Chapter 3
REVIEW OF LITERATURE

3.1. History of the Family

The family Lauraceae was appeared first time in the book Herodotus histories, (450–420 BC) as cinnamon and cassia. The first comprehensive and authentic publication of plants including laurels of India was Hortus Malabaricus, an enormous work by the former Dutch Governor of Cochin Hendrik Andriaan van Rheede (1678-1693) and included 3 genera and 3 species of present day Lauraceae. The 3 genera viz., Carua (=Cinnamomum), Mala-poenna (=Litsea) and Acatsja-vali (=Cassytha).

Linnaeus (1753) described 1 genus with species in Species Plantarum as Cassytha filiformis L. in the section Triandria Monogynia. Antoine Laurent de Jussieu (1789) was proposed a system of classification in his Genera Plantarum Secundus Ordines Naturales Disposita. He established the family Lauraceae with 3 genera viz., Laurus L., Ocotea Aubl. and Ajovea Juss. The name ‘Lauraceae’ was derived from the well-known member, the Grecian laurel, Laurus nobilis L., is characterized by plants which have prominent oil cells in the leaves, wood and fruits. Robert Brown (1810) treated Laurineae with 4 genera and 12 species. He too described the genus Cryptocarya as a new genus for Australia with 3 species. Blume (1825) classified the family based on the number of anther locules into two viz., anthers bi-locular and quadri-locular with 7 genera and 54 species.

Nathanniel Wallich (1830) superseded Roxburgh as Superintendent of Botanic Garden at Culcutta. He had published Plantae Asiaticae Rariores (1831) and included the family Lauraceae (Laurineae) with 22 genera. He too numerically listed and catalogued the dried specimens of plants in the East India
Company's Museum. William Roxburgh (1832) treated Laurineae under Enneandria Monogynia with 2 genera with 15 species. The first major treatment of the family Laurineae on a world-wide basis were by Nees von Essenbeck (1836) in his Systema Laurinarum with 13 genera and established a new genus Caryodaphne Blume ex Nees.

Robert Wight explored the South Indian flora and included 14 genera and 46 species of Lauraceae in his Icones Plantarum Indicae Orientalis (1852). In this publication, he described a new species Tetranthera tomentosa Roxb. ex Wight from Deccan, which was later named as Litsea deccanensis Gamble. Miquel (1855) classified Laurineae with 4 tribes, 23 genera and 234 species in his Flora Van Nederlanddsch Indie. Lecomte (1857) included 14 genera and 102 species in Lauracees De Chine et D’ Indo-China.

Meissner in De Candolle Prodromus Systematis naturalis (1864) elaborated a complete monograph of Laurineae with 51 genera. Kostermans, (1937) has revised the genera Endlicheria Nees, Cryptocarya and Licaria Aubl. Naturalists consider the family is originated from Magnoliales by reduction. The genus Cassytha L. shows close similarities with most other genera of the Lauraceae in the attributes: trimerous flowers; two perianth whorls with slight differentiation; several staminodal whorls usually four in Lauraceae with one or two whorls in Cassytha; dehiscence of anthers by flaps; single carpel with one pendulous ovule; similarities in the vascular supply of various organs (Sastri, 1952).

Hegnauer (1966) in his chemotaxonomic study, created a system rather similar to that of Pax (1889), placing the monogeneric subtribe Cassytheae in subfamily Lauroideae. Roth, (1977) suggests that fruits of Lauraceae are typically considered drupes, but are better classified as a berry since the endocarp is only made up of a thin, single-celled sclerified endodermis. Weber (1981) stated that the genus Cassytha was not evolved from other members of
the family Lauraceae, it might have been evolved in the old-world tropics or it may be in Australia, after the Gondwanaland split. He also suggested that parasitism arose in the Lauraceae in Australia. Takhtajan (1986) classified Lauraceae under the order Laurales, which comprises 11 families. Van der Werff (1987) revised the genus *Mezilaurus* Kuntze from Neotropics. Rohwer and Richter (1987) described the genus *Aspidostemon* Rohwer & H.G. Richt. for a group of 11 closely related species from Madagascar, which were previously included in the genus *Cryptocarya*.

Van der Werff and Endress (1991) established a new genus in the family Lauraceae as *Gamanthera* van der werff from Costa Rica. Van der Werff (1991) erected a few new taxa from the genera *viz.*, *Caryodaphnopsis*, *Cinnamomum* Schaeff., *Endlicheria*, *Ocotea* and *Rhodostemonodaphne* Rohwer & Kubitzki from Ecuador and Peru. In addition, Van der Werff, (1992) successfully suggested a proposal to conserve *Cryptocarya* against *Ravensara* Sonnerat. The main argumentation given was that the two genera were separated solely on one fruit character, *i.e.* presence of ruminate cotyledons in *Ravensara* versus non-ruminate cotyledons in *Cryptocarya*. Kostermans, (1994) described 4 new species in the genera *Beilschmiedia*, *Cassytha*, *Cryptocarya* and *Endiandra* R. Br. from Asia.

on two versus four-locular anthers are not phylogenetically supported, *Litsea, Lindera*, and *Actinodaphne* are not monophyletic, but *Neolitsea* is monophyletic, and inflorescence ontogeny is phylogenetically important in the Laureae. Nishida (1999 & 2008) revised the genus *Beilschmiedia* Nees in Borneo and from the Neotropics. The new genus *Sinopora* J. Li, N.H. Xia & H.W. Li is reported from Hong Kong in South China and is based on *Syndiclis hongkongensis* N.H. Xia, Y.F. Deng & K.L. Yip (Li et al., 2008). Yang et al., (2011) made critical notes and lectotypified *Beilschmiedia xizangensis* H.P. Tsui.

