and diseases of eyes, headache, skin diseases, bleeding disorders, itching and arthritis. The root is aphrodisiac; purgative; tonic to the brain, liver and spleen (Priya Thambi et al., 2004). As per the Siddha medicines, the plant *T. divaricata* is known as the best herb for all eye diseases as well as rejuvenator for eyes. In Thai herbal medicine, it has been recommended to improve memory (Chattipakorn et al., 2007). Pullaiah, (2006) have noted the most common use of this plant for wound healing and for preventing inflammation. The milky juice of the leaves has anti-inflammatory action, so it is applied over the wounds. The milky juice of the leaves along with oil is applied over the forehead for pain in the eyes. The juice of the flowers can be applied
over eyes as eye drops for eye diseases or it can be mixed with oil and used as eye drops or it can be applied over skin diseases. Juice squeezed out of the flower bud added with little amount of breast milk makes a good eye salve that can stop secretion of sticky pus in the eyes. Buds kept in clean water overnight may be used as a good eye wash. Decoction of the leaves is an anti-hypertensive and diuretic. The roots are an anodyne hence used to relieve toothache and the roots are ground along with water and given internally for intestinal worms (Pullaiah, 2006). The root is chewed to relieve toothache (Kirtikar and Basu, 2005). Studies have shown properties including: antioxidant, antitumor, anti-infection, analgesic (Pratchayasakul et al., 2008). In Meghalaya, rural folks apply leaf paste of *T. divaricata* with lime for insect bites and skin diseases. Whole plant has anthelmintic properties and leaf paste is applied to relieve headache and fever (Hynniewta & Kumar, 2008). Various parts of the plant are used in folk medicine and one of its recommended uses is for the application on wounds and inflamed parts of the body (Talapatra et al., 1975).

**E. Phytochemistry of *T. divaricata***

Various phytochemical studies on various parts of the plant have revealed the presence of non-alkaloids, enzymes, flavonoids, hydrocarbons, phenolic acids, steroids, and terpenoids. Pratchayasakul et al., (2008) have reported that at least 66 alkaloids have been isolated from *T. divaricata*; it is these alkaloidal activities that possibly justify its use in traditional medicines. Among the other non-alkaloid constituents detected in the plant, include free radical-scavenging enzymes such as super oxide dismutase, catalase, glutathione reductase, ascorbate peroxidase and phenolic peroxidase. The presence of such a very good scavenging system makes the plant combat air pollution (Pratchayasakul et al., 2008). Basavaraj et al., (2011) have shown the presence of carbohydrates, steroids, tannins, triterpenes, flavonoids, proteins, amino acids and glycosides. The ethanol extract of leaves showed presence of steroids, tannins, saponins, gums and reducing sugars (Sharker et al., 2011) whereas Raj et al., (2013) have reported the presence of alkaloids, tannins, resins, proteins, amino acids, flavonoids, saponins, phenols, glycosides, steroids, triterpenoids, fixed oils and fats. The flowers of *E. coronaria* contains α-amyrin acetate, β-amyrin acetate, lupeol β–sitosterol and stigma-sterol, flavone, apigenin, four indole alkaloids harmine, heyneanine, voacristine and apparic-ine, phenolicacids
namely salicylic acid, syringic acid and vanillic acid (Joshi, 2004) while Qamruzzama et al., (2012), and Asif et al., (2013) have confirmed the presence of alkaloids, carbohydrates, flavonoids, saponins, and terpenes while proteins, amino acids, phenols, glycosides, fixed oils, volatile oils steroids in the flowers. Talapatra et al., (1975) have isolated terpenoids and alkaloids from the leave and Atta-Ur-Rahman et al., (1985; 1986) have established the presence of indole alkaloids stapfinine. The presence of the compounds, viz. dimeric indole alkaloids; conophyline and conophyllidine, voaharine; along with the isolation and structural identification of total of 23 alkaloids including few of new alkaloids and few of previously known alkaloids along with preparation and characterization of quinones of the biologically active bisindoles with respect to their action in stimulating insulin expression have been reported by Kam et al., (1992; 1993; 2003). Root bark contains α- amyrin acetate, lupeol acetate, α-amyrin, lupeol cycloartenol, β-sitosterol, campesterol, benzoic acid, aurantiamide acetate, coronaridine, coronaridine hydroxyindolenine, ibogamine, 5-hydroxy-6-oxocoronaridine, 5-oxo-coronaridine, 6-oxocoronaridine, (±) 19- hydroxykoronaridine and 3- oxocoronaridine and voacamine (Rastogi et al., 1980). Stems of E. coronaria contains bisindole alkaloid 19,20-dihydro ervatanine A, other alkaloids coronidine, heyneanine, voacristine, voacamine, descarbomethoxy voacamine and five phenolic acids (Henriques et al., 1996).

E. Pharmacology of T. divaricata

The most common medicinal use of the plant T. divaricata extract involves its antimicrobial action against infectious diseases such as syphilis, leprosy, gonorrhea and as its antiparasitic action against worms, dysentery, diarrhoea and malaria (van Beek et al., 1984). The alkaloidal components of T. divaricata could play important roles in these pharmacological activities (Henriques et al., 1996). Coronaridine, an alkaloid found in the leaves, stems, barks and roots of T. divaricata has been demonstrated as having an effect on autonomic and central nervous system activity (van Beek et al., 1984). The isolated indole alkaloids from the ethanolic extract of aerial parts of T. divaricata exhibited antineoplastic and antimicrobial activity (Singh et al., 2011). Some of the isolated alkaloids of T. divaricata have been reported to be bioactive; viz. 12-hydroxy akuammicine had gonadotropic activity via follicular stimulation. Apart from these reports, some of the other pharmacological efficacies
reported for the plant include, analgesic and antipyretic efficacies (Henriques A.T. et al., 1996; Kanthal et al., 2011; Khan and Islam, 2012; Qamruzzama et al., 2012); hepatoprotective potential (Umarani et al. 2012; Ansari and Rasheed, 2012); hydroxyl radical scavenging, and topoisomerase inhibitory activities (Thind et al., 2008); antinociceptive characteristics (Sharker et al., 2011); anti-fertility efficacy (Sachin Jain et al., 2010); antimicrobial efficacy (Pullaiah, 2006; Raj and Balasubramaniam, 2011; Rahman Ashikur et al., 2011); antifungal action (Wankhede et al., 2013); antidiabetic and cytotoxic effects (Thind et al., 2008; Rahman et al., 2011; Khan and Islam, 2012); antidiarrheal properties (Raj et al., 2013); *in vitro* acetylcholinesterase (AChE) inhibitory activity of the roots (Ingkaninan et al., 2003, 2006; Pratchayasakul et al., 2010; Nakdook et al., 2010); neuronal acetylcholinesterase inhibitory activity (Chattipakorn et al., 2007); cardiovascular effects (Yoysungnoen et al., 2008); anti-inflammatory action (Henriques et al., 1996; Priya Thambi et al., 2006; Qamruzzama et al., 2012); *in vitro* superoxide, hydroxyl radicals, nitric oxide scavenging and lipid peroxidation inhibiting activities (Mandal and Mukherji, 2001; Priya Thambi et al., 2006; ); gastroprotective effect (Ali Khan, 2011); anxiolytic properties (Basavraj et al., 2011); anti-seizure activity (Khan and Mukhram, 2011); antiulcer and anti secretory properties (Asif et al., 2013). Kuo et al., (1999) have reported blocking of human mesangial cell proliferation, cytokines production and genes expression. Findings reported by Taesotikul et al., (1989) suggested that *T. divaricata* has depressive effects on both central and peripheral nervous system in animals and it acted as a skeletal muscle relaxant.

### 3.1.4. *Polyalthia longifolia*

#### 3.1.4.1. Profile of *Polyalthia longifolia*

*Polyalthia longifolia* is a tall evergreen tree belonging to the family Annonaceae. It is a tall evergreen tree. It is planted throughout India and Sri Lanka and widely distributed in the Mediterranean region and Asian region. In India it is commonly planted in gardens avenues and parks. Figures 3.1.E shows representative images for the plant *P. longifolia*.
A. Plant classification of \textit{P. longifolia}

The taxonomical classification of the plant \textit{P. longifolia} is described in Table 3.4. (http://eol.org/pages/1054075/names).

<table>
<thead>
<tr>
<th>Kingdom</th>
<th>Plantae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subkingdom</td>
<td>Magnoliophyta</td>
</tr>
<tr>
<td>Class</td>
<td>Magnoliopsida</td>
</tr>
<tr>
<td>Order</td>
<td>Magnoliales</td>
</tr>
<tr>
<td>Family</td>
<td>Annonaceae</td>
</tr>
<tr>
<td>Genus</td>
<td>Polyalthia</td>
</tr>
<tr>
<td>Species</td>
<td>\textit{Polyalthia longifolia} var. pendula</td>
</tr>
</tbody>
</table>

B. Synonyms of \textit{P. longifolia}

Some of the synonyms of the plant \textit{P. longifolia} are \textit{Uvaria longifolia} Sonner, \textit{Unona longifolia} (Sonn.) while some of the common and vernacular names of \textit{P. longifolia} include Mastor cemetery tree in English; Ashoka, Deodar in Hindi; Devdar in Marathi; Asopahala, Asopalav in Gujarati; Ulkatah, Kastsdaru in Sanskrit; Debdaru in Bengali.

C. Botanical description of \textit{P. longifolia}

It is a tall, evergreen tree with a conical crown. Leaves are 7-20 cm long, narrowly lanceolate with wavy edges. Flowers are 2.5-3.8 cm across, yellowish green, in fascicles or short umbels from the axils of fallen leaves; petals subequal, linear, spreading, tapering to a point. Fruits are 18 mm long, ovoid, produced in great clustered on glabrous stalks, black when ripe and are present in a cluster of one-seeded berries.

D. Traditional uses of \textit{P. longifolia}

The plant has been used in traditional system of medicine for the treatment of fever, skin disease, diabetes, hypertension and vitiated conditions of \textit{vata} and \textit{pitta} (Pullaiah, 2006). The bark is used as febrifuge in Balasore district of Orissa. Decoction of leaf
and bark is used as tea in cold and cough. The seed of this plant are used as febrifuge (Kirtikar and Basu, 1995). This plant is traditionally employed to cure various health ailments in Bangladesh, especially in the treatment of colitis, diarrhoea, anorexia, skin diseases, sore throat, cough and cold (Sharker and Shahid, 2010). The aqueous extract of bark stimulates the ileum and uterus; lowers blood pressure, stimulates respiration and depresses the heart. Traditionally dried bark powder is given with milk for relief in menorrhagia and leucorrhea. Decoction made of bark is used to cure mouth ulcers. The bark is having Javaranashaka (reducing fever) action. The bark is bitter, acrid, cooling, febrifuge, and anthelminthic.

E. Phytochemistry of P. longifolia

The leaves of the plant have been reported to contain an azafluorene alkaloid, polylongine and three aporphine. Pentacyclic triterpenes, tarexasterol, stigmasterol, \( \beta \)-sitosterol, campesterol, \( \alpha \)-amyrine and \( \beta \)-amyrin have also been identified in the leaves. Katkar et al., (2010) have reported that the essential oils of the leaf and stem bark was almost exclusively composed of sesquiterpene derivatives. The ethanol extract of bark of \( P. \) longifolia showed presence of alkaloids, steroids, tannins, reducing sugars, glycosides, gums, and flavonoids (Sharker and Shahid, 2010). Rastogi & Mehrotra, (1993) have reported isolation of a new proanthocyanidin along with \( \beta \)-sitosterol and leucocyanidin from the stem bark. Aporphine and azafluorene alkaloids, proanthocyanidins, \( \beta \)-sitosterol, and leukocyanidin, clerodane, and ent-helimane, diterpenoids were isolated from the leaves, stem, and stem bark. Bioassay-guided isolation studies on the root extract led to the isolation of three new alkaloids, pendulamine A, pendulamine B and penduline along with stigmasterol 3-O-\( \beta \)-D-glucoside, allantoin, diterpenoid kolavenic acid, and the azafluorene alkaloid isoursuline (Faizi et al., 2003). Chakrabarty and Nath, (1992) have reported presence of new clerodane-type butenolide diterpene from the petroleum ether extract of the bark of \( P. \) longifolia. The hexane extract of stem bark furnished nine new clerodane and ent-helimane diterpenes (Hara et al., 1995).
E. Pharmacology of *P. longifolia*

*P. longifolia* var. pendula leaf possessed significant anti-inflammatory and hepatoprotective activity (Tanna *et al.*, 2009; Sharma *et al.*, 2011). The bark and leaves of the plant showed effective antimicrobial activity (Katkar *et al.*, 2010; Chanda *et al.*, 2011; Uzama *et al.*, 2011); antifungal efficacy (Murthy *et al.*, 2005; Nair and Chanda, 2006; Annan *et al.*, 2013); antileishmanial properties (Dipayana Pal *et al.*, 2011); antidiabetic and anti-hyperlipidemic efficacies (Laddha *et al.*, 2012a, b); cytotoxic function (Katkar *et al.*, 2010); antiulcer properties (Malairajan *et al.*, 2008; Sharma *et al.*, 2011; Chanda *et al.*, 2011), antipyretic activity (Annan *et al.*, 2013); the blood pressure lowering capacity (Saleem *et al.*, 2005); hypoglycemic and hypotensive efficacies have been established by Chanda *et al.*, (2007) and Katkar *et al.*, (2010). Mittal *et al.*, (2010) have revealed anti-inflammatory and estrogenic properties for the plant and also confirmed the presence of high content of phytosteroids which can be useful for postmenopausal women with coronary artery disease. An antitumor and antioxidant activity; DPPH radicals scavenging effect, and inhibition of lipid peroxidation was established by many researchers (Manjula *et al.*, 2010; Kashalkar *et al.*, 2011; Jothy *et al.*, 2012). The presence of potential anti-tumor compound *viz.* clerodane diterpenes has been reported by Zhao *et al.*, (1991) whereas Chen *et al.*, (2000) have also reported many cytotoxic, antitumor and anticancer constituents from the methanolic extract of the plant. Verma *et al.*, (2008) have reported that alcoholic extract of leaves and its chloroform fraction inhibited cell proliferation of various human cancer cell lines, and the chloroform fraction induced apoptosis in human leukaemia cells. Bioassay guided fractionation of the ethanolic extract of leaves led to the discovery of the clerodane diterpene, 16a-hydroxycleroda-3, 13; Z-dien-15, 16-olide as a new structural class of HMG-CoA reductase inhibitor (Sasidhara *et al.*, 2011). The methanol extract of stem parts of *P. longifolia* showed presence of cytotoxic aporphine alkaloid liriodenine as well as few other alkaloids that were not bioactive (Wu. *et al.*, 1990)

3.2. Rationale for selection of the plants for the present study

Through the present research study, a sincere attempt has been made in evaluating the traditional folklore claims and medicinal uses of the selected plants for their wound
healing efficacy. Through the literature review done so far for the present study, it was observed that leaves of none of these four selected plants have been evaluated for their wound healing potential and no such scientifically validated study reports are available. Moreover, it is preferable for a wound care management agent that the drug or the pharmacological agent should be easily available at the same time it is preferable that these agents should be cheap. So while selecting the plants that were proposed to be studied for the present study, one of the important and basic selection criterions was to choose and select those plants that are commonly and readily available.

From the literature available, it was observed that not much substantial research reports has been reported for the plant *E. aureum* to demonstrate the pharmacological efficacy and medicinal properties of this commonly available plant. The wound healing efficacy of the leaves of the plant *E. aureum* was intended to be investigated and evaluated through the present study.

Similarly, it was also noted that comparatively very little research has been undertaken on the morphology, pharmacognostic characterization and phytochemical composition of the methanolic extracts of the leaves of the plant *E. aureum*. Therefore, in the present study, detailed pharmacognostic studies were undertaken with a view to establish the quality control standards for the crude drug from the leaves of *E. aureum*. These quality control standards will be of utmost important not only for determining the genuineness of the new plant material, but will also help in the detection of adulterants present, if any, in the drug material or in its formulation. In addition, the antimicrobial properties of the crude drug have also been investigated using methanolic leaf extracts as it was noted that this aspect has not been dealt in depth earlier, besides, the fact that the existing literatures reported so far revealed contraindicating results. Additionally, this plant was intended to be evaluated for its wound healing potential; so if it possesses antibacterial activity, then it would be an added advantage in its favour for being a good therapeutic agent. This is so because, not only it would aid in controlling infection, if any, but also at the same time would enhance and promote the normal wound healing processes for faster and better recovery from an injury.
The findings of several scientific studies reported in the literature so far, showed that different parts of plant, *viz.* leaves, flowers, roots of the plant *H. rosa-sinensis* have been very well studied in detail for their effectiveness for treatment of various disease conditions. Especially, the red flowers and its pigments are studied widely in detail and they are also very popularly used for its hair growth promoting activity. Moreover, it’s an established fact that hair and the hair follicles are integral part of the skin tissue. So when skin is injured and damaged during an injury or when a wound occurs, along with the other cellular components of the skin, normal developmental processes and functions of hair follicles and hair growth is also hampered. As a natural corollary the processes of wound repair should encompass hair follicle regeneration, redevelopment of hair in the newly synthesized and healed skin along with regeneration and remodeling of all different cells and their structures. But this aspect of the plant has not been studied earlier. In spite of the wide uses of this plant species for its medicinal values, it was observed that the use of leaves for wound care management have not been reported so far. Hence the leaves of the plant *H. rosa-sinensis* were assessed for the present study to evaluate the wound healing activity.

Several studies have been undertaken for the plant *T. divaricata* for its efficacy in treatment of various diseases and thus making this plant as a popular source of medicine. But, more importantly, this plant has been recommended in the traditional and folklore medicine for the treatment of wound healing and for preventing inflammation. The juice of the leaves of plant *T. divaricata* is known to be used against skin irritation and for the wound healing. But, surprisingly, there is no scientific validated data in support of its claim for its wound healing properties. Hence, this plant was selected to evaluate its capacity in promoting wound healing processes employing phytochemicals from the methanolic extract of the leaves.

Abundant literature is available on the efficacy of the plant *P. longifolia* in the treatment of various diseases and it’s been extensively used as a popular source of natural medicine. But the leaves of this common tree have not been explored and investigated for their wound healing potential. Lack of availability of validated scientific data for the same prompted to evaluate the methanolic extract of the leaves of the plant for assessment of their wound healing characteristics.