INTRODUCTION

The indigenous civilizations of different regions of the world have discovered various uses of natural resources around them. This traditional knowledge is based on their observation, instinct, necessities, trial and error and long experience. Medicinal plants are the richest bioresource of drugs for traditional systems of medicine, conventional medicines, nutraceuticals, food supplements, folk lore medicines, pharmaceutical preparation and chemical entities for synthetic drugs. The range and sheer number of plants with therapeutic uses is quite astounding. People across the world are consulting trained herbal professionals and are using herbal based medicines. Medicinal plants play an important role in the lives of country side people, particularly in the secluded parts of developing countries with limited health facilities. Nature has provided complete repository of remedies to alleviate human and animal suffering.

Herbs have always been the prime form of medication in India and presently they are becoming popular throughout the developed world. India is endowed with a unique wealth of biota which includes a large number of medicinal and aromatic plants. India has about 8% of the world's biodiversity on 2% of the earth's surface area, making it one of the 12 mega-diversity centres of the world due to the species richness and level of endemism recorded in the various agro-climatic zones of the country (Lingaraju et al., 2013). India has a unique biogeographical position with ecosystems ranging from coldest place, the dry desert to temperate, alpine and sub-tropical regions of north-west and trans-Himalayas; rain forests with high rainfall; wet evergreen humid tropics of western Ghats and arid and semi-arid regions of peninsular India; dry desert conditions of Rajasthan and Gujarat to the tidal mangroves of Sunderban, harbouring plants that
are used in various classical system of medicine like Ayurveda, Siddha and Unani.

The history of herbal medicines is as old as human civilization. The knowledge of drugs over thousands of years as a result of human inquisitiveness, intervention and inventions have contributed to effective and safe health care. During the course of developments, many civilizations have raised and perished but the systems of medicines developed by them in various parts of the world are still being practised. The earliest record of medicinal plant use in the Himalayas is found in the Rigveda. A good number of medicinal plants are found mentioned in the ancient classical ayurvedic texts 'Charaka Samhita', 'Susruta Samhita' and 'Astanga Hrdaya Samhita'. Indian medicinal plants are the essence of ayurveda and ayurvedic treatments. Ayurvedic form of medicine is believed to be existent in India for thousands of years. When used judicially and clocking with the basic principles they produce miraculous effects. It employs various techniques and things to provide healing to ailing patients and have played an important role in ayurvedic treatment, from ancient time to most modern time. Hence ayurvedic drugs are rightly called the elixirs of life.

Medicinal plants and phyto-preparations are used for therapy and prevention of various human diseases, including cardiovascular, gastrointestinal, nervous system, and skin diseases, and even malignancies (Lovkova et al., 1990; Mashkovskii, 1988). In recent years, the huge demand for herbal and ayurvedic preparations in the urban market, coupled with massive deforestation, has taken its toll on the country's natural medicinal plant resources. Since these resources are the mainstay of the rural healthcare support system in India, where modern healthcare is both expensive and often inaccessible, it has become vital to preserve local health traditions, pharmacopoeia drugs and their products in India.
Knowledge of medicinal plants, processing of new foods and medicines and how to prepare and process them safely and effectively, has been in large part incremental and growing among the societies living in close connection with nature. The importance of medicinal plants has been overlooked in the past. However, at present medicinal plants are looked upon not only as a source of affordable health care but also as a source of income. According to the World Health Organization (WHO) 80% of the population in the developing countries rely on medicinal plants for primary health care needs (Jarald and Jarald, 2009). Besides medicinal values, pharmaceuticals, herbal food supplements, toiletries and cosmetics are growing in consumption in the international market.

A large number of plant species, specifically those used extensively in various Indian traditional herbal drugs, have been, and are still being investigated for ascertaining their specific inherent vital pharmacological and microbiological activities. During the past one century there has been a significant growth of the allopathic system of medical treatment in India. With ascending population and overexploitation of medicinal plants, the demand for herbal medicines has risen rapidly. An advantage of herbal medicinal plants is that they provide a complex of natural compounds to the patients which have smoother action and are better tolerated than synthetic drugs and produce few allergic reactions.

During the past decades, bulk production of plant based drugs has become an important segment of Indian pharmaceutical industry. Under the duress of over exploration and habitat degradation a number of wild plants are essentially facing a constant threat of extinction. Unscrupulous and unscientific management practices and ever increasing demand for phytochemicals have threatened the existence of most medicinal plants.
Conservation of natural resources and the capability to utilize them in sustained manner are essential for the well being and continued survival of man. The conservation of genetic resources is approached in two basically scientific techniques. They are the \textit{in situ} and \textit{ex situ} method of conservation. \textit{In situ} conservation that involves the preservation and the management of the specific ecosystems and by \textit{ex situ} conservation that involves the collections in the botanical gardens, field cultures, seed storage and gene banks. Several research institutes have undertaken studies on the cultivation practices of medicinal plants, which would be a help for the income generation for the underprivileged socially and geographically. Efforts have been made to introduce many of these drug plants to farmers.

The bio resources of Western Ghats are quite rich. Almost all groups of economically significant plants grow here which include numerous life saving drug plants, nutraceuticals, life support species, wild aromatic species, ornamental species, metal tolerant species, wild genetic resources and so on. While many species await discoveries, the flora is getting depleted in an alarming rate. Therefore, not just conservation of these bio-resources in the region but also their sustainable utilization for human welfare is the priority agenda (Rao, 2012). Karnataka state is known for its rich biological diversity, although the natural ecosystems experience threat from recurrent natural calamities (Ravikumar and Theerthavathy, 2012).

Reports on ethnobotanical knowledge in Karnataka state are restricted to certain areas like Uttara Kannada, Mysore and Shimoga district (Ghatapanadi \textit{et al.}, 2011; Parinitha \textit{et al.}, 2004; Prakash \textit{et al.}, 2010; Rajasab \textit{et al.}, 2004). Kodagu (also called Coorg) is one of the tiniest districts in the Southern part of Karnataka covering an area of 4104 sq km. It belongs to Western Ghats, one of the 8 hottest biodiversity hotspots of the world (Lingaraju, \textit{et al.}, 2013). The herbal
folk medicine of Kodagu district have been reported by few workers (Kshirsagar et al., 2007, Kshirsagar, 2001; Nanjunda and Venu Gopal, 2009; Nanjunda, 2010).

In this pursuit, *Drymaria cordata* (L.) Willd. ex Roem & Schult., is one such common but less known folklore herb of Kodagu District which finds its utilization in the folklore treatment of many ailments and was thus selected for micropropagation, mycorrhizal studies, phytochemical evaluation, antioxidant and antimicrobial studies.

**In vitro propagation studies**

Tissue culture techniques are being increasingly exploited for clonal multiplication and *in vitro* conservation of valuable indigenous germplasm threatened with extinction (Anand and Jeyachandran, 2004). Considerable progress has been made in the *in vitro* propagation of medicinal plants with few seeds and/or low germination rate (Sarasan et al., 2006; Singh et al., 2009). Plant cell *in vitro* culture technology provides a prospective solution for species whose seeds cannot be stored at low temperatures or those that can only be propagated through vegetative parts. The prime focus of *in vitro* culture of medicinal plants has always been clonal micropropagation of the most desirable genotypes.

Micropropagation is the most significant and conventional method which is widely used in commercial production of plants (Morel, 1960). Multiplication of elite clones and crop improvement through tissue culture technique offers possibilities of introducing variability among the regenerates (Tejavathi et al, 2009; Gnanesh et al., 2012). *In vitro* cultures bring about an increase in the propagation rate and in the obtaining of a healthy material.
In vitro organogenesis is regulated by the inclusion of many plant growth regulators as well as other nutrients in the culture medium. Propagation of plants through direct and indirect organogenesis is in great demand. The use of in vitro propagation techniques in germplasm conservation is increasing and successfully applied in the conservation of medicinal and aromatic plants species through shoot regeneration via callus organogenesis (Dhar and Joshi, 2005; Shen et al., 2007) and direct organogenesis (Lakshmanan et al., 2006, Unda et al., 2007, Feyissa et al., 2005a; Liu and Pijut, 2008). Differentiation of plants from callus cultures has been suggested as a potential method for rapid propagation and for induction of variation (Martin, 2002; Tejavathi et al., 2012). A variety of explants such as cotyledonary node, leaf, petiole, internode, and hypocotyls were used to induce in vitro multiple shoots and adventitious buds in many medicinally plant species (Corredoira et al., 2008; Palanivel et al., 2009; Tiwari et al., 2006; Makunga and Staden, 2008).

Studies on plant secondary metabolites have been increasing over the last 50 years. These molecules are known to play a major role in the adaptation of plants to their environment, and also represent an important source of active pharmaceuticals. Many studies have been undertaken with the objective of improving the in vitro production of plant secondary compounds. Cell suspension cultures and regenerative callus have found a vast applicability in biotechnology, but a large interest has also been shown in hairy roots and other organ cultures (Bourgaud et al., 2001). It gives many benefits to the breeders such as, increase in propagation rate of plants, availability of plants throughout the year and conservation of genetic resources (Bajaj et al., 1988).

Germplasm of vegetatively propagated plants is conventionally conserved ex situ in clonal field repositories, which is expensive,
labour intensive and leaves the material susceptible to natural calamities. Therefore the need of the hour is to develop alternative techniques of storage for safe conservation and utilization of germplasm. Conservation of germplasm of medicinal plants has attracted attention because of its potential for the long term conservation of high yielding cell clones (Bajaj, et al., 1988). Farmers who adopt in vitro propagated plant material may benefit more from income increase through reduced pest control costs and higher effective yields (Muyanga, 2009).

In vitro propagation techniques have paved way for multiple shoots and root induction in large number of medicinal plants in a short span of time to meet their demand in drug industry (Ramesh et al., 2006). Improvement in germination methods through in vitro methods can raise genetically diverse propagules and preserve genetic diversity (Sarasan et al., 2011). This technique affords alternative solution to problems arising due to current rate of extinction and decimation of flora and ecosystem (Shah and Seth, 2010). As a result plant tissue culture finds its practical application ranging from agriculture to industry.

Arbuscular Mycorrhizal Fungal Studies

One of the critical impediments to the success of micropropagation is the very high mortality rate of in vitro plantlets either during acclimatization phase or during transfer to the field conditions (Fortuna et al., 1992). Generally, most of the in vitro derived plantlets fail to survive due to impaired stomatal mechanism, absence of cuticle, poor photosynthetic activity, vitrification of shoots, poor vascular connection and poor root hair development. Treatment of micropropagated plantlets with arbuscular mycorrhizae (AM) fungi have been proven to play a very crucial role in supporting the survival, growth and establishment of plant regenerates
(Bagyaraj and Varma, 1995; Karthikeyan et al., 2009). The use of mycorrhizal fungi can also be applied for the conservation of rare and threatened plants and especially medicinal plants. As this can be done at relatively at low cost and is easy to incorporate into the ex vitro rooting stage or weaning stage, the implementation will be straightforward (Sarasan, 2011).

Over 90% of plant species associate with Arbuscular Mycorrhizal Fungi (AMF), which are important for accessing and recycling nutrients (Haystead et al., 1988; Smith and Read, 2008). Only few plants develop normally without mycorrhiza. These non-pathogenic relationships are geographically ubiquitous. Many plant families such as Chenopodiaceae, Brassicaceae, Caryophyllaceae, Cyperaceae and Polygonaceae appear to be non-mycorrhizal (Brundrett, 1991; Francis and Read, 1994).

Weeds are undesirable plant growing at wrong place at a wrong time. Due to its wide diversity in climate and edaphic factors, the weed flora also widely differs from one region to another due to different seasons, cropping patterns adopted and association with crops. Besides the crop loss aspect of weeds there is another aspect of mycorrhizal association in weeds (Gupta and Mukherji, 2000). However, it is quite plausible that interaction with AMF can increase the beneficial effects of weeds on the functioning of agro-ecosystem (Jordan et al., 2000, 2005; Gupta and Mukerji, 2003). Zainab and Burni (2005) have reported the presence of AMF in weeds in wheat fields. Morphological types of arbuscular fungi in roots of weeds have been reported (Yamato, 2004; Thangavelu and Prakash, 2009).

Endomycorrhizal fungi grow intra and intercellularly forming specific fungal structures in the cortical region of the host. They are obligately symbiotic and colonize the cortical region of the very fine absorbing roots of host plants. On root colonization the AM fungi
produce two specialized structures known as vesicles and arbuscules in the cortex region of root. Arbuscules are complex structures similar to haustoria produced within the host cells and serve as sites of nutrient exchange between host and the fungus. The vesicles are terminal, ovate to globose structures that act as temporary food storage organs. Nutrient ions taken up by the hyphae are transported through the hyphae and released in the root cells by means of arbuscules.

The most remarkable consequence of arbuscular mycorrhizae colonization is the enhanced host growth and yield. Enhanced plant growth due to AM fungus has been commonly attributed to nutrient uptake. They help in the uptake of nutrients like phosphorus, potassium, zinc, iron, copper, magnesium and calcium. AM fungi are known to increase root growth due to the production of growth hormones such as auxins, gibberellin like substances and cytokinins (Rajesh, 2011). Recent studies suggest that arbuscular mycorrhizal infection may change the biochemical composition of the host plant. The secondary metabolites may be defined as plant products, which are derived biosynthetically from primary metabolic compounds. There are many reports on the enhancement of secondary metabolism in micropropagated plants than the source of explants (Giulietti and Ertola, 1999; Tejavathi and Rao, 1998; Leal et al., 2009). Mycorrhization of tissue-cultured propagules has the potential to produce plants with increased levels of biologically active secondary metabolites (Rai 2001; Kapoor et al., 2008).

Interest in AM fungi propagation for agriculture is increasing due to their role in the promotion of plant health, faster growth, in soil nutrition improvement, greater drought tolerance, protection from soil borne pathogens, greater resistance to invasion by weeds and soil aggregate stability (Dalpé and Monreal, 2004). The contribution of vesicular arbuscular mycorrhizae in the improvement
of agriculture and horticulture has been reported in many countries (Lovato et al., 1995; Aboul Nasr, 1996) and new areas of research are being explored that hold prospects of AMF involvement in crop productivity (Dubey et al., 1997).

The present study was under taken to examine the effects of AM fungi on colonization and morphological variations in *Drymaria cordata*, a commonly occurring medicinal weed in the coffee plantations of Coorg District, Karnataka State.

**Studies on phytochemical and therapeutic aspects**

The significance of ‘medicinal plants’ right from the very dawn of civilization up to the last couple of decades have witnessed a tremendous cumulative and informative volume of researches carried out in the ever expanding field of pharmaceutically significant naturally occurring plant products. Herbs provide the starting material for the isolation or synthesis of conventional drugs. The plant kingdom contributes, in a more meaningful way to supply the useful substances for the treatment of human diseases (Philipson and Anderson, 1998). Phytochemicals present in a variety of plants are utilized as important components of both human and animal diet (Okwu, 2005).

Medicinal plants have curative properties due to the presence of various complex chemical substances of different composition, which are found as secondary plant metabolites distributed in one or more plant parts. Phytochemical screening of plants has revealed the presence of numerous chemicals including alkaloids, tannins, flavonoids, steroids, glycosides and saponins etc. Plant secondary metabolites have been of interest to man for a long time due to their pharmacological relevance (Arora et al., 2003). It is believed that crude extract from medicinal plants are more biologically active than
isolated compounds due to their synergistic effects (Jana and Shekhawat, 2010).

Polyphenolic compounds have shown antibacterial, anticarcinogenic, anti-inflammatory, anti-viral, anti-allergic, estrogenic and immune-stimulating properties (Larson, 1988). Secondary metabolites of plants serve as defense mechanisms against predation by many microorganisms, insects and herbivores (Cowan, 1999). It is reported that phytochemicals constituents directly influences the antioxidant properties of plant extracts (Misra et al., 2008). In recent times, plant flavonoids have attracted attention as potential therapeutic agents. Many medicinal plants are being still harvested in the wild, and conditions for growth in cultivation have not been optimized yet. Wild harvesting of medicinal plants can be problematic in terms of biodiversity loss.

Phytochemical screening including molecular markers will facilitate the accurate identification of elite materials from plants and their parts, where plant chemistry varies between different specimens. Once optimal source genotypes have been identified, in vitro tools may be applied to mass propagate from seeds or vegetative materials (Sarasan, 2011). Many phyto-medicines exert their beneficial effects through synergistic action of several chemical compounds acting at single or multiple target sites associated with a physiological process. As pointed out by Tyler (1999), the synergistic pharmacological effect can be beneficial by eliminating the problematic side effects associated with the predominance of a single xenobiotic compound in the body.

The combinations of secondary products in a particular plant are often taxonomically distinct (Wink, 1999). This is in contrast to primary products, such as carbohydrates, lipids, proteins, heme, chlorophyll, and nucleic acids, which are common to all plants and
are involved in the primary metabolic processes of building and maintaining plant cells (Kaufman et al., 1999; Wink, 1999). Some plant secondary products may exert their action by resembling endogenous metabolites, ligands, hormones, signal transduction molecules, or neurotransmitters and thus have beneficial medicinal effects on humans due to similarities in their potential target sites (e.g. central nervous system, endocrine system, etc.) (Kaufman et al., 1999).

