2. REVIEW OF LITERATURE

Biosystematics is an experimental taxonomic study of organisms from the standpoint of evolutionary processes which occur within the population (Stace, 1989). It is largely concerned with morphological, anatomical, genetical, cytological, chemical and palynological aspects. Biosystematics is considered as the taxonomical application of these experimental disciplines. Biosystematics although difficult to define precisely, is the consideration of the natural relationships among taxa. It includes the description, naming and classification of organisms together with studies of their evolution and phylogeny.

The application of phytomorphological, anatomical, epidermal, palynological, cytological and biochemical studies in biosystematics can better be appreciated from the review works done in plant species by various researchers. Some of which are on morphology, diversity and developmental aspects of floral parts, leaf epidermis, stomata and trichomes. Parameters such as external morphology, shape of epidermal cell wall, stomatal index, stomatal aperture, trichome type, nature of trichome, nature and structure of pollen grains, number of chromosomes and presence of alkaloids were used by various authors in their biosystematic studies. Some of the studies related to morphology, epidermal, palynology, cytology and biochemical aspects of the genera *Solanum* are given below.

Bentham and Hooker (1873) based on morphometric analysis classified the series bicarpellatae into four cohorts such as Gentianales, Polemoniales, Personales and Lamiales. They again classified Personales into five families such as Polemoniaceae,
Hydrophyllaceae, Boraginaceae, Convolvulaceae and Solanaceae. Hutchinson (1969) has splitted the order Tubiflorae into a number of smaller groups. He has placed the families Solanaceae and Convolvulaceae in the order Solanales.

Singh *et al.*, (1978) described leaf architecture in Berberidaceae and discussed bearing of the circumstances of the family. They concluded that in leaf architecture of *Holboellia* and *Podophyllum* stand apart from other taxa of the family and this support their view of removal to a separate family. Foster (1959) suggested that open dichotomous venation of the ranalian genus *Kingdonia* may be primitive within angiosperms. The minor venation pattern in certain species of Compositae provides taxonomic and evolutionary clues (Carlquist, 1959). He also described the foliar venation pattern in the Rutaceae and devices a key for the identification of various species on the basis of these characters.

Hickey and Wolfe (1975) provided the first systematic summary of dicot leaf architectural features and they demonstrated that a number of lower order leaf architectural features, including leaf organization, configuration of first three vein orders and characteristics of leaf margin are significant systematic indicators within dicotyledons. Levin (1929) emphasized the taxonomic value of veinlet areas. He pointed out that veinlet number is nearly constant for a species and it can be used as a valuable character. Carlquist (1959) reported that minor venation pattern in certain species of Compositae provides taxonomic and evolutionary clues.

Banerji and Das (1972) have shown that minor venation pattern is useful in the distinction of the Indian species of *Acer*. The size of areoles, number of terminations per
areole and characteristics of branches provide useful taxonomic characters. Hickey (1973) published the most comprehensive system of descriptive terminology of leaf form and venation pattern of dicotyledonous leaf. Data obtained from leaf architectural features, particularly venation pattern have been successfully utilized for systematic and evolutionary considerations. Gupta (1961) could not establish any direct correlation between the size of areole and number of vein endings in the family Euphorbiaceae. They divided the genus *Euphorbia* on the basis of venation pattern and grouped it into various species. According to him veinlet number and veinlet termination number are inversely proportional to the area of lamina and their absolute numbers are constant for a species.

Hall and Melville (1951) pointed out that the number of veinlets in conjunction with other histological characters could be used as taxonomic criteria. The use of architectural pattern is gaining significance in phylogeny and classification of angiosperm. The leaves of various dicotyledonous taxa of angiosperms possess consistent and recognizable patterns of architectural organizations. In recent years these characters have been successfully used by several workers in the diagnosis of fossil as well as living material (Dilcher, 1974).

The shape of the epidermal cell provides useful confirmatory evidence, if the identity of a leaf is already suspected. Epidermal cells differ considerably in size, shape and outline in different plants, but external factors such as light intensity and atmospheric humidity often have a marked effect on those features (Metcalfe and Chalk, 1950). Sclerification of the walls of epidermal cells is a feature of taxonomic importance in the
tribe Mustisieae of Compositae (Carlquist, 1958) and extremely narrow cells are characteristic of the epidermis of Stylidiaceae (Mildbraed, 1908).

There are two types of stomata in Solanaceae. They are Anisocytic and Anomocytic. In 1975, Ahmad studied cuticular structure in some species of the family. Stomata are usually evenly distributed in the epidermis of leaves.

Ahmad (1974) studied the leaf epidermal structure in the species of Strobilanthes and Petaldium. Comparative studies showed that there was much similarity and significant differences in their epidermal characters. He has shown that epidermal characters of different species of Hemigraphis and Strobilanthes are sufficiently pronounced as to justify their use in making distinctions at specