

CHAPTER - 2

Literature Review

Literature review

2.1. LAURACEAE IN PLANT KINGDOM

The family Lauraceae was established by A.L. de Jussieu (1789) in *Genera Plantarum*. The family covers 55 genera and about 2800 species (Van der Werff & Richter 1996) distributed widely in tropical to temperate regions of the world. The name Lauraceae was come from the type genus *Laurus* Linnaeus.

Bentham & Hooker (1862-1883) placed Lauraceae Jussieu in their classification as follows:

Kingdom: Plantae
Subkingdom: Phanerogamia
Class: Dicotyledons
Subclass: Monochlamydeae
Series: Daphnales
Family: Lauraceae

Cronquist (1981) placed Lauraceae in his classification as follows:

Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Magnoliidae
Order: Laurales
Family: Lauraceae

Takhtajan (1997) placed Lauraceae in his classification as follows:

Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Magnoliidae
Order: Laurales
Suborder: Laurineae
Family: Lauraceae

APG III (Chase & Reveal 2009) placed Lauraceae as follows:

Kingdom: Plantae

Clade: Angiosperms

Clade: Magnoliids

Superorder: Magnolianae

Order: Laurales

Family: Lauraceae

2.2. FAMILY CHARACTERS

Deciduous or evergreen shrubs or trees (*Cassytha* Linnaeus a twining, virtually leafless semi-parasitic perennial herb) (Li *et al.* 2008a), often with aromatic bark and leaves. Terminal buds often very large and bounded by several scales which leave behind dense clusters of scars in rings around the twigs (perulate buds). Leaves usually alternate, sometimes opposite or sub-opposite or clustered at branch ends, simple, usually entire, rarely lobed (*Sassafras* Linnaeus), mostly pinnately veined or strongly 3-veined. Stipules absent (Long 1984). Flowers usually small, in panicles, cymes or umbels surrounded by decussate bracts. Flowers generally bisexual, sometimes unisexual, trimerous or rarely dimerous (e.g. *Potameia* Thouin), actinomorphic, greenish, yellowish, or white (Datta 1988). Perianth segments usually six, in two whorls of three, deciduous or persistent; perianth tube usually persisting as a cupule at the base of fruit (Judd *et al.* 2002). Androecium usually of 4 whorls of 3 stamens each, adnate to perianth tube, often with an inner whorl of 3 staminodes; filaments usually free, innermost filaments usually bearing glands; female flowers with 9 or 12 staminodes; anthers basifixed, 2 or 4 celled (Prain 1903). Pistil 1; ovary usually superior, 1-locular; ovule anatropous in parietal placentation; style 1; stigma 1, rarely 2 or 3 lobed (Li *et al.* 2008a). Fruit a drupe usually borne on enlarged cup like remains of perianth, occasionally perianth completely absent or totally surrounded the fruit. Seeds with straight embryo; endosperm absent (Cronquist 1981).

2.3. ECONOMIC IMPORTANCE

The members of Lauraceae are economically important as sources of medicine, timber, nutritious fruits, spices and perfumes (Judd *et al.* 2002). *Persea americana* Miller (avocado) is a highly nutritious fruit, rich in proteins and fats and low in sugar. The total food value of avocado is high; it provides nearly twice the energy of an equivalent weight of meat and an abundance of several vitamins, such as A, B, C, D, and E (Wolstenholme & Whiley 1999). The leaves of the *Laurus nobilis* Linnaeus (bay Laurel) were dried and used as a flavouring agent for cooking, particularly for meat and fish dishes. A fat extracted from the seeds of this plant was used to make soap (Bergh & Ellstrand 1986). Cinnamon spice is derived from the inner bark of *Cinnamomum verum* J. Presl, the cinnamon tree, a native of Sri Lanka and southern India. Eugenol, one type of oil distilled from the green leaves of *C. verum*, is used as a substitute for clove oil, as an ingredient in some perfumes, and as a flavouring substance for sweets, foods, and toothpaste. Camphor was derived from *Cinnamomum camphora* (Linnaeus) J. Presl. Camphor was one of the raw materials used in making celluloid, which has now been replaced by other plastics. Camphor is employed in pharmaceuticals, especially in liniments, and in insecticides (Seth 2004).

Many other species of *Cinnamomum* Schaeffer have uses as spices and medicines. The essential oil of the leaves of *Cinnamomum tamala* (Buchanan–Hamilton) T. Nees & Eberm known as *Tejpat* oil, is medicinally used as a carminative, antifatulent, diuretic and in cardiac diseases (Mir *et al.* 2004). *Cinnamomum cambodianum* Lecomte bark is used to make joss sticks, which are burned as incense. Sassafras oil was extracted from the root-bark of *Sassafras albidum* (Nuttal) Nees. This oil once served as a flavouring agent for sweets, medicines, toothpastes, root beer and sarsaparilla (Seth 2004).

It is said that the wood of all trees of Lauraceae is suitable for industrial purposes, a statement that seems to be only a slight exaggeration. Most of the best-known timbers of Lauraceae have been depleted through overexploitation, however, and are not likely to remain economically important in the future unless serious conservation efforts are undertaken. Many species of the widespread genus *Ocotea* Aublet have been utilized for their widely useful timber (www.woodwindowalliance.com).

2.4. GENERA UNDER LAURACEAE

The Lauraceae consists of some 30 to 55 genera as recognized by different authors. Of these, about two-thirds of the species are belonging to only 6 genera: *Ocotea* Aublet (over 400 species), *Litsea* Lamarck (over 250 species), *Persea* (about 200 species), *Cinnamomum* Schaeffer (about 200 species), *Cryptocarya* Brown (about 200 species) and *Beilschmiedia* Nees (about 150 species) (Cronquist 1981). According to Heywood (1993) the family is represented by 32 genera, where as Kostermans (1957) reported 55 genera of Lauraceae. J. Hutchinson (1964) distinguished the Lauraceae into 47 genera as presented in Table 2.1.

Table 2.1. Genera of Lauraceae according to Hutchinson (1964)

<i>Actinodaphne</i> Nees	<i>Micropora</i> Hooker f.
<i>Aiouea</i> Aublet	<i>Misantheae</i> Chamisso & Schlechtendal
<i>Aniba</i> Aublet	<i>Nectandra</i> Roland ex Rottboell
<i>Apollonias</i> Nees	<i>Neolitsea</i> Merrill
<i>Beilschmiedia</i> Nees	<i>Nobeliodendron</i> O. Schmidt
<i>Brassiodendron</i> Allen	<i>Nothaphoebe</i> Blume
<i>Cardiodaphnopsis</i> Airy-Shaw	<i>Ocotea</i> Aublet
<i>Cassytha</i> Linnaeus	<i>Persea</i> Miller
<i>Cinnamomum</i> Schaeffer	<i>Phoebe</i> Nees
<i>Cryptocarya</i> R. Brown	<i>Phyllostemonodaphne</i> Kostermans
<i>Dahaasia</i> Blume	<i>Pleurothyrium</i> Nees
<i>Dicypellium</i> Nees	<i>Potameia</i> Thouin
<i>Dodecadenia</i> Nees ex Wallich	<i>Ravensara</i> Sonnerat
<i>Endiandra</i> R. Brown	<i>Sassafras</i> J. Presl
<i>Endlicheria</i> Nees	<i>Sassafridium</i> Meisner
<i>Eusideroxylon</i> Teijsmann & Binnendijk	<i>Stemmatodaphne</i> Gamble
<i>Hypodaphnis</i> Stapf	<i>Synandrodaphne</i> Meisner