### 3.2. Indian Scenario

Major Beddome (1864), an English Army officer and forest Botanist had studied the floristic diversity of India. He too worked a lot in angiosperms and concentrated his major work in south India and included 10 genera with 23 species in *Flora Sylvatica*. Kurz (1887) recognized the family with 13 and 53 species in his *Flora of British Burma*. George Bentham and J.D. Hooker (1880) classified Laurineae into 4 tribes *viz.*, Perseaceae, Litseaceae, Cassythaceae and Hernandiaceae with a total of 34 genera. Most of the Hooker genera are still recognized, but the taxa he placed in the genus *Tetranthera* is now included in *Litsea*. He also commented on the difficulty to categorize the genera in the case of 2-locular and 4-locular anthers separating generically plants. In his subsequent studies, Hooker (1886) reported about 207 species in his *Flora of British India*. These recorded species belong to 16 genera with several doubtful species and varieties. Cooke, Theodore (1907) British Botanist in India, prepared *Flora of Presidency of Bombay*. He enumerated 8 genera and 13 species of Lauraceae and excluded the occurrence of *Cryptocarya stocksii* Meissn. Bourdillon (1908) listed 9 genera and 22 species in his *The Forest Trees of Travancore*. He too erroneously included *Cinnamomum gracile* Miq. along the banks of river in Malayattool, Northern Travancore was later published as *Cinnamomum riparium* by Gamble. Talbot
(1912) in *Forest Flora of Bombay Presidency* recorded 13 species under 7 genera and described a new species *Cryptocarya procera* from central Western Ghats, which was later excluded Gangopadhyay (2005) in the revision of the genus *Cryptocarya* in Indian subcontinent.

In the past, attempts were made by Rama Rao (1914) to prepare a systematic account of Lauraceae of Travancore appeared in and listed 44 Lauraceae members in *Flowering Plants of Travancore*. Gamble (1925) in *The Flora of the Presidency of Madras* recognized 60 species and 5 varieties belonging to 11 genera in this family. Razi (1955–56), who reviewed the probable centres of origin of various species found in Mysore hill tops and has shown that the species like *Cinnamomum*, *Litsea* and *Neolitsea* to be of Malayan affinity. Parkinson (1923) recorded 4 genera and 10 species from Andaman Islands.


Ramachandran and Nair (1988) recorded 9 genera and 19 species in *Flora of Cannanore*. Nicolson *et al.* (1988) reviewed the nomenclature of the plants described by Rheede (1688) in *Hortus Malabaricus* and provided a new
combination for *Litsea quinqueflora* (Dennst.) Suresh. and reduced *L. ligustrina*. Manilal (1988) enumerated 6 genera and 13 taxa from the Silent Valley National Park. Subramanian *et al.* (1989) have reported *Litsea ghatica* C.J. Saldanha from Wayanad as a new report from Kerala. Keshava Murthy *et al.* (1987) reported a new species *Litsea lakshmanammaniana* from Tadiandamol in *Flora of Coorg district*. A total of 7 genera 16 species were reported in *Flora of Palghat District* (Vajravelu, 1990). Mohanan & Henry (1991) published a new species of *Cinnamomum* namely *Cinnamomum chemungianum* from Chemungi forest of Agasthyamala region. There are 9 genera and 16 taxa were recorded in *Flowering Plants of Thrissur Forest* (Sasidharan & Sivarajan, 1996). Nayar (1996), who described endemism in Western Ghats, considered 44 taxa endemic to peninsular India, among them *Litsea nigrescens* Gamble, was possibly extinct and 4 species are under threatened category. He also mentioned species such as *Litsea, Cinnamomum, Actinodaphne, etc.* as relict endemics.


### 3.3. Economic importance

Economically, the family is very important and it is major source for medicine, timber, fruits, spices and perfumes. Dried leaves of the *Laurus nobilis* L. (bay laurel) are used as a flavor for meat and fish dishes. A fat extracted from the seeds is used for making soaps. Cinnamon spice, extracted from the inner bark of *Cinnamomum verum*. in India and Sri Lanka. Eugenol oil, distilled from the green leaves widely used as a substitute for clove oil, as an ingredient in some perfumes, and as a flavouring agent for sweets, foods, and toothpaste. Camphor oil, a product is derived from the tree *Cinnamomum camphora* a native tree in China, Japan and Taiwan. Safrole, a component in the camphor oil used in perfumes, for flavourings and also used pharamaceuticals industry. 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 liniments, and in insecticides. *Ocotea venenosa* Gleason, a tree species widely seen in South America, is a source of a poison used for the tips of arrows by Brazilian natives. Bebeerine, a highly poisonous alkaloid produced as a secondary compound, has been extracted from several species of *Ocotea* (Rohwer, 1993). *Cinnamomum tamala* (Buch.-Ham.) T. Nees & Eberm. leaves (tejpat), are used extensively in different dishes in Bhutan, India and Nepal. The species in lauraceae are commonly used for making plywood, for interior decorative works, and for making boats. Ethereal oils are found in many Lauraceae, used for spices and perfume industry.

Sassafras tea, a semi-medicinal preparation with several alleged curative properties, has been a home remedy used for many years by rural persons of the Eastern United States. The distilled bark and chipped wood of *Sassafras albidum*, is widely used in carbonated beverages and dentifrices. Safrole, used in flavors and medicinals, is derived from the roots of this plant. The *Laurus nobilis*, an ornamental plant known from ancient times as a symbol of "achievement" and "highest honor," was prominent among the ancient Greeks, who honored their heroes and victors of the Pythian games and as a mark of distinction for certain offices by bestowing a garland consisting of laurel branches. A crow of laurel was used to indicate academic honors. The word "laureate," such as in poet laureate, indicates "crowned or decked with laurel as a mark of honor, hence distinguished, worthy of honor especially for poetic excellence." *Cinnamomum camphora* is a native to Formosa, China and Japan. A most renowned timber tree of Borneo is *Eusideroxylon zwageri* ("billian") which has a heavy brown wood, twice as strong as teak. It is utilized for roofing shingles, water troughs and heavy structural work. The Chinese use this species as a coffin wood. The "spicy cedar" of Liberia and Nigeria (*Tylostemon mannii*) has a golden brown, fine textured, hard and heavy wood used for furniture, doors and boats (Schroeder, 1975-76).
Asolkar et al., (1981) suggests the inner bark of shoots of *Cinnamomum verum* is used for preparing flu-preventive, indigestion and flatulence control and for mouth wash. It is also applied in the treatment of dyspeptic conditions of the gastrointestinal tract, fullness and loss of appetite and to cure abdominal pain with diarrhoea, amenorrhoea and dysmenorrhoea. Many species are used locally for wood or medicine, i.e. the widely used wood of *Actinodaphne nantoensis* (Hay.) Hay. and *A. mushanensis* (Hay.) Hay. for architecture and furniture, and the important medical properties of the roots of *A. cupularis* (Hemsl.) Gamble and leaves of *A. pilosa* (Lour.) Merr. (Li et al., 1984).