Plant cell suspension cultures produce all the metabolites, primary and secondary, that are produced by the parent plant from which cultures are derived. The most widely applied empirical approach to enhance synthesis of secondary products is optimization wherein medium and environmental factors of the cultures are manipulated (Ramawat, 2004). Extraction of the bioactive plant constituents has always been a challenging task for the researchers (Tiwari, 2011).

In the area of phyto-chemistry, medicinal plants have been characterized for their possible bioactive compounds, which have been separated and subjected to detailed structural analysis. The secondary compounds are usually extracted from plants using various solvents. Through the use of sophisticated instruments like High Performance Liquid Chromatography (HPLC), Gas/ Liquid chromatography coupled with mass spectroscopy (GC-MS), a number of compounds have been isolated and identified for their specific characteristics which not only help to screen the compounds but also validate the formulations of all traditional medicine which can be made more effectively and safely.

Extensive opportunities exist for basic research on medicinal plants and the study of their phyto-medicinal chemical production (Briksin, 2000). Variation in morphological, genetic and chemical
characters of medicinal plants in developing countries is not well studied, although Van Wyk (2008) reported the variations in the natural stands. This is crucial to guide commercialization of medicinal plants, selection of elite clones, and the standardization of raw materials. Hence, the prevailing bio dynamism of the ‘active principles’ strategically located in the plant kingdom would certainly provide the mankind with an eternal storehouse of clinically beneficial herbal drugs (Shah and Seth, 2010).

Drymaria cordata is known to possess medicinal and healing properties (Akindele, 2012; Barua et al., 2009; Majumdar et al., 1978; Sowemimo et al., 2009). Therefore the present studies were undertaken to explore its phytochemical potentialities.

**Studies on antioxidant activity**

Recently interests have increased considerably in finding natural antioxidants for use in medicinal or food purposes. Free radicals or oxidative injury have come into sight as fundamental mechanism underlying a number of human neurologic and other disorders. Rapid production of free radicals can lead to oxidative damage to biomolecules and may cause disorders such as cancer, diabetes, inflammatory disease, asthma, cardiovascular disease and premature aging (Young and Woodside, 2001). Hence, therapy using free radical scavengers (antioxidants) has potential to prevent, delay or ameliorate many of these disorders (Delanty and Dichter, 2000).

Antioxidant based formulations are used for the prevention and treatment of complex diseases like atherosclerosis, stroke, diabetes, Alzheimer's disease and cancer (Devasagayam et al., 2004). Due to depletion of immune system natural antioxidants in different maladies, consuming antioxidants as free radical scavengers may be necessary (Halliwell, 1994; Kuhnan, 1976; Younes, 1981). Currently
available synthetic antioxidants like butylated hydroxyl anisole (BHA), butylated hydroxyl toluene (BHT), tertiary butylated hydroquinone and gallic acid esters have been suspected to cause or prompt negative health effects. Moreover, these synthetic antioxidants also show low solubility and moderate activity (Barlow, 1990; Branen, 1975).

Over the past two decades, an expanding body of evidence from epidemiological and laboratory studies have demonstrated that some edible plants as a whole or their identified ingredients with antioxidant properties have substantial protective effects on human carcinogenesis (Tsao et al., 2004; Surh and Ferguson, 2003; Greenwald, 2002; Park and Pezzuto, 2002, Wattenberg, 1996). Of late there has been an upsurge of interest in the therapeutic potential of medicinal plants as antioxidants in reducing such free radical induced tissue injury. This has attracted a great deal of research interest in natural antioxidants. Spices and herbs are recognized as sources of natural antioxidants that can protect from oxidative stress and thus play an important role in the chemoprevention of diseases that has their etiology and pathophysiology in reactive oxygen species.

The medicinal properties of folk plants are mainly attributed to the presence of flavonoids, but may also be influenced by other organic and inorganic compounds such as coumarins, phenolic acids, isoflavones, anthocyanins, lignans, catechins, isocatechins and antioxidant micronutrients, e.g., Cu, Mn, Zn (Repetto and Llesuy, 2002). In addition to these compounds found in natural foods, vitamins C and E, β-carotene and α-tocopherol are known to possess antioxidant potential (Cai et al., 2004; Prior, 2003; Kaur and Kapoor, 2002). Phenolic compounds are commonly found in both edible and non-edible plants and have been reported to have multiple biological effects. Phenolic compounds, with potential ability for losing
hydrogen atoms and/or single electrons (due to the stability of resulting free radicals) and with metal chelating properties (due to the presence of hydroxyl and carbonyl functional groups in their structures) exhibit considerable antioxidant activities (Rice-Evans et al., 1996). Therefore consumers should increase their intake of foods rich in antioxidant compounds that lower the risk of chronic health problems associated with several diseases (Klipstein-Grobusch et al., 2000).

In the present study, free radical scavenging activity of *Drymaria cordata* was carried out in order to evaluate its antioxidant potential.

**Studies on antimicrobial activity**

The use of drugs derived from plants has been in practice for a very long time (Lewis and Elvin-Lewis, 1977) because they contain components of therapeutic value. The potentials of higher plants as source for new drugs is still largely unexplored. Despite the advancement made in the field of microbiology, infectious diseases are still a significant cause of morbidity and mortality worldwide, where drug-resistant strains of pathogenic bacteria and fungi are increasingly prevalent. Epidemic due to the limitations of currently available treatments pose a major threat to public health. The emergence and spread of microbes that are resistant to a cheap and effective first choice drugs have become a common occurrence. The problem of microbial resistance is growing and the outlook for the use of antimicrobial drugs in the future is still uncertain. Therefore, actions must be taken to reduce this problem, for example, to control the use of antibiotic, develop research to better understand the genetic mechanisms of resistance, and to continue studies to develop new drugs, either synthetic or natural. The ultimate goal is to offer appropriate and efficient antimicrobial drugs to the patient (Nascimento et al., 2000).
Many studies have been undertaken with the aim of determining the different antimicrobial and phytochemical constituents of medicinal plants and using them for the treatment of both topical and systemic microbial infections as possible alternatives to chemical synthetic drugs to which many infectious microorganisms have become resistant (Akinpelu and Onakoya, 2006; Chopra, 2007). During the last two decades, the development of drug resistance as well as the appearance of undesirable side effects of certain antibiotics has led to the search of new antimicrobial agents (Okemo, 2003). The need for the development of more effective and safe antimicrobial agents has stimulated multidisciplinary investigations focused on plant-derived compounds as source of new leading antimicrobial drugs.

Preliminary in vitro screening for antimicrobial activity of plant extracts may serve as a guide to select those with significant activity as potential resources for such new drugs and therefore, forerunners for further phytochemical and pharmacological research. A number of plants have been used in traditional medicine for many years due to their antimicrobial properties (Sofowora, 1993).

The use of plant extracts and phytochemicals, both with known antimicrobial properties, can be of great significance in therapeutic treatments. Specifically, the medicinal value of these plants lies in some chemical substances that produce a definite physiological action on the human and animal body (Edeoga et al., 2005). The most important of these bioactive constituents which are mainly secondary metabolites are alkaloids, flavonoids, tannins and phenolic compounds. Numerous studies have identified compounds within herbal plants that are effective antibiotics (Basile et al., 2000). These phytochemicals are toxic to microbial cells (Doherty et al., 2010).
Clinical trials are sets of tests in medical research and drug development that generate safety and efficacy information about adverse drug reactions and adverse effects of other treatments concerning health. India has been increasingly attracting collaborative contract proposals for conducting clinical trials and many entrepreneurs have already come forward to set up their Clinical Research Organisations (CROs). Clinical trials on pathogenic microorganisms have hinted significant results, where the antimicrobial potential of traditional folklore medicines is revealed.

Despite abundant literature on the antimicrobial properties of plant extracts, not many of plant derived chemicals have successfully been exploited for clinical use as antibiotics. The success achieved using medicinal plants and herbal formulations therapeutically based on ethnomedicinal and traditional use against a number of bacterial infections, raises optimism about the future of phytoantibiotics. Research being conducted by pharmaceutical and biotechnology companies in India has been on the increase. India being a land of diversity where Ayurveda, Unani, Siddha, and Homeopathy are practiced, clinical studies for evaluation of various alternate systems of medicine can also be conducted. Considering the vast potentialities of plants as sources of antimicrobial drugs with reference to antibacterial and antifungal agents, studies were undertaken to screen *Drymaria cordata* for antibacterial and antifungal activity.

Reports have indicated that *Drymaria cordata* possesses antibacterial properties (Mukherjee *et al.*, 1997a). To further substantiate the claim that the plant is used against various infections, the present investigation was undertaken to compare and evaluate the antimicrobial efficacy of normal and *in vitro* regenerated plants of *Drymaria*. 
Plant Profile

Plants still represent a large untapped source of structurally novel compounds that might serve as lead for the development of novel drugs. *Drymaria cordata*, is a wild folklore medicinal herb, and not been commercially exploited and has great potential for research.

Identification and Authentication

The authentication of the taxon was done by Botanical Survey of India (BSI), Coimbatore and recorded as *Drymaria cordata* (L.) Willd. ex Roem. & Schult. ssp. *diandra* (Blume) Duke.

Classification

- Super Division: Spermatophyta
- Division: Magnoliophyta
- Class: Magnoliopsida
- Sub Class: Caryophyllidae
- Order: Caryophyllales
- Family: Caryophyllaceae
- Genus: *Drymaria*
- Species: *cordata*

Distribution of the plant

The genus *Drymaria cordata* Willd. ex Roem. & Schult. (Caryophyllaceae) comprises 48 species distributed mainly in subtropical areas of the Western Hemisphere (Duke, 1961). *Drymaria cordata* is an annual creeping herb which is found distributed widely in the tropical regions of Asia, Africa, Central and North and South America (Burkill, 1985) and in tropical and sub tropical India, extending into the Himalayas upto a elevation of 2100 metres.
It is also found growing on the Nilgiris and Western Ghats (Nadkarni, 1976). *Drymaria cordata* is native to lowland areas in Central Japan. It is indigenous in the Galápagos Islands and in lowland areas of Columbia, Peru, and Bolivia. In Karnataka, it is found distributed in Chikmagalur, Hassan and Kodagu (Manikandan and Lakshminarasimhan, 2012).

*Drymaria cordata* is found growing in dense patches in moist shady places and also in sun-exposed areas. It dwells well in plantation crops such as tea and coffee, as well as pastures, lawns, gardens, riverbanks and ditches. It is found as a common weed found along road sides and in cultivated fields and often seen as an understorey weed in the trees in home gardens (Sahoo, 2013).

*Drymaria cordata* is commonly known as West Indian Chick weed. It is known by different names across India and other countries. In India they are known in different languages across states:

**Kannada** : Uluku yele  
**Hindi** : Pithpara, Yatikhoi  
**Tamil** : Kodicharai  
**Assamese** : Lajjabori  
**Manipur** : Tandan-pambi  
**English** : Heart Leaf Drymary / West Indian Chick weed

**Cultivation**

*Drymaria cordata* propagates vegetatively by rooting from nodes and also by seeds as well. Seeds are sown *in situ*. Germination usually takes place within 1 - 4 weeks at 20°C. It prefers a rather rich soil in full sun. However, low germination rate and poor seed viability limits its propagation.
**Parts used:** Whole plant and leaves

**Utility of *Drymaria cordata***

General survey and ethnobotanical studies have shown that *Drymaria cordata* is a potential medicinal herb utilized by the tribal people as it has medicinal properties and is used by the local folk to cure a number of ailments. *Drymaria cordata* is used as food and medicine in India and in other countries (Majumder *et al.*, 1978; Rao and Jamir, 1982a, Rao and Jamir, 1982b; Magneisto and Rao, 1983; Bennet, 1985; Kumar *et al.*, 1987; Gangwar and Rama Krishnan, 1990; Mahanti, 1994; Saklani and Jain, 1994).

- *Drymaria cordata* is widely used in traditional African medicine for the treatment of various ailments including cold, headache, bronchitis, as poultice on sore (to treat aching, inflamed or painful parts), leprosy, tumors, as fumigant for eye troubles, as cerebral stimulant and antifebrile agent (Burkill, 1985, Akindele *et al.*, 2012).

- Pounded leaf of *Drymaria* is applied to snake bites in China (Akendengue, 1994). The plant is made into paste and applied on fore head to cure headache (Ramashankar and Rawat, 2008). In Nigeria, *D. cordata* (Chick Weed; “Calabar woman’s eye”) is used in folk medicine to treat sleeping disorders, convulsions, and febrile conditions in children (Adeyemi *et al.*, 2008).

- Inhalation of warm leaves can also help in treating headache. Paste of fresh leaves is also applied to cure itching, skin diseases, dysentery, burns, stomach problems and ring worm. Monpa Tribes of Arunachal Pradesh use the plant for fever and bone fracture of hen (Anonymous, 1976). It is used for the cure of tooth ache by Idu Mishmi tribes of Dibang Valley (Saklani and Jain, 1994). The plant is roasted in banana leaves and used for gastrointestinal trouble. The
tender shoots are used in asthma and inflamed or clogged sinuses (Majumder et al., 1978).

- Tender young leaves and shoots are consumed raw or cooked as a vegetable (Singh et al., 2012). The leaves are used as a salad for their cooling properties.

- Whole plant of *Drymaria cordata* is also used traditionally for the treatment of fungal infections (Moshi, 2007), oral candidiasis and skin fungal opportunistic infections of H (199) HIV / AID, eye infections and arthritis (Giday et al., 2010).

- Further medicinal properties include its use as a depurative, emollient, febrifuge, laxative, appetizer and stimulant. The juice of the plant is used in the treatment of female infertility in Baham (Telefo et al., 2011).

- Extracts of *Drymaria cordata* have led to the anxiolytic effect (Barua et al., 2009), anti-inflammatory (Adeyemi et al., 2008), antimicrobial (Mukherjee et al., 1997a) and antitussive activity (Mukherjee et al., 1997b).

**Other economic uses:**

- The plant is a good soil binder and prevents erosion of soil.
- The leaves are collected as fodder for domesticated animals.
- Beautiful lawns can be prepared by cultivating this plant in the garden.

**Chemistry of *Drymaria cordata* (L.) Willd. ex Roem. & Schult**

*Drymaria cordata* contains phytochemicals like cyclopeptides (Ding et al., 2000), flavonoid glucosides (Ding et al., 1999), norditerpenes and norditerpene glycosides (Vargas et al., 1988), which have been isolated from the leaves. A new anti-HIV alkaloid,
drymaritin, and a new C-glycoside flavonoid, diandraflavone, along with eight known compounds, torosaflavone A, isovitexin, spinasterol β-D-glycoside, p-hydroxybenzoic acid, p-hydroxybenzaldehyde, cis-p-coumarate, methyl 5-hydroxy-4-oxopentanoate, and glycerol-α-lignocerate are isolated from whole plants of *Drymaria diandra* (Hsieh *et al.*, 2004a).

**Isovitexin:**

Synonym: Saponaretin, 6-C-glucosyl apigenin  
IUPAC Name: 5,7-dihydroxy-2-(4-hydroxyphenyl)-6-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one.

![Isovitexin Molecular Structure](image)

Molecular Formula: C$_{21}$H$_{20}$O$_{10}$  
Molecular Weight: 432.3775  
Melting Point: 220-221 °C  
Boiling Point: 807°C at 760 mmHg  
Density: 1.686 gms cm$^3$  
CHEBI ID: 18330

Isovitexin is a flavone C-glycoside isolated from the whole plants of *Drymaria diandra* methanolic extracts. Several pharmacological activities such as anti-hypertensive, anti-inflammatory, antispasmodic, antimicrobial and antioxidant are associated with this compound.
Prospects and scope for research

• To awaken and sustain interest among the people in indigenous drugs and remedies.

• Low germination rate and poor seed viability may become the reason for its gradual disappearance and hence conservation of the taxon.

• Although *Drymaria cordata* propagates vegetatively in its natural state, but propagation is too slow for commercial plant production. Hence, development of alternate propagation techniques for a non conventional plant like *Drymaria cordata* and to bring them into large scale cultivation may prove rewarding.

• Despite of its phytochemical constituents, edible and medicinal usage, not much attempt has been made to propagate *Drymaria cordata in vitro*.

• The plant is known to possess antioxidant, antimicrobial, anti-inflammatory and other significant medicinal properties which could be harnessed for human benefits.

• Although the said plant is having a promising therapeutic value, it is less known. Therefore an attempt is made by the present study to putforth folklore herbal medicine to manifold.

• Cultivation of *Drymaria cordata* would be of help not only in relieving diseases but for revenue generation for the deprived society.

Accordingly, the present investigation was carried out with the following objectives:
OBJECTIVES OF RESEARCH

1. To micropropagate the taxon through
   • multiple shoot proliferation
   • by callus cultures
   • by somatic embryos
2. To establish regenerates in land.
3. To study the effect of Arbuscular Mycorrhizal (AM) fungal association with normal and regenerated plants.
4. To determine the phytochemicals by preliminary screening the solvent extracts of normal and regenerated plants.
5. To estimate and compare the primary and secondary metabolites in normal, regenerated and AMF treated plants.
6. To determine the antioxidant activity of normal and regenerated plants.
7. To estimate the isovitexin (flavonoid) content by HPLC studies in normal, regenerated and AMF treated regenerated plants.
8. To determine the antimicrobial efficacy of normal and regenerated plants against human pathogenic microbes.