<i>Iteadaphne</i> Blume	<i>Syndiclis</i> Hooker f.
<i>Laurus</i> Linnaeus	<i>Systemonodaphne</i> Mez
<i>Licaria</i> Aublet	<i>Thouvenotia</i> Danguy
<i>Lindera</i> Thunberg	<i>Umbellularia</i> Nuttall
<i>Litsea</i> Lamarck	<i>Urbanodendron</i> Mez
<i>Machilus</i> Nees	<i>Valvanthera</i> C.T. White
<i>Mezilaurus</i> Taubert	

2.5. DEVIATIONS FROM NORMAL CHARACTERS IN DIFFERENT GENERA

Stems filiform twining and leaves reduced to scales in *Cassytha* Linnaeus; leaves sometimes sub-opposite in *Beilschmiedia* Nees; mostly prominently 3-nerved from the base in *Cinnamomum* Schaeffer (Long 1984); flowers in *Misanteca* Chamisso & Schlechtendal arranged in dense heads; male and female inflorescences dissimilar in *Endlicheria* Nees; ovary inferior in *Hypodaphnis* Stapf; fruits supported on a double-margined receptacle in *Misantheae* Chamisso & Schlechtendal (Hutchinson 1964); inflorescence enclosed up to flowering time by an involucre of bracts in *Litsea* Lamarck (Prain 1903); flowers dimerous in *Potameia* Thouin; receptacle or pedicle of the Malayan genus *Dehaasia* Blume is swollen; calyx persistent and reflexed in the fruit in *Machilus* Nees; outer sepals much smaller than the inner whorl in *Dehaasia* Blume and *Cyanodaphne* Blume (Judd *et al.* 2002); anthers opening by minute pores in *Micropora* Hooker f.; annular disk present in *Synandrodaphne* Meisner; mature fruit completely or almost completely enclosed by the accrescent calyx-tube in *Cryptocarya* Brown (Li *et al.* 2008a).

2.6. GEOGRAPHICAL DISTRIBUTION

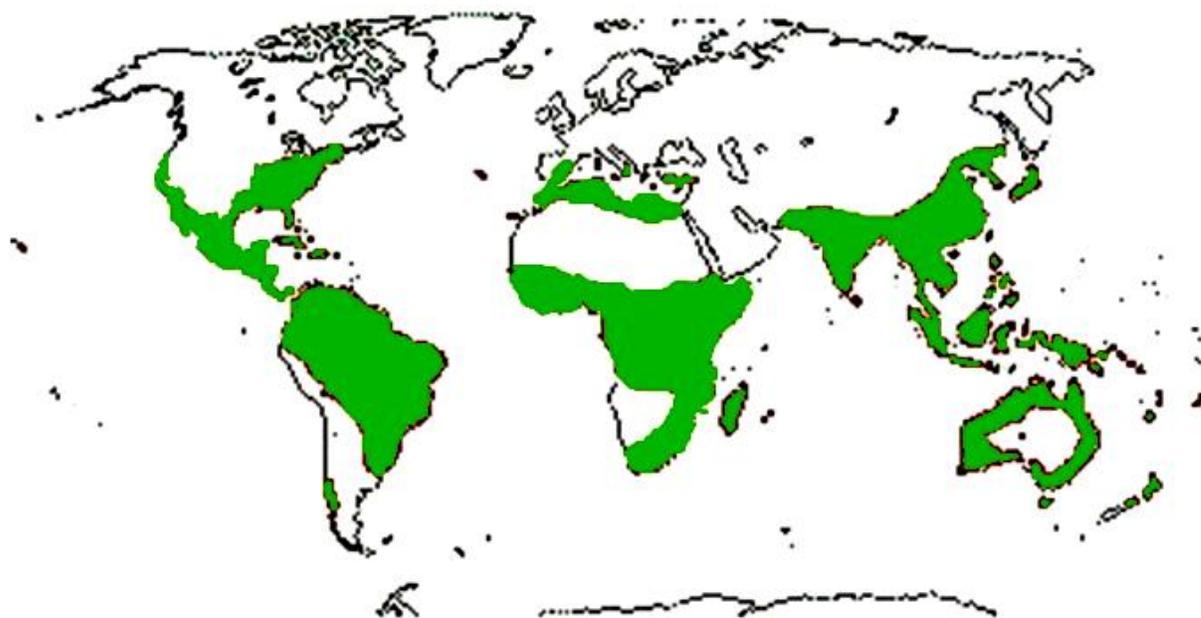


Figure 2.1. Distribution of Laurels in the world [Source: Heywood 1993]

The family Lauraceae was widespread in tropical and subtropical regions throughout the world (Cronquist 1981) (Fig: 2.1). Trees of the Laurel family are predominant in the world's Laurel forests, which occur in a few humid subtropical and mild temperate regions of both the hemispheres, including the southern Japan, Macaronesian islands, central Chile and Madagascar. According to J. Hutchinson (1964) the family is most abundantly represented in the tropics of both hemispheres, with about 18 genera in tropical America and nearly as many in tropical Asia; few genera are common to both the regions. However, the large genus *Cryptocarya* Brown is very widely spread. They are very rare in tropical Africa and Madagascar, though there are about 18 species of the genus. The Atlantic Islands are claimed to be the home for 3 indigenous genera, namely *Persea* Miller, *Laurus* Linnaeus and *Apollonias* Nees. The genus *Apollonias* Nees constituting one of the chief arboreal elements of the evergreen forest belt of the Canary Island and Madeira. There are very few Lauraceae in North-East Australia. Sassafras occurs both in East Asia and Atlantic North America. According to Cronquist (1981) two greatest centers for Lauraceae are in South-East Asia and in Brazil. Long (1984) has recorded fourteen genera for the *Flora of Bhutan*. Among those, *Litsea* Lamarck is the most dominant. Li *et al.* (2008a) reported 25 genera and 444 species for the *Flora of China*. *Machilus* Nees (82 species) *Litsea* Lamarck (74 species) were the widely extending genera in China. Ngernyuang *et al.* (2003) reported 19 species from tropical lower montane forest in northern Thailand. In Bangladesh, the family is represented by 13 genera and 46 species (Ara *et al.* 2007). 11 genera and 39 species were recorded earlier from the present Bangladesh areas by Hooker (1886). Heinig (1925) listed 20 species distributed under 9 genera from the Chittagong and Chittagong Hill Tract regions. Sinclair (1955) enumerated 5 species and 3 genera from the area of Cox's Bazar. Alam (1988) recorded 30 species and 9 genera from the forests of Sylhet region of Bangladesh. Three species of *Litsea* Lamarck were reported by Siwakoti and Varma (1999) for Plant Diversity of Eastern Nepal.

2.7. LAURELS IN INDIA

Hooker (1886) reported 15 genera and 204 species of Laurels for *The Flora of British India*. In *Flora Indica*, William Roxburgh (1832) described four genera and nineteen species of Lauraceae. Brandis (1874) recorded eleven species distributed under seven genera from North-West and Central India. Six genera and twenty four species from Agasthyamala were described by Mohanam and Sivadasan (2002). From Chota Nagpur, four genus and six species were described by Hains (1925). Parasitic herb *Cassytha filiformis* Linnaeus was reported from Indian desert by Bhandari (1978). Singh (1986) reported two species of *Cinnamomum* in the *Flora of Patna*. Fifteen genera and sixty eight species were described in *Flora of Assam* (Kanjilal 1940). Hajra (1996) described fourteen species distributed under eight genera from the Namdapha region of Arunachal Pradesh. Eleven genera and fifty species were recorded from Meghalaya by Haridasan & Rao in 1987. Momiyama (1966, 1971, 1975) reported nine genera and twenty nine species from Eastern Himalayan region. Six genus and fifteen species of Lauraceae was reported by Duthie (1915) for *Flora of The Upper Gangetic Plain*. Sanyal (1994) described two genera and two species for *Flora of Bankura District*, West Bengal. Eight genera and twenty four species were described from the pre-independent Bengal by Prain (1903). Cowan & Cowan (1929) listed forty eight species allocated under eight genera from North Bengal. Matthew (1981) enumerated eight genera and seventeen species from the Kurseong sub-division of Darjeeling district. However, some taxonomist have made contribution to the lauraceous flora of Darjeeling-Sikkim Himalaya including Das (1986) enumerated 14 species; P.C. Rai (2001) reported 15 species; U. Rai (2006) listed

twenty one species; Ghosh (2006) enumerated ten species. So, Lauraceous plants are distributed all over the India covering wide range of vegetation structures.

2.7.1. Lauraceae in Terai and Duars of West Bengal

Only few works were done regarding the distribution of Laurels in Terai and Duars region. Banerjee (1993) reported eleven species distributed under six genera from Jaldapara Rhino Sanctuary and are *Actinodaphne obovata* (Nees) Blume, *Beilschmiedia sikkimensis* Hooker f., *Cinnamomum bejolghota* (Hamilton) Sweet, *Cinnamomum glaucescens* (Nees) Drury, *Cryptocarya amygdalina* Nees, *Litsea glutinosa* (Loureiro) Robinson, *Litsea monopetala* (Roxburgh) Persoon, *Litsea salicifolia* (Nees) Hooker f., *Persea gamblei* (Hooker f.) Kostermans and *Persea glaucescens* (Nees) Long. Das *et al.* (2010) reported nine Lauraceous species from three MPCAs (Medicinal Plant Conservation Area) of Terai and Duars region. These MPCAs are situated at Rajavatkha forest, Lataguri forest and North Sevok forest. According to Das *et al.* (2010) the most dominated genus in this area is *Litsea* Lamarck and is followed by *Actinodaphne* Nees, *Cinnamomum* Schaeffer, *Persea* Miller and *Phoebe* Nees.

2.8. GEOLOGICAL HISTORY

Phylogenetic analyses is based on molecular markers and combined with inferences about timing of the phylogenetic events in the group which is based on branch lengths calibrated from fossil records. These fossil records suggested that bulk of the species diversity has accumulated from the time of the Cenozoic for which the family is represented in many fossil floras by leaves, wood, flowers and fruits (Eklund 1999; Chanderbali *et al.* 2001). These analyses further suggest that the basal lineages of Lauraceae, in which few extant species included, were already recognized in the Late Cretaceous (Chanderbali *et al.* 2001).

The fossil record, from the Cretaceous, plays a major role in understanding the early history of angiosperms (Friis *et al.* 2006). Direct fossil evidences of Lauraceae in the Cretaceous are sparse compared to that in the Cenozoic period, but there is nevertheless a growing record of leaves, wood, and reproductive structures which clearly support that the family was present and was also widespread at the early stages of angiosperm evolution. Interestingly, the fossil record of the flowers is much widespread from the Cretaceous than that of the Cenozoic. Particularly several well-preserved fossil flowers are important and have been described during the past two decades. The Cretaceous floral structures assigned to Lauraceae are now known, which are based on 12 taxa from several localities in North America, Europe, and Asia (Drinnan *et al.* 1990; Crane *et al.* 1994; Herendeen *et al.* 1994; Eklund & Kvaaek 1998; Eklund 2000; Takahashi *et al.* 2001; Frumin *et al.* 2004). These fossils provided insights into the floral structure of the Cretaceous representatives of this family. Because of the importance of the floral structure in the systematics of extant Lauraceae, the fossil flowers permitted us to compare the extinct members with those of extant representatives and also help to draw preliminary conclusions about their phylogenetic relationships and distribution over different geological era. These records also provided a new data-set for understanding the biological and geographic history of the family as well as to know their possible phylogenetic and functional differentiation (e.g., floral biology and pollination). According to Arthur Cronquist (1981) some Upper Cretaceous (Maestrichtian) wood from California falls well within the range of variation of the Lauraceae and Eocene wood from Yellowstone National Park is considered to be lauraceous. Von Balthazar *et al.* (2007) reported that Early Cretaceous (Early to Middle Albian) fossil flowers of lauraceous affinity from the Puddledock locality, Virginia, USA.

The flowers have several typical lauraceous structural features but are remarkable for their simple androecium. Nondestructive optical sectioning of single specimen, using synchrotron-radiation x-ray to monographic microscopy (SRXTM) offered crucial information on floral organization and internal structure. This flowers or fragmentary floral material assigned to Lauraceae have already been described from the Puddledock locality (Crane *et al.* 1994), supplied the earliest evidence of the family and also securely establishes its existence in the Early Cretaceous. The material further evidently demonstrated the phylogenetic and functional diversification of Laurales at very early phase of angiosperm evolution (Von Balthazar *et al.* 2007).

2.9. PHYLOGENATIC RELATIONSHIP

Lauraceae is under the order Laurales which is close to Magnoliales (Takhtajan 1981), but more advanced in some respects than the bulk. The perigynous (or even epigynous) flowers, single functional ovule, biaperturate or inaperturate pollen and usually fairly conventional stamens of the Laurales are the all advanced as compared to most of the Magnoliales (Cronquist 1981). Laurales consists of seven families and 3400 species. Major families include Calycanthaceae, Lauraceae, Monimiaceae, Siparunaceae and Hernandiaceae (Judd *et al.* 2002). In 2008, Stevens recorded the molecular and morphological phylogenetic studies in the Laurales. He found that Hernandiaceae, Lauraceae, and Monimiaceae (*sensu stricto*) are belonging to a monophyletic group (Fig. 2.2). Because of the insufficiency of phylogenetically informative substitutions, the relationships among families within this clade remain doubtful. Generally, molecular phylogenies may conflict because of a diversity of factors, including substitution rate dissimilarity among sites and lineages, taxon sampling and base compositional biases (Kubitzki 1981; Renner & Chanderbali 2000).

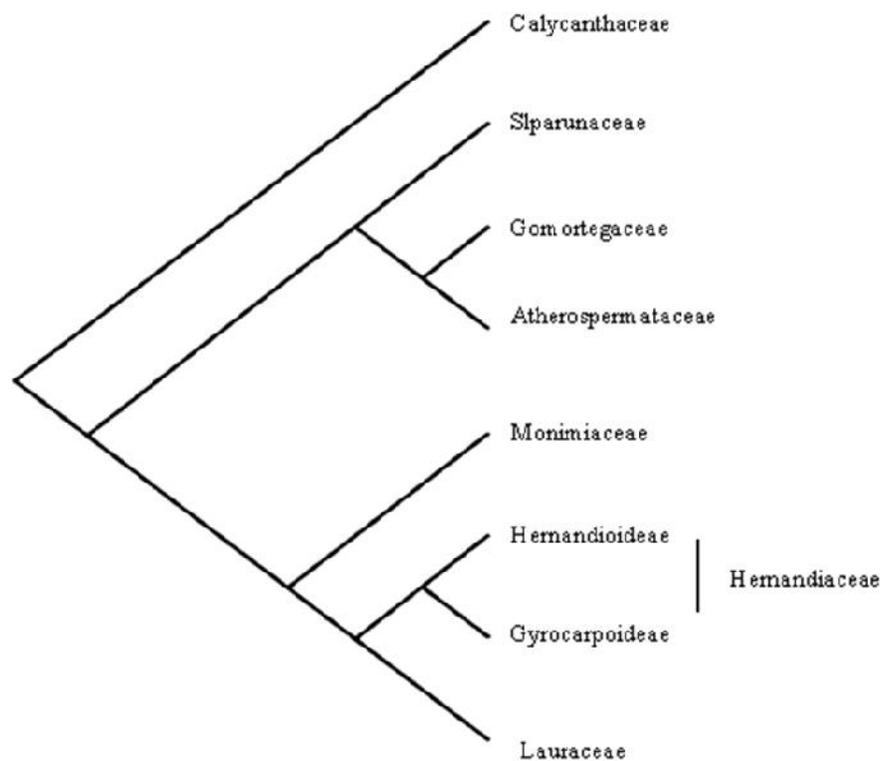


Figure 2.2. Phylogenetic tree of Laurales on the basis of Cronquist and Takhtajan's classification (Stevens, 2008)

According to Hutchinson (1964), Lauraceae is remarkably homogeneous like Sapotaceae. Lauraceae is closely related to Monimiaceae (Renner & Chanderbali 2000). In their study, they analyzed a total of 2846 aligned nucleotides present in a plastid intron, three spacers, and a portion of the nuclear 26S rRNA gene from Hernandiaceae, Lauraceae, and Monimiaceae. Searching of the data indicates that insufficient taxon sampling, fast-evolving outgroups, or biased base composition is very challenging to explain.

Arthur Cronquist (1981) reported that the gynoecium of the Lauraceae is truly monomerous or only pseudomonomerous and derived eventually from 3 carpels. However, Takhtajan (1997) has postulated that the Lauraceae originated from primitive members of the Monimiaceae those had several separate carpels. Now, the question arises, did the evolutionary reduction from numerous separate carpels to a single carpel occur bypassing the formation of a compound pistil, or did the reduction to a particular carpel occur only after a compound pistil evolved in some unknown intermediate ancestor! Sastri (1958, 1962, 1965) has pointed out a significant statement that ontogenetically the gynoecium of a flower develops in from a single conduplicate carpel and the appressed carpellary margins do not unite until a relatively late stage in development. After reviewing the available proofs, Endress (1972) firmly decided that the gynoecium of Lauraceae is truly monomerous, but the argument is probably not ended. Contrasting with the other lauralean families such as Monimiaceae, Calycanthaceae, Trimeniaceae and Hernandiaceae using Chloranthaceae as outgroup, Lauraceae is best for resemble Hernandiaceae embryologically (Heo & Tobe 1995).

Lauraceae and Hernandiaceae share pachychalazal seeds or ovules with raphal vascular tissues ramified at an enlarged chalaza. Close affinities between Hernandiaceae and Lauraceae are also suggested through shared benzyl-isoquinoline (Gottlieb 1972) and micro-fibrillar structure with tubular exine (Kubitzki 1981) and through a cladistic analysis based on morphological characteristics (Loconte & Stevenson, 1991). However, several core lauralean families *viz.* Amborellaceae, Monimiaceae and Gomortegaceae are as yet little known by embryologically, production of these data will probably be helpful for more critical comparison. Certainly, a shared isorhamnetin rather suggested close relationships of Lauraceae with Monimiaceae and Gomortegaceae (Crawford *et al.* 1986). Macromolecular verification from *rbcL* nucleotide sequence analysis suggests that Lauraceae also can be relate to Monimiaceae than to Hernandiaceae (Qiu *et al.* 1993). However, such molecular records are restricted to very few species of Laurales and Lauraceae; when such data will be available, based on more species, better conclusion can be drawn regarding the closest allies of Lauraceae.

2.10. CHALLENGES IN CLASSIFICATION OF LAURACEAE

Classification within the Lauraceae remains unresolved till date, though, numerous classificatory schemes based on morphological characteristics have already been proposed (Van dar Werff & Richter 1996). However, none of these is fully accepted. The knowledge of all the taxa at genus and species levels comprising Lauraceae is still incomplete. Till 1991, approximately 25 – 30 % of neotropical species of Lauraceae had not been described (Rohwer *et al.* 1991). As of 2001, Kimoto & Tobe completed only embryological studies on individuals from 26 genera of this family. Additionally, the huge amount of variation within the family poses a major challenge for developing a reliable classification (Van Dar Werff & Richter 1996; Rohwer *et al.* 1991). Till date, it is impossible to describe even one genus or a tribe by a single well-defined character (Rohwer *et al.* 1991). For this reason, all the proposed classifications rely on a set of characteristics where the combination presents the most frequently observed traits for

the group (Van dar Werff & Richter 1996; Rohwer *et al.* 1991). However, due to an array of molecular and embryological evidences those disagrees with such groupings, kept the scientific community without accepting those classifications in their totality. Their classification is based on inflorescence structures as well as bark and wood anatomy. It splits Lauraceae into two subfamilies *viz.* Cassythoideae and Lauroideae. The Cassythoideae is comprised of a single genus i.e. '*Cassytha*', and is defined by its herbaceous and parasitic habit. The Lauroideae is then divided into three tribes: Laureae, Perseeae, and Cryptocaryeae (Radford *et al.* 1974).

The subfamily, Cassythoideae, is not fully supported. Support has come from "matK" sequences of chloroplast genes (Rohwer 2000), while a questionable placement of *Cassytha* has been concluded from analysis of intergenetic spacers of chloroplast and nuclear genomes (Chanderbali *et al.* 2001). Embryological studies by Heo *et al.* (1998) also supported the creation of this subfamily. It is found that *Cassytha* develops an 'ab initio' cellular type endosperm and rest of the family (with one exception) develops a nuclear type endosperm. Kimoto *et al.* (2006) suggests that *Cassytha* should be placed in the Cryptocaryeae tribe because it shares a glandular anther tapetum and an embryo sac protruding from the nucellus like other members of the Cryptocaryeae.

The Laureae and Perseeae tribes are not well supported by any molecular or embryological studies. Sequences of the "matK" chloroplast gene as well as sequences of chloroplast and nuclear genomes revealed close relationships between the two tribes. Embryological proof does not support a clear division between the two tribes either. Genera such as *Caryodaphnopsis* Airy-Shaw and *Aspidostemon* Rohwer-Richter those share embryological characteristics with one tribe as well as wood and bark characteristics or inflorescence characteristics with another tribe blur the decision to accept these two groups at the rank of Tribe. All available evidence, except for inflorescence morphology as well as wood and bark anatomy, fails to support the segregation of the tribes Perseeae and Laureae.

The tribe Cryptocaryeae is partially supported by embryological and molecular studies. Chloroplast and nuclear genomes supports a tribal grouping that contains all the genera circumscribed by Van der Werff and Richter (1996) as well as three additional genera. Partial support for the tribe is also attained from the "matK" sequences of chloroplast genes as well as from embryology.

2.11. USE OF ANATOMICAL CHARACTERS IN TAXONOMY

Anatomical features have long been used for solving many taxonomic disputes (Agbagwa & Ndukwu 2004; Kharazian 2007). Like other biological characters, anatomical characters also provide preliminary identification of species. For this purpose stem, lamina and petiole anatomy played crucial role (Metcalf & Chalk 1950).

In woody dicotyledons information of wood elements are extremely significant from taxonomic, systematics and phylogenetic points of view (Metcalf & Chalk 1950). For the phylogenists, stem anatomy is the most rewarding source of information because of the widespread data can be produced and are already available for most families on comparative basis (Thorne 1976). Lersten & Curtis (2001) indicated that stem anatomical studies support to solve many systematic problems. The wood anatomy of some Laurels like *Beilschmiedia emarginata* (Meisner) Kostermans, *B. rigida* (Mez) Kostermans, *B. taubertiana* (Schwartz *et* Mez) Kostermans and *Anaueria brasiliensis* Kostermans are described by Callado and Costa (1997). The main anatomical differences are: presence and arrangement of secretory cells and the arrangement of the axial parenchyma. In 1981, Weber studied a taxonomic revision of Australian

Cassytha species on the basis of morphology and anatomy. In 2012 Rao *et al.* used anatomical features for the identification of economically important *Litsea glutinosa* (Loureiro) C.B. Robinson.

Not only stem but also the structure of lamina and petiole anatomically shows differences between genera and species (Shaheen 2007; Eric *et al.* 2007). Vaikos (1987) studied foliar epidermis of eight species of Iridaceae. He illustrated epidermal features which were useful for species identification. A notable study on leaf anatomy of 597 species of *Rhododendron* Linnaeus was done by Cowan (1950) and Hayes *et al.* (1951). Foster (1951) has explained the careful description of mesophyll along with detailed leaf anatomy which can yield valuable taxonomic dividends. Like other families anatomical structures of leaf are also very important in Lauraceae (Metcalf & Chalk 1950). Leaf anatomical investigation was carried out in *Cinnamomum pauciflorum* Nees by Baruah and Nath in 2006. Bhatt and Pundya (2012) examined the leaf anatomy of *Litsea chinensis* Lamarck. According to them uniseriate epidermal layer, anisocytic stomata and presence of abundant mucilage in developed vascular bundle might eventually allow recognition as well as standardization of the species. Thus, useful leaf anatomical characters are determined in designated taxonomical structures of some species.

2.12. USE OF LEAF ARCHITECTURE IN TAXONOMY

Leaf architecture was initially used and described by Hickey to represent the placement of plant species through the expression of leaf structure with leaf shape, gland position, venation pattern and marginal configuration (Hickey 1973; Zetter 1984; Kohler 1993). From earliest to recent times, for fossils to living plant species identification, leaf architecture is used in large scale. In paleobotany, macro-fossils which were showing leaf venation patterns those were extensively employed in identifying fossil taxa (Alvin & Chaloner 1970; Cleal 1981; Walther 1998; Melville 1969). Earlier in 1951, Foster carefully prepared the description of various forms of venation. Pattern of leaf venations are of great significance both in monocots and dicots (Foster 1959). Leaf architecture were studied in several dicotyledonous and monocotyledonous families like Asteraceae (Banerjee & Deshpande 1973), Euphorbiaceae (Sehgal & Paliwal 1974), Berberidaceae (Singh *et al.* 1978), Betulaceae (Frank 1979), Bignoniaceae (Jain 1978), Labiatae (Tyagi & Kumar 1978), Rosaceae (Merrill 1978), Solanaceae (Inamdar & Murthy 1978) and Scrophulariaceae (Verghese 1969), Hydrocharitaceae, Taccaceae, Dioscoreaceae, Smilacaceae, Araceae, Alismataceae, Aponogetonaceae (Inamdar *et al.* 1983). In 1974, Sehgal and Paliwal explained the venation pattern of *Euphorbia* sp. On the basis of leaf venation they created categories, groups and subgroups. Micro-morphological characteristics like epidermal hairs played a significant role in plant systematics at generic and specific levels (Hardin 1979). Todzia and Keating (1991) have determined the relationship of Lauraceae and Chloranthaceae by the data of leaf architecture. Moore *et al.* (2008) analyzed and used the epidermal characters of leaves in *Smilax* (Tournefort) Linnaeus, which is recognized as a successful taxonomic method for distinguishing every individual taxon. Beside these characters, stomata also provide taxonomically many important diagnostic characters, like stomatal index, stomata type and the occurrence of stomata on the adaxial or abaxial leaf surface, etc. (Tripathi & Mondal 2012).

2.13. PHYTOCHEMICAL DATA FOR SOLVING TAXONOMIC PROBLEMS

The subject of chemotaxonomy is concerned with the application of chemical characters to solve the problems of classification and phylogeny. This rapidly expanding discipline of plant taxonomy has been variously called as chemotaxonomy, chemosystematics, biochemical systematic or phytochemistry (Pullaiah 2007). Botanists, of late, have come to the conclusion that evidence for discussing the relationships and

phylogeny must be taken from as many sources as possible. As more comprehensive survey of phytochemistry has become available, taxonomists have shown a growing interest in the application of chemical characters to taxonomic problems (Judd *et al.* 2002). Living organisms produce many types of natural products in unstable amounts, and quite often the biosynthetic pathways responsible for the production of these compounds also differ from one taxonomic group to another. The distribution of these components and their biosynthetic pathways correspond well with existing taxonomic arrangements based on more traditional criteria like morphology (Swain 1963). During evolution it sometimes happens that unrelated groups of plants produce morphologically alike structures. This is called ‘convergence’ or ‘parallel development’. Conversely related plants may give rise to very dissimilar descendants i.e. ‘divergence’. These occurrences sometimes cause considerable taxonomic difficulties (Erdtman 1963). Chemical contributions to plant classification are based on the chemical constituents of plants, i.e. on their ‘molecular characteristics’. These characteristics are genetically controlled and have the advantage over morphological characteristics (Wink & Waterman 1999). The method of chemical taxonomy is simple in principle and consists of the investigation of the distribution of chemical compounds or groups of biosynthetically related compounds in series of related or supposedly related plants (Mannheimer 1999). Chemical variation has considerable taxonomic value in several ways:

- ◆ Confirmation or support of putative classifications derived from other sources of taxonomic characters, such as morphology
- ◆ Resolution of problems where relationships based on other evidences are ambiguous or conflicting
- ◆ Providing evidence to suggest more natural positioning of anomalous taxa, as well as to separate taxa; often the presence of anomalous taxa in a group is accentuated by their chemical peculiarities
- ◆ Detection and confirmation of hybridization
- ◆ Providing additional on/off characters for numerical taxonomy by their presence or absence in taxa.

Chemotaxonomy has made rapid progress in the last 40 years because of new instruments and newer techniques (Pullaiah 2007). A crude extract of a plant can be separated into its individual components, especially in the case of micro-molecules, by using one or more techniques of chromatography, including paper, gas, thin-layer, high-pressure liquid chromatography and high performance thin layer chromatography. The resulting chromatogram gives a visual display or “fingerprint” characteristic of a plant species for the particular class of compounds under study (Erdtman 1963; Swain 1963). The individual spots can be further purified and then subjected to one or more types of spectroscopy, such as ultraviolet (UV), infrared (IR) or nuclear magnetic resonance (NMR) or mass spectroscopy (MS) (or both), which may provide information about the structure of the compound. So, for taxonomic purposes, both visual patterns and structural knowledge of the compounds can be compared among different species (Wink & Waterman 1999). Research has shown that there is generally an inverse relationship between the taxonomic distribution of a compound or class of compounds and its biogenetic complexity such that if it is biosynthetically simple and widespread it may be assumed to be primitive, while those are more limited in their distribution and more complex to biosynthesis may be assumed more advanced (Gershenzon & Mabry 1983). Certainly chemotaxonomic investigations have been employed at all levels of the taxonomic hierarchy from sub variety to division (Smith 1978; Stace 1980). Abbott (1886) has made the earliest attempts to correlate chemistry with the phylogenetic level

of development. According to her the saponin containing plants occupied the middle level of Hackel's scheme of plant evolution. The first successful attempt to combine chemical and morphological evidence in the study of a single genus was the work of Baker and Smith (1920) on the essential oils of *Eucalyptus* sp. They recommended that the level of relationship should be in chemical similarities. After collection of the morphological and chemical data from 176 species of *Eucalyptus*, they divided the genus into three groups differing in both morphological structure and chemical constituents.

The subject really came to the age with the publication of several seminal works, especially those of Alston and Turner (1963), Swain (1963, 1966) and Harborne (1964, 1967). Hegnauer had already embarked on his epic series 'Chemotaxonomic der Pflanzen', in which with great carefulness he compiled the current information on occurrence and distribution of metabolites within and between plant families (Hegnauer 1962 – 1990; Hegnauer & Hegnauer 1992 – 1996). By this time, sufficient data had been gathered concerning the occurrence of a wide range of secondary metabolites to allow for generalizations to be made on the taxonomic range of their distribution.

Thin layer chromatography (TLC) is an important technique for plant components identification. To differentiate the diversity of plant species this technique is used frequently. In 2011, Zafar *et al.* compared different category of phytochemicals and classified different groups by preparing cladograms through TLC. In 2009, Choze *et al.* noticed through TLC that the absence or presence of certain compounds in the plant *Augusta longifolia* (Sprengel) Rehder supplied various taxonomic markers with important information about the position of this species in the Rubiaceae. In 1979, Floyd compared the fresh *Pelea* with herbarium samples. He took the both extracts and determined phenolic components through TLC. He obtained the identical result. So, in numerous cases TLC can be used for identification of plant specimens and employed as chemotaxonomic technique.

2.14. COMPOUNDS USEFUL IN PLANT TAXONOMY

Although in theory all the chemical constituents of a plant are potentially valuable to a taxonomist, in practice some sorts of molecules are far more valuable than others. Excluding the inorganic compounds, metabolites which are of relatively little use can be recognized with three broad categories of compounds viz. primary metabolites, secondary metabolites and semantides.

2.14.1. Primary Metabolites

Although some primary metabolites are utilized chemo-systematically, as a whole their efficacy is limited. They are intermediates or products of essential metabolic pathways and are present in ubiquitous distribution (e.g. sugars that participate in the Calvin cycle). Occasionally they assemble in high concentrations as unusual storage products and in such instances that they can be used for taxonomic entity (Stace 1980).

2.14.2. Secondary Metabolites

These are very numerous and of more restricted occurrence than primary metabolites, which makes them more valuable as a source of taxonomic evidence (Stace 1980) and a large amount of information on their distribution in angiosperms is available. However, the data was demonstrated that some secondary compounds are more useful than others, particularly on a broad scale (Gershenzon & Mabry 1983). The following are those groups of compounds which were so far established to be most useful:

2.14.2.1. *Flavonoids*

Jones and Luchsinger (1987) showed that the flavonoids are one of the most useful taxonomic markers for a variety of reasons:

- ◆ These demonstrate a wide range of chemical structures, which have a demonstrable genetic basis for their variation
- ◆ These are chemically stable, so that analysis of materials can be done by earlier collected materials
- ◆ These can be isolated easily and identified even from small amount of plant materials; huge number of plants can easily and rapidly be surveyed for flavonoids using paper, thin-layer or one or two dimensional chromatography and through which, in recent years, many useful results have been achieved (Zafar *et al.* 2011)
- ◆ These occur variously but ubiquitously almost in all plants; and
- ◆ These can be used at all taxonomic levels in most groups of plants.

Although flavonoids are present in all higher plants (Vickery & Vickery 1981), they are absent in bacteria and the majority of algae. The most primitive group that exhibits them is the Charophyceae (stoneworts), a group of green algae considered to be advanced for a number of reasons. Simple flavonoids have been found in primitive Bryophytes, whereas far more complex ones have been isolated from the most advanced angiosperms (e.g. Orchidaceae).

Flavonoids can be used as a ‘fingerprint’ in some genera where it has been found that each species has a distinct flavonoids pattern. For example, the *Eaptisra* genus (Fabaceae), 62 different flavonoides are available and each of its 17 species has different characteristic flavonoid pattern. However, closely related species has almost identical pattern of flavonoides (Vickery & Vickery 1981).

Percentage of natural hybrids may be deduced if flavonoids biosynthesis is assumed to be additive (Vickery & Vickery 1981). By recombination, arising from species with differing flavonoids can synthesize compounds found in neither parent. The hybrid was exhibited intermediate characters i.e. exomorphic by this chemical recombination (Davis & Heywood 1973).

2.14.2.2. *Terpenoids*

Although terpenoids are present in wide range and they show many variation, but they have been used less extensively than flavonoids in taxonomy, possibly due to difficulty of analysis. However, they have been used extensively in the chemosystematics of some groups in which they occur (e.g. mints, umbellifers). Comparison of terpenoid content between plants has been facilitated by gas chromatography, and they have been used to clarify specific and subspecific taxa as well as geographic races and hybrids (Jones & Luchsinger 1987).

2.14.2.3. *Alkaloids*

A great deal of information on alkaloid occurrence is available and their distribution has contributed to taxonomic studies in various groups. However, these are chemically less stable than flavonoids, and are structurally and biosynthetically more complicated (Jones & Luchsinger 1987). Due to the lack of knowledge as to the relative advancement of the different biosynthetic pathways leading to the various skeletal types, little attempt has been made to compare different alkaloid types phylogenetically (Gershenzon & Mabry 1983). Their contribution to such classifications has thus been restricted. Exceptions among the alkaloids are the benzyl-

isoquinoline alkaloids, which are important taxonomic markers in the angiosperms. Gershenzon and Mabry (1983) attributed this to their biosynthetic uniformity and 'coherent distribution'.

2.14.2.4. Glucosinolates (*Mustardoil glucosides*)

These, together with the alkaloids, have been used to divide the four families comprising the old order Rhoadales into two new orders: Capparales, containing the Cruciferae and Capparaceae which produce glucosinolates and Papaverales containing Papaveraceae and Fumariaceae, on the basis of alkaloid pattern. Research has shown that glucosinolate patterns may also be used to document hybridization as well as provide infrageneric characters (Jones & Luchsinger 1987).

2.14.2.5. Iridoids

This group of secondary metabolites is of increasing taxonomic importance (Gershenzon & Mabry 1983; Jones & Luchsinger 1987) and they show promise in the clarification of relationships at various levels. They have also contributed to solving the debate over the ancestral progenitor of the Asteraceae, which do not produce iridoids. Several putative progenitors' cases were weakened when they were shown to produce iridoids, leaving only the Campanulaceae, Araliaceae and Apiaceae, which do not produce iridoids (Jones & Luchsinger 1987).

2.14.3. Semantides

Semantides are the information carrying molecules. DNA is a primary semantide and RNA a secondary semantide, where proteins are tertiary semantides, following from the sequential transfer of the genetic code from the primary genetic information (DNA) (Swain 1963). Stace (1980) mentioned three main methods used in protein taxonomy: electrophoresis, amino-acid sequencing and systematic serology. Electrophoretic techniques enable proteins to be 'fingerprinted' their relative isoelectric point by separating them in variable gel mixtures across a voltage gradient (Stace 1980). Protein profiles produced *via* electrophoretic separation and subsequent staining have been used in various systematic studies investigating polyploid taxa, as well as at interspecific, intraspecific and population levels. Particular care and expertise are required in the use and interpretation by establishing size, charge and of protein profiles (Jones & Luchsinger 1987). Amino-acid sequencing attempts to establish the variation in the precise sequence of amino acids in a single homologous protein throughout a range of organisms (Stace 1980). Sometimes the semantides together with the larger polysaccharides are known as macromolecules and the primary and secondary metabolites as micromolecules (Pullaiah 2007). Most of the micromolecules are shown the antioxidant activity (Hakkim *et al.* 2008; Moura *et al.* 2007; Edreva *et al.* 2008).

So, chemotaxonomy has undoubtedly made a big contribution to taxonomic work in the past and will certainly continue to do so in future. However, given the lack of fossil evidence and the need for live material in some analyses it seems that its contribution to a phylogenetic classification must perforce remain limited. The valuable information it offers is best used in conjunction with other sources of taxonomic evidence and thus a multidisciplinary approach is required in order to establish a system of classification which reflects natural relationships as accurately as possible.

2.15. CHEMOTAXONOMIC IMPLICATION IN LAURACEAE

Economically Lauraceae is an important family of higher plants. But, it is difficult to identify the lauraceous species based on morphological features only, due to short flowering and fruiting period and genera

encompass many species which have shown same type of morphological appearances (Gomes *et al.* 1983). Errors of botanical identification could be prevented by using the information obtained from a comprehensive analysis of the chemical profiles of the putative species. So, crucial value of the chemotaxonomic approach can be seen here. Johns *et al.* (1969) studied an excellent work on the genus *Cryptocarya*. They identified 1-benzyl-1,2,3,4-tetra-hydro-isoquinoline alkaloid from the leaf extract of *Cryptocarya archboldiana* C.K. Allen and also reported several alkaloids from the genus *Cryptocarya* such as the phenanthroquinolizidine alkaloid cryptopleurine from *C. pleurosperma* C.T. White & W.D. Francis, the cryptowolline and dibenzopyrrocoline alkaloids cryptausoline from *C. bowiei* Druce, aporphine alkaloids from *C. angulata* C.T. White, *C. triplinervis* Brown and a benzyloquinoline alkaloid from *C. konishii* Hayata. In 1989, Lajis *et al.* reported that the leaves of *Alseodaphne perakensis* (Gamble) Kostermans contain one major and a complex mixture of minor alkaloids. The chief component was identified as N-methyl-2,3,6-trimethoxymorphinandien-7-one through spectroscopic analyses of the parent compound. A chemotaxonomic investigation was carried out with eight species of *Cinnamomum* Schaeffer as part of a biosystematic study on this genus occurring in the state of Kerala by Ravindran *et al.* (1992). They analyzed flavonoids, terpenoids and steroids of these species. The results signified the much chemical variability among those species. According to them chemically *Cinnamomum perrottetii* Meisner, *Cinnamomum verum* J.Presl and *Cinnamomum camphora* (Linnaeus) J. Presl were the most complex, whereas some collections of *Cinnamomum malabatum* (N.L. Burman) J. Presl were the least complex. They also claimed that *C. camphora*, *C. verum*, *C. camphora*, *C. cassia* (Linnaeus) J. Presl and *C. riparium* Gamble are chemically very distinct. A large amount of infra-specific variability was observed in *C. malabatum*. The diverse flavonoid pattern in this genus resulted from o-methylation which is considered as an advanced character and flavonols were found to be replaced by flavones. Flavonols and flavones are advanced characters in the evolutionary history of flavonoids. Joshi *et al.* (2009) examined the leaf terpenoid compositions in nine species of Lauraceae, viz., *Lindera pulcherrima* (Nees) Hooker f., *Neolitsea pallens* (D.Don) Momiyama & Hara, *Persea duthiei* (King) Kostermans, *Dodecadenia grandiflora* Nees, *Persea gamblei* (King ex Hooker f.) Kostermans, *Persea odoratissima* (Nees) Kostermans, *Cinnamomum tamala*, *C. camphora*, and *Phoebe lanceolata* (Nees) Nees collected from the Indian Himalayan region by GC, GC-MS, and NMR analyses in order to determine the similarities and differences among their volatile constituents. They established that Furano-esquiterpenoids were the principal constituents of *N. pallens*, *D. grandiflora*, and *L. pulcherrima*. Limonene, (E)-Nerolidol, a-pinene and b-pinene were the major constituents of *P. duthiei*; a-pinene, b-caryophyllene and sabinene were noticed predominantly in *P. odoratissima*, while the oils of *P. gamblei* and *P. lanceolata* possessed b-caryophyllene as common major constituent. *C. tamala* and *C. camphora* were marked by the existence of camphor and cinnamaldehyde, respectively. They also made cluster analysis of the oil composition within these nine species of six genera of Lauraceae. Phytochemical investigations on three Brazilian species of Lauraceae from the Cerrado region of Sao Paulo State, *Ocotea elegans* Mez and *O. corymbosa* (Meissner) Mez, *Persea pyrifolia* Nees & Martius ex Nees resulted in the isolation of an ester of the 4-O-E-caffeoylquinic acid, flavonoids, an aromatic sesquiterpene besides furofuran lignans (Batista *et al.* 2010). Four aporphine alkaloids from the wood of *Ocotea macrophylla* Kunth were isolated and characterized as (S)-3-methoxy-nordomesticine, (S)-N-formyl-3-methoxy-nordomesticine, (S)-N-ethoxycarbonyl-3-methoxy-nordomesticine and (S)-N-methoxycarbonyl-3-methoxy-nordomesticine; alkaloids 2-4 are reported for the first time by Pabon and Cuca in 2010. Perez *et al.* (2011) could able to differentiate eight Mexican *Litsea* species on the basis of their terpenoid substance. The terpenoids viz. 1,8-cineole,

linalool, α -pinene, β -pinene, α -terpinene, terpinen-4-ol, caryophyllene, α -terpineol and caryophyllene oxide are commonly found in all the *Litsea* species. From the hierarchical classification, three groups of species were recognized: (i) 1,8-cineole group (C-10 terpenes), consisting of *L. glaucescens* Kunth, *L. pringlei* Bartlett, *L. schaffneri* Bartlett and *L. muelleri* Rehder; (ii) limonene-rich group (C-10 oxygenated terpenes), including *L. neesiana* (Schauer) Hemsley and *L. guatemalensis* Mez, (iii) oxygenated sesquiterpenes-rich group (C-15 oxygenated terpenes), includes *L. parvifolia* (Hemsley) Mez.

2.16. SIGNIFICANCE OF ANTIOXIDANTS IN PHYLOGENETIC CLUSTERING

The early classifications of plants were artificial and served practical purposes. After Darwin, botanists proposed 'natural system' in which they were thrashing about for real relationships but it is yet to construct such a true 'phylogenetic system'. The main reason for this is that the vast majority of extinct species is unknown. The natural systems are based essentially on comparative studies of genetically controlled, morphological and anatomical characteristics of plants. Some of these characteristics are of a very general nature and serve for the separation of systemic categories, like divisions, classes, orders, families, genera, subgenera etc. Chemical contributions to plant classification are based on the chemical constituents of plants such as on their 'molecular characteristics'. These characteristics are genetically controlled and have the advantage over morphological characteristics that they can be very exactly described in terms of definite structural and configurational chemical formulae. The greatest virtue of the chemical method is that it is entirely independent of the classical biological methods. Very early in the development of natural products chemistry, many botanists and chemists characterized and classified plants on the basis of their chemical constituents (Smith 1978; Stace 1980). Moreover, botany and chemistry become more and more separated due to increasing specialization of their respective followers. With the growing knowledge of the structure the natural products and their occurrences in plants, it is obvious that the potentialities of chemotaxonomy is now becoming increasing. In 1992 Ravindran *et al.* clustered and made phylogenetic tree of *Cinnamomum* species according to the presence of flavonoids, triterpenoids and steroids which are the potent antioxidant compounds. Kim *et al.* (2009) proved that phenolic compounds, mainly flavonoids are naturally occurring antioxidant components produced by plants. In 2009, Mohy-Ud-Din *et al.* grouped five taxa of *Solanum* on the basis of percentage variation of the flavonoids using GC-MS analysis and 2,4-dinitrophenylhydrazine method. They stated that the significant distance found between *S. americanum* P. Miller, *S. chenopodioides* Lamarck, *S. nigrum* Linnaeus and *S. villosum* P. Miller indicated them as distinct species. But, the noticeable difference is absent in *S. retroflexum* Dunal and therefore hence it is considered as a variety or subspecies of *S. nigrum*.

2.17. ANTIOXIDANT MOLECULES AS CHEMOTAXONOMIC MARKER

Antioxidant molecules are used as marker in chemotaxonomy. For example, anthocyanins are a group of naturally occurring antioxidant compounds related to the colouring of plant parts like fruits and flowers. These pigments are important as quality indicators, as taxonomic markers and for their antioxidant ability. Paola *et al.* (2003) have investigated that the therapeutic efficacy of anthocyanins contained in blackberry extract (cyanidin-3-O-glucoside represents about 80% of the total anthocyanin contents) in an experimental model of lung inflammation induced by carrageenan in rats. Vaccination of carrageenan into the pleural cavity elicited an acute inflammatory response characterized by fluid accumulation which contained a large number of neutrophils as well as an infiltration of polymorpho nuclear leukocytes in lung tissues and subsequent lipid peroxidation, and increased generation of nitrite/nitrate (NO_x) and

prostaglandin E2 (PGE2). All parameters of inflammation were prohibited by anthocyanins. The degree of stain accumulation was lowered by anthocyanins treatment. According to them, the anthocyanins contained in the blackberry extract exert multiple protective effects in carrageenan-induced pleurisy. Zarnowski *et al.* (2004) differentiated soft and hard wheat plants utilizing alk(en)ylresorcinols which is a chemotaxonomic marker. Ferrandino and Guidoni (2010) used phenolic compounds such as anthocyanins, flavonols, and hydroxycinnamates as taxonomical markers to discriminate *Vitis vinifera* Linnaeus cv. 'Barbera' clones. Through the analysis of phenolic profiling Siracusa *et al.* (2012) recommended that the secondary metabolites in "Long-storage" tomato (*Solanum lycopersicum* Linnaeus) fruits may be more genetics-dependent than environment-dependent.

A large number of reports concerning the antioxidant ability of essential oils of aromatic plants have been published (Bhargava *et al.* 2013). It is well known that compounds of essential oils are the outstanding marker of chemotaxonomy, therefore the antioxidant activity of these oils are easily used as chemotaxonomic marker. Baker and Smith (1920) worked on *Eucalyptus* spp. They noticed that primitive species are those which have feather-veined leaves and high Pinene content in their essential oils (terpenes), while more advanced types have intermediate venation and contain Pinene and Cineole (Pullaiah 2007). Recently, Basak and Chandan (2013), identified three components of essential oil of *Laurus nobilis* Linnaeus and noticed that these components have significant amount of antioxidant potentiality.

So, antioxidant molecules could be adopted as chemotaxonomic markers in the traceability of this niche product as well as these bioactive components are especially useful for both plant breeders and taxonomists to classify species or cultivars.

The family Lauraceae has been studied worldwide from the botanical and chemical standpoints. Terai and Duars is under the sub-Himalayan region, and its vegetation is enriched with many species of Laurels. Controversies about phylogeny and affinity of species as well as uncertain positioning of different genera are still under consideration. Many researchers showed that this group is enriched with versatile secondary metabolites and these natural products have a wide structural diversity and have been isolated in great scale from plant species; they can be used as taxonomic markers at hierarchical levels. Although there are some controversies on the usage of antioxidant molecules to solve taxonomic problems, it can be said from this study, since a large amount of data will be employed, some positive inferences might be made, when these markers will be utilized. So the utilization of a greater diversity of data will give us safer tools to elucidate at least some existing doubts in the near future concerning the chemical evolution of the family Lauraceae.