They were largely used in the preparation of scent, clearing agents, detergents, shampoos and lotions as pest repellent, ingredients in cosmetics, perfumes, flavors also in medicine Mallavarpu (1995). Cinnamon spice is derived from the inner bark of *Cinnamomum verum*. Cinnamon oil is distilled from bark chips and used to alleviate stomach upset. Cinnamon was used by the ancient Egyptians during the embalming process. Eugenol, an oil distilled from the green leaves, is used as a substitute for clove oil, as an ingredient in some perfumes, and as a flavouring for sweets, foods, and toothpaste. In Asia, several Litsea species are cultivated for timber and essential oil extraction for the perfume industry, as well as for food and flavoring (Nath et al. 1995).

*Litsea aestivlis* (L.) Fernald is commonly known as “pond spice” is the only species that is native to the America (Van der Werff, 1997). It is also applied to treat impotence, frigidity, dyspnoea, inflammation of the eye, leucorrhoea, vaginitis, rheumatism neuralgia, wounds, toothache and diabetes (WHO, 1999). The leaves *L. monopetala* are used in Assam to feed muga silk-worm. The bark is mucilaginous and said to be used as binding material for local manufacture of mosquito coil in Sylhet. Bark has medicinal properties and used to cure diarrhoea. The seeds yield an oil which can be used in candle making and in ointment. An oil is extracted from the seeds of *L. glutinosa* is
used for candle making in Java and China, bark is crushed and used medicinally for sprains and bruises (Das & Alam, 2001).

The extracts from *C. cassia* have been claimed to reduce inflammation (Lee, 2002) and to decrease serum glucose, total cholesterol and platelet counts (Khan et al., 2003). *Cinnamomum tamala* leaves are used extensively in the cuisines of India, Nepal and Bhutan, particularly in the Moghul cuisine of North India and Nepal and in Tsheringma herbal tea in Bhutan (Nirmal Babu et al., 2003).

The Chinese cassia extract has a direct anti-diabetic potency (Verspohl, 2005). Many plants of Lauraceae have been employed in folk medicine for their interesting bioactivities. Camphor is taken orally to calm hysteria, nervousness, neuralgia and to treat serious diarrhea, also known to be effective in treating colds and chills (Lee et al., 2006).

Maridass and Victor (2008) suggested that the *Cinnamomum* species namely, *C. walaiwarense*, *C. travancoricum* and *C. malabatrum* was used for the treatment for stomach pain. Likewise, *C. riparium*, *C. sulphuratum*, *C. filipedicellatum* and *C. wightii* were used for treating wounds, fever, intestinal worms, headaches and menstrual problems.

Jiménez-Pérez et al. (2011) reported the uses of *Litsea* spp. in Mexico as *L. glaucescens* is used as condiment, and is sold in market. *Litsea guatemalensis* Mez has been used to treat fever, chills, infectious diseases of the digestive system and arthritis. *Litsea glaucescens* Kunth is used to cure paralysis with its odorous smoke, decoction managed in washing and baths heals fatigue, and epilepsy of children. It is also applied in gynecological problems, as postnatal pains, facilitate birth, treat dysmenorrheal, sterility, and to heal pain, infections, fevers, and rheumatism.

In India, the plants in the family Lauraceae are commercialized as timbers, especially for making plywood and interior decorative works, finishing, paneling, furniture, and cabinet making. The bark of many species has
commercial value such as Cinnamon (*Cinnamomum verum*, & *C. malabatrum*) and the avocado or alligator pear (*Persea americana*), a species indigenous to Tropical America is now widely cultivated in tropical countries for fruits. The genus *Litsea* has (*Litsea glutinosa* and *L. quinqueflora*) ethereal oils, they form important sources for spices and perfumes. The plants of this family are source of fuel wood and furniture. The timber has been found suitable for the manufacturing of plywood tea-chest (Thakura *et al.*, 2012).

Fresh leaves of *L. stocksii* are exploited by the natives to cure irritations of urinary bladder and urethra, fruit juice is for sprains and itches. The bark of *L. glutinosa* is applied to cure diarrhoea, dysentery, rheumatic pain, sprains, wounds, burns and also to fix broken bones. The fruits and seeds are orally used to cure rheumatic problems. There are reported uses of bark and root paste of *L. monopetala* to heal bruises, contusions and an ointment for rheumatism.

In northeast India *L. cubeba*, *L. salicifolia* and *L. nitida* are cultivated to rear muga silkworms. The essential oils *viz.*, citral, lauric acid and oleic acid are extracted from *L. cubeba*, *L. glutinosa*, *L. monopetala* and *L. stocksii* are commercially very important for the preparation of medicines, insecticides, perfumes, flavours. Leaf extract and flowers *L. cubeba* are used to treat athlete’s foot, other skin diseases and often used to flavour tea respectively, decoction of different parts of this plant is used to cure burns, sprains, indigestion, cough and bronchitis, paralysis and even mental disorders like hysteria and forgetfulness among the tribals of Arunachal Pradesh, Meghalaya and Sikkim (Kataky *et al*. 1976 & Bhuniya, 2010).

*Cinnamomum zeylanicum* demonstrates numerous beneficial effects both *in vitro* and *in vivo* as a potential therapeutic agent for diabetes (Ranasinghe *et al.*, 2012). The *Cinnamomum cassia* used orally in mean dose of 2 g daily, for a period ranging from 4 to 16 weeks reduce fasting blood glucose level (Leach & Kumar, 2012). The cinnamon oil has shown significant antibacterial properties against *E. coli* ATCC 25922 and fungicidal activity (Yehouenou *et al.*, 2012).
3.4. Anatomy

3.4.1. Leaf Anatomy

Anomocytic stomatogenesis were reported in *C. verum* by Shylaja (1984). Bakker *et al.*, (1992) carried out detailed study on the anatomy and oil and mucilage cells of *Cinnamomum* species. He too finds out the oil and mucilage cells played a significant role in the grouping of the species. Papillate trichomes are the characteristic of *C. bejolghota* (Baruah & Nath, 1997). Cinnamon leaves are hypostomatic, anomocytic, paracytic and the rare representations of other types of stomata are also reported (Baruah & Nath, 1997). Christophel *et al.* (1996) applied the leaf cuticular features in relation to taxonomic delimitation in the family Lauraceae.

According to Mikage and Senoo (2003), the leaves of *C. tamala* and *C. impressinervium* can be differentiated by the presence or absence of papillae on the abaxial surface of the lamina. This was observed during the studies carried out to clarify the botanical origin of the Nepalese natural drug Tejpat. These species differ in outline of the midribs, and number of phloem rays in the transverse sections of midribs.

Recent critical studies on the leaf cuticles of 48 species of *Beilschmiedia*, *Endiandra*, *Potameia*, *Sinopora*, and *Syndiclis* from eastern Asia and Madagascar using light microscopy and scanning electron microscopy showed that the stomatal ledges and the surface of the stomatal complex are valuable in supraspecific grouping. While ornamentation of periclinal walls, thickness and straightness of anticlinal walls, and presence/absence of round oil deposits are applicable to species identification (Yang *et al.*, 2012). This study also identified the veinlet anatomy and macromorphology of terminal buds. Further, this identified features were tentatively applied to classify the Asiatic *Beilschmiedia* group in to five groups such as *Beilschmiedia delicata* group, the *B. glauca* group, the *B. intermedia* group, the *Endiandra* group, and the *Syndiclis* group, each of which shares a suit of cuticular characters.
Another recent study on leaf epidermal anatomy of *Caryodaphnopsis* Airy Shaw, a genus disjunct between tropical Asia and tropical America, using light microscope and scanning electron microscope revealed that this genus has an additional layer covering the lower leaf epidermis and the stomatal apparatus, it is either closed or poriferous/reticulate. This is an autapomorphic character. They also commented that the periclinal wall of the lower leaf epidermis has been gradually modified in Lauraceae, from a smooth pattern in most genera, to papillate pattern (e.g. *Neocinnamomum*), and to the double layered lower leaf epidermis in *Caryodaphnopsis* (Gang et al. 2014).

### 3.4.2. Wood anatomy

Earlier studies on wood anatomy of *C. porrectum* elucidated the bark anatomy and briefly assessed the histology of *C. cassia* bark (Parry, 1969). However, further detailed studies on the wood anatomy of *Cinnamomum camphora* explained the salient characteristics of wood anatomy such as distinct growth rings, pore size of 17-35 sq. mm and thin walled tyloses. The wood is mostly diffuse porous and rarely ring porous. For instance, it is observed that in Sassafras that wood is occasionally ring porous. The vessels small, or medium (mostly); solitary, radially paired, and in radial multiples, or in tangential arcs (mostly solitary and in numerous small radial multiples, but multiples of 4 or more cells and oblique rows also occur in some genera). The vessel end-walls scalariform, or simple, or scalariform and simple. The vessels without vestured pits; without spiral thickening. The axial xylem with tracheids, or without tracheids; with vasicentric tracheids (rarely), or without vasicentric tracheids; with fibre tracheids, or without fibre tracheids (usually); with libriform fibres (usually), or without libriform fibres; including septate fibres (commonly), or without septate fibres. The parenchyma paratracheal. The secondary phloem not stratified and ‘Included’ phloem absent (Rohwer, 1993).
3.5. Karyology

Okada and Tanaka, (1975) provided a summary on the cytogenetics of South American Lauraceae. The base number is $x = 12$ ($2n=24$), with very little variation in the karyotype throughout the family. Polyploidy has however been observed in Cassytha, Laurus, Litsea and Sassafras ($2n=48$), and in species of Laurus and Neolitsea aciculata ($2n=72$). Metaphase chromosomes are 1–3 mm long (5–7 mm in Cassytha), the position of centromere varies from median to sub terminal and heterochromatin is found only in the proximal regions of both arms.

3.6. Reproductive biology

3.6.1. Palynology

On the basis of shape and exine sculpture, four pollen types may be distinguished in the Lauraceae by Kostermans (1957) namely, Type A (spheroidal, spiniilose grains): Tribes Perseeae, Cinnamomeae, Litseeae and Illypodaphneae; Type B (oblate, non-spindose grains): Tribe Cryptocaryaeae; Type C (spheroidal, verrucate grains): Subfamily Cassythoideae, with the single genus Cassytha; Type D (striate grains): only known in Dahlgrenodendron J.J.M. van der Merwe & A.E. van Wyk, a monotypic southern African genus of uncertain suprageneric position.

Palynological features have, however, attracted little attention for defining groups in the closely related lauraceae. Lauraceae is generally considered as a stenopalynous family. Its pollen grains have usually been described as more or less spheroidal, apolar and inaperturate, with the exine highly reduced and consisting only of a thin coherent layer ornamented with spinules. In many taxa the spinules are formed by cable-like strands and surrounded by minute granules at the base (Raj & Van der Werff, 1988).

Raj and van der Werff (1988) considered the family eurypalynous and concluded that grains of most genera are easily identifiable by their size and
by the number and organization of the spinules. As discussed by Van der Merve (1988) pollen characters of lauraceae are taxonomically useful on the generic rather than specific level, and he agrees with the findings of Raj and Van der Werff (1988). The pollen grains of species of *Cryptocarya* have been described as inaperturate, spheroidal, with a characteristic pollen wall, that was thin exine and a massive nature of the intine (Raj & Van der Werff, 1988).

Van der Merwe *et al.* (1988) suggests southern African *Cryptocarya* species, the pollen grains are strongly flattened, peroblate/oblate. The exine surface of a pollen grain can be either more or less smooth or variously verrucate (wrinkled). It is interesting to note that palynological studies can provide important spaces for understanding the evolutionary history of the taxon.

Rohwer (1993) reported that the exine sculpture in some species of *Cryptocarya* presents a pattern densely covered with minute spinules. However subsequent studies showed that this palynological record of the lauraceae is very poorly documented, because their pollen grains have thin exine with little sporopollenin in the mature pollen wall and consequently are seldom preserved (Drinnan *et al.* 1990, Herendeen *et al.* 1994). Rohwer (2009) studied the timing of nectar secretion in stamina and staminodial glands in Lauraceae. Perez-Balam (2012) investigated the pollinators like, honey bees, flies and wasps visiting the flowers of avocado (*Persea americana* Mill.) in Southern Mexico.

### 3.6.2. Pollination biology

Sedgley (1979) reported that, irrelevant of the number of pollen grains germinating on the stigma, only a few pollen tubes will exhibit prolonged growth and eventually reach the ovule. Avocado flowers periodically close and re-open, resulting in alternating female and male phases. The flowers are thus functionally dichogamous, representing a kind of temporal dioecy which is well known for members of the lauraceae (Kubitzki & Kurz, 1984).
Pollen tubes exhibit active and prolonged growth in styles of flowers from boron-sufficient trees. It can thus be concluded that the addition of boron to avocado flowers has a significantly positive effect on the in vivo growth of the pollen tubes (Coetzer & Robbertse, 1987). Endress and Igersheim (1997) studied the carpel and ovule structure in lauraceae. The carpels are closed at anthesis and the closure takes place in three different modes, it is by postgenital fusion of the stylar (and ovarian) ventral slit in Lauraceae. Besides, there is no micropyle and the nucellar apex makes direct contact with the inner ovary surface or the funicle and the ovule is pachychalazal (or perichalazal) in lauraceae.

Recent empirical studies to explain the cytological, physiological, chemical and ecological characteristics of pollen and nectar offered by male and female flowers of the dioecious plant *Laurus nobilis* observed various phases of floral penology like insect pollinator, pollen and nectar structure, pollen viability, opening and closing of anther valves, pollenkit, nectaries of male and female flowers, more concentrated nectar sucrose in male flowers, thin layer of nectar. They were also identified the hymenopteran pollinators (about half the total number of all visits), recalcitrant type pollen, but its viability is long-lasting because the intine is thick and stores water and insects are attracted by male and female flowers similarly, males offer nectar and pollen, whilst females only nectar (Pacini et al., 2014).

### 3.6.3. Embryology

Studies on the embryology of lauraceae family considered that the genus *Cassytha* cannot be removed to a separate family by using embryological grounds (Sastri, 1962). In addition carpel and ovule structure of lauraceae family has been subjected to systematic empirical validation (Endress & Igersheim, 1997). The results of this study revealed that the carpels are closed
at anthesis and the closure takes place in three different modes, it is by postgenital fusion of the stylar (and ovarial) ventral slit in Lauraceae. Besides, there is no micropyle and the nucellar apex makes direct contact with the inner ovary surface or the funicle and the ovule is pachychalazal (or perichalazal) in Lauraceae.

The embryology of Lauraceae is poorly known, and was investigated. The genus Cassytha is clearly distinct from the rest of the family in having a cellular type endosperm instead of a nuclear type endosperm (an apomorphy) as in the rest of the family, in lacking the nucellar cap and in having the micropyle formed by from the inner and outer integument, facts supporting the traditional taxonomic placement of Cassytha in its own subfamily and the remainder of the family in the other subfamily. The amoeboid tapetum (an apomorphy) distinguishes 15 genera (Actinodaphne, Cinnamomum, Laurus, etc.) from the 6 genera with the glandular tapetum. In addition, a mature embryo sac protruding from the nucellus (an apomorphy) distinguishes five genera (Beilschmiedia, Caryodaphnopsis, Cryptocarya, Endiandra, Potamria) and the species of Ocotea rubra from the rest of the family (Kweon et al., 1998). The Sassafras randaiense (Hayata) Rehder shows temporal dioecy in its sexual system and has been variously described as a dioecious, androdioecious, or polygamous species in the past (Chung et al., 2010).

3.7. Phylogeny

Li et al. (1966) suggested that the family is primitive due to the trimerous nature of the flowers. Phylogenetically, the family forms a monophyletic group with Monimiaceae and Hernandiaceae in the Laurales, but although morphology-based interpretations place Hernandiaceae as sister to Lauraceae (Doyle & Endress, 2000). Genes for phylogenetic inference of Lauraceae are limited, with trnK, psbA–trnH, and ITS preferred, mainly due to their relatively
fast rates of evolution (Rohwer, 2000; Chanderbali et al., 2001; Li et al., 2004, 2006, 2007, 2008a; Rohwer & Rudolph 2005).

Molecular and morphological phylogenetic studies in the Laurales have found that Hernandiaceae, Lauraceae, and Monimiaceae sensu stricto form a monophyletic group. Other characters, such as phyllotaxy and anthotaxy, have also been adduced to support a sister group relationship between Lauraceae and Hernandiaceae, but these patterns are not straightforward (Renner & Chanderbali, 2000).

It was Rohwer (2000), who sequenced the larger part of the matK gene and the (3′−) adjacent spacer and used for phylogenetic analyses in 48 species of Lauraceae from all parts of their geographical range. The separation between taxa with involucrate and non-involucrate inflorescence is not supported by his studies. Chanderbali et al. (2001) found that Neocinnamomum was sister to Cassytha, with the pair placed between the Cryptocaryeae and a Chlorocardium-Meziolaurus clade with Caryodaphnopsis. The trnK gene has proved to be useful in inferring intergeneric relationships, especially for the basal part of Lauraceae, though few informative substitutions were detected within Laureae (Rohwer 2000; Rohwer & Rudolph 2005).

Phylogenetic studies within lauraceae using trnK intron sequences, suggest that Neocinnamomum was sister to Caryodaphnopsis, but with low support, and agreeing with Chanderbali et al. (2001) that the Neocinnamomum and Cassytha clade was the result of Long Branch Attraction (LBA). Another phylogenetic analysis of the genus Actinodaphne using sequences from the nrDNA (nuclear ribosomal DNA) internal transcribed spacer (ITS) and external transcribed spacer (ETS) regions revealed the genus Actinodaphne polyphyletic in origin (Li Zhi-Ming et al., 2006).

In addition Nuclear DNA ITS and ETS sequences studies were carried out on 71 representatives from nine genera and 11 sections of the core Laureae (Li et
The results of this study showed that the large genera *Actinodaphne* Nees, *Lindera* Thunb., and *Litsea* Lam. were polyphyletic. In contrast, *Neolitsea* (Benth.) Merr. were monophyletic and terminal in a larger monophyletic lineage above an *Actinodaphne* grade. These suggest that the use of two- versus four-celled anthers for Laureae generic delimitation has resulted in polyphyletic or paraphyletic genera, and the character of dimerous versus trimerous flowers is of only limited phylogenetic value.

Another study was to elucidate the relationship between *Litsea* and related genera by using cpDNA and nrITS, the rpb2 gene as a source of molecular information to better resolve the phylogenetic analysis (Izu & Murakami, 2009). They find out the genetic distance among copies from any one species was low, and these copies always formed monophyletic groups in our molecular trees. They too observed the monophyly of the genus *Litsea* is supported only for section *Litsea*. As a genus, *Litsea* was shown to be polyphyletic and the genera *Actinodaphne* and *Neolitsea* are recognized as monophyletic groups. *Cassytha* is clearly related to the core *Cryptocaryaeae* and *Caryodaphnopsis*, though still very different from these taxa and with its position still uncertain, probably due in part to the extreme morphological and genetic changes resulting from its hemiparasitic lifestyle (Wang et al., 2010).

Wang *et al.* (2010) investigated the phylogeny of the Southeast Asian endemic genus *Neocinnamomum* H. Liu and concluded that the origin of this genus was monophyletic. Lang Li *et al.*, (2011) studied the molecular phylogenetic analysis of the *Persea* group and its biogeographic implications on the evolution of tropical and subtropical Amphi-pacific disjunctions. Rohwer *et al.* (2014) investigated the phylogeny of the *Cryptocarya* group, and relationships of *Dahlgrenodendron* J.J.M. van der Merwe & A.E. van Wyk, *Sinopora*, *Triadodaphne* Kosterm., and *Yasunia* van der Werff.
3.8. Paleontology

In India the first fossil wood in the family lauraceae was recorded from Baratang, Andaman-Nicobar Islands. It was the carbonized wood fragment referable to the genus *Laurinoxylon* from flyschoid gritty sandstone (Palaeocene-Eocene) (Aswathi & Jafar, 1990).

The diverse fossil record of lauraceae begins in the cretaceous and includes flowers, fruits, leaves, and wood (Drinnan *et al*., 1990; Herendeen, 1991; Herendeen *et al*., 1994; Crane *et al*., 1994; Mickle, 1996; Eklund and Kvaček, 1998; Frumin *et al*., 2004). Numerous lauraceous fruits in the Cenozoic are assigned to extant genera, often based on cupule morphology alone (Mai, 1971), but these assignments are have been questioned because similar cupule morphology occurs in several genera (Kostermans, 1957; Rohwer, 1993; Pingen *et al*., 1994).

The lauraceous fruits were identified for the first time by Penner (1996) from the Middle Eocene Princeton Chert. They were observed more than 100 specimens at various developmental stages, and this developmental series reveals a sequence from isolated lauraceous flowers, post anthesis, (Sun & Stockey, 1991; Little & Stockey, 2006) to mature fruits. The fruits and cupular structures generally occur throughout the fossil record (Eklund, 2000; Mai, 2001), but few are known anatomically, with some exceptions (Drinnan *et al*., 1990). Stefan *et al.* (2009) investigated the development of fossil fruits of Lauraceae, made possible by the parautochthonously deposited, subcanopy litter of a self-pruning fruit tree.

3.9. Phytochemistry

The alkaloides like, sesquiterpenes, linderalactone, linderane, neolinderane, zeylanine, zeylanicin and zeylanidine were isolated from the roots of *Neolitsea*
zeylanica. (Joshi et al., 1967; Shwu-Li & Wen-Shyong, 1991). Gottlieb (1972) reported the advanced flavonoids from some other members of lauraceae such as Lindera. Brazilian Aniba is rich in flavanoids such as neolignans or 6-aryl (or 6-styryl-) 2-pyrones and 5,7,8,3',4',5'-hexamethoxyflavone (Sergio et al., 1982). Bohm, (1987) observed the more infraspecific flavanoid variation in the genus Cinnamomum.

According to Shylaja et al. (1992), infraspecific variability is more in C. malabatrum (Burm.f.) J. Presl complex. They also analyzed morphometric and chemical aspects and the results showed that the Indian and Ceylon C. verum are identical. Species from different ecological conditions shows variation in chemical compounds, but similar in flavanoid contents, flavanoides are present in all species of Cinnamomum. The most complex species is C. verum in chemical basis and least complex is C. nicolsonianum in south India. Several cinnamon species are distilled on a much smaller scale and the oils used either locally or exported (Anonymous, 1992). Mallavarapu et al., (1995) has identified 53 constituents along with the major component eugenol in Cinnamomum leaf oil. Sandigawad and Patil (2011) identified camphor, β-terpineol, heptanal, safrol, trans-cinnamaldehyde.

There are four chemotypes of C. sulphuratum such as linalool-type (Nath et al., 1994), citral and cinnamaldehyde-type (Baruah et al., 1999), methyl cinnamate-type (Baruah et al., 2001) and cinnamaldehyde-type (Baruah et al., 2002) have been reported from Northeast India. There are two chemotypes of Cinnamomum tamala in India, the eugenol type is found in north India and cinnamic aldehyde-type in eastern India (Nirmal Babu et al., 2003). A benzyl benzoate rich natural chemotype has been reported from the southern Western Ghats (Rameshkumar & George, 2006).

Cinnamomum shows anti-hyperglycaemic properties and potential to reduce postprandial blood glucose levels (Kirkham et al., 2009). Yoon et al. (2010)
studied the chemical constituents of *Neolitsea sericea* and isolated sericenine (32.3%), sabinene (21.0%), trans-beta-ocimene (13.3%), beta-caryophyllene (4.8%), and 4-terpineol (4.2%). Kumar *et al.* (2012), isolated methyl eugenol, cinnamaldehyde, trans-cinnamyl acetate from *Cinnamomum tamala* leaves.

Andrea *et al.* (2010) reported the occurrence of flavonoids such as, 4-O-E-caffeoylquinic acid, an aromatic sesquiterpene besides furofuran lignans from *Ocotea corymbosa* (Meins) Mez., *O. elegans* Mez. and non-volatile compounds from *Persea pyrifolia*. The essential oil extracted from *Neolitsea aciculata* is an attractive candidate as an ingredient in skin care products (Kim *et al.*, 2011). *Litsea* spp. are rich in terpenoids, fatty acids, alkaloids, and flavonoids (Gottlieb 1972; Yan *et al.*, 2000). In Mexican *Litsea* spp. flavanoides *viz.*, 1,8-cineole, linalool, α-pinene, β-pinene, m-cymene, terpinen-4-ol, α-terpineol, caryophyllene, and caryophyllene oxide were isolated (Jiménez-Pérez *et al.*, 2011). The essential oil from the bark of *Cinnamomum zeylanicum* Blume are (E)-cinnamaldehyde (68.95%), benzaldehyde (9.94%) and (E)-cinnamyl acetate (7.44%) (Unlu *et al.*, 2010). The bark and fruits of *C. zeylanicum* were found to contain proanthocyanidins with doubly linked bis-flavan-3-ol units in the molecule and trans-cinnamyl acetate in fruits, flowers, and fruit stalks (Jayaprakasha & Rao, 2011).

Jiménez-Pérez *et al.* (2011) had reported the occurrence of essential oils in *L. mielleri*, *L. parvifolia*, *L. pringlei* and *L. schaffneri* and observed the terpenoids *viz.*, 1,8-cineole, linalool, α-pinene, β-pinene, m-cymene, terpinen-4-ol, α-terpineol, caryophyllene and caryophyllene oxide.

The methanol extract of the bark of *Machilus odoratissima* revealed compound like terpenoids, tannins, deoxy sugar, saponins and phenolic compounds (Amit *et al.* 2012). The chemical constituents of *Cinnamomum sulphuratum* are β-phellandrene (6.64%), α-phellandrene (6.32%), linalool (4.53%), 1,1-dicyclopropyly-2-methyl-1-pentene (3.35%) and Z-β-oicimene (2.53%) (Nath &
Baruah, 1994). Sunil Kumar et al., (2013) reported the presence of β-phellandrene and 1,1-dicyclopentyl-2-methyl-1-pentene for the first time from the leaves of *C. sulphuratum* growing in Kodagu, Karnataka. The chemical profile demarcated would be helpful to differentiate *C. sulphuratum* from other related species, there are 8 compounds reported from *C. sulphuratum*. Saravanan et al. (2013) had investigated the GC-MS Analysis of Phytocomponents if the leaves of *Actinodaphne madraspatana* and isolated compounds like sesquiterpene lactone, triterpene, steroid and fatty acid ester.

### 3.10. Pharmacology

The leaves have been reported to possess anti-inflammatory and antifungal activities (Prusky, 1991; Adeyemi, 2002). The active constituents of *Cinnamomum keralaense* were anthraquinone, cardiac glycosides, cyanogenic glycosides, flavonoids, reducing and non-reducing sugars and saponins recognized to having anti-inflammatory effects of carrageenan-induced paw edema in rats (Maridass & Ghanthi Kumar, 2008).

Methanol and hexane extracts of *Persea americana* shows higher antimicrobial activity against strains H37Ra and H37Rv (Gomez-Flores et al., 2008). The essential oil from *Neolitsea sericea* leaves are proved useful for treatment of inflammatory diseases (Yoon et al., 2010). Analysis on the methanolic extracts of bark of *Litsea grandis* proved to be antioxidant in its activity (Chin et al., 2010). The antioxidant, antibacterial and anti-inflammatory, anticancerous activities of *Neolitsea aciculata* essential oil has been recorded by Kim et al. (2011). The strong antimicrobial, anti-carcinogenic properties of the essential oil of *Cinnamomum zeylanicum* bark, indicating the possibilities to treatment of infections and neoplasms (Unlu et al. 2010). The methanol extract of *Machilus odoratissima* shows antibacterial activity (Amit et al. 2012). Maridass (2013) examined the ethanolic extract of *Cinnamomum wightii* and identified
that the antibacterial activity of *C. wightii* leaves were active against *Staphylococcus aureus, Escherichia coli*, and *Pseudomonas aeruginosa* and the antidiuretic activity of the leaves were significant.


### 3.11. Diseases

Studies during 1940 reported that nymphs and adults of *Pauropsyila depressa* Crawford (Homoptera: Triozidae) produced galls on leaves and shoots of cinnamon in India for the first time (Ayyar, 1940). Subsequent empirical study on plant galls reported various types of plant galls *viz.*, globose or irregular swellings of the inflorescence axis, pit gall, pouch or epiphyllus, hypophyllus, biconvex green, conical and rugose pouch gall on the various species are
Cinnamomum zeylanicum, C. camphora, C. nitidum, C. macrocarpum, Machilus gamblei, M. macrantha, M. odoratissima, Phoebe lanceolata, Lindera assamica, L. pulcherrima, Litsea polyantha, L. glabrata, L. ligustrina, Neolitsea zeylanica, Beilschmiedia sikkimensis (Mani, 1965). In addition this study also prepared a dichotomous key for the identification of the plant galls.

Rajapakse and Kulasekera (1982) have listed the pest fauna associated with cinnamon in Sri Lanka for the first time in Sri Lanka. Devashayam et al. (1997) reported that the major insect pests of cinnamon, which include cinnamon butterfly Chilasa ciyua and leaf miner Conopomorpha civica in India. Fox et al. (2008) observed the Cinnamomum camphora (Camphor-Tree) has a root rot, especially in poorly-drained soils. Rajeev and Dinesh (2005) reported the leaf spot and die back disease (Colletotrichum gloeosporioides), seedling blight caused by Diplodia sp. and Grey blight caused by Pestalotia palmarum. They also recognized the attack of leaf miner infestation by the Conopomorpha civica and cinnamon butterfly (Chilasa clytia), a most serious pest in younger plantations of Cinnamomum verum.

Anonymous (2013) reported the occurrence of White Root disease in cinnamon, caused by a fungus known as Fomes naxis. White colour fungal mycelia growths can be observed on roots of infected plants. Other minor diseases are leaf blight, Black powdery mildew algae growth on leaves. They also recognized the attack of Pink Stem Borer (Ichneumoniptera cf. xanthosoma). Rough bark disease is the most common disease of cinnamon which affects on young bark of immature shoots as brown spots and spread gradually throughout the bark. Leaves of the infested plants show chlorosis.

3.12. Germination

It is observed that seeds of laurels germinates best in almost pure sand and occurs in (spring) September and October (Kostermans, 1957) and the
cryptocotylar mode of germination is regarded as advanced (Sporne, 1969). Empirical examination of the seedling morphology of Cassytha filiformis identified that the seeds show 2 months of seed dormancy, the ripened fruits were snow-white in color (Augustine, 2004). The seeds Ocotea pulchella do not exhibit dormancy, they are non photoblastic, and a loss of viability in dry stored seeds can be related to a decrease in water content of the seed. The presence of the pulp and the flooded substratum influenced negatively the germination of seeds tested in the laboratory. The germinability of seeds in the understorey, both in wet and dry soil, was higher than in gap (Pires et al., 2009).

3.13. Micropropagation

Somatic embryogenesis has reported in C. camphora by Ravishankar and Jagadish, (1987) and also has reported tissue culture works of Cinnamomum verum and C. cassia. A multiple shoot induction and in vitro rooting was done by Huang et al., (1998). Rajeev and Dinesh (2005) was successful in the semi hardwood cuttings of Cinnamomum verum treated with rooting hormone IBA 2000 ppm and also practiced the air layering method by the help of IBA 2000 ppm or IAA 2000 ppm.

Deb et al. (2013) made a successful attempt for callus mediated plant regeneration of the species from leaf and zygotic embryos. The cultured foliar explants developed callus on MS medium fortified with sucrose (3%, w/v), PVP (100 mg l-1) and BA + NAA (6 and 3 μM respectively in combination) where ~28% explants responded positively. The cultured immature embryo of 12 week after flowering developed callus on MS medium conjunct with sucrose (3%), PVP (100 mg l-1) and NAA + BA (6 and 2 μM respectively in combination) where 55% cultured embryos resulted into callus. The meristematic loci and shoot buds developed from the resultant calli subsequently on the respectively initiation medium.
3.14. Evolution

The genus *Persea* Miller has arisen from woody magnolian forebears and represents a terminal group which is specialized by reduction and fusion and from which no extant plant taxa have since evolved. With the Annonaceae, Magnoliaceae, and Proteaceae, it ranks among the oldest recorded flowering plants. *Persea indica* (L.) Spreng., a naturally surviving Gondwanaland species, also present in the Laurasian Neogene, differs from the other tested species of subgenus Eriodaphne by its quantitatively extremely low monoterpenene profile (Rainer & Bob, 1992).

Gottlieb (1972) has reviewed Perseineae with the Beilschmiediineae (frequent companions in the fossil record) as very old based on the presence of alkaloid, arylpropanoid, flavanoid and terpenoid constituents. The family is very old indeed. *Persea* was part of the African Gondwanaland flora in paleocene times; from there its taxa migrated to Asia. When North and South America joined in the late Neogene, the genus was united again. Other species migrated to southwestern Europe, and from there to North America when Eurasia and North America were in direct contact into the late cretaceous (Tarling, 1971).

It’s present disjunct distribution in the Neotropics and in Southeast Asia is due to extinction in Europe and Africa, with only *Persea indica* surviving as endemic in the laurel forests of the north coast of the Canary Islands. Madagascar is the principal refuges for the remnants of the formerly far more widespread African laurel forest taxa (Raven & Axelrod, 1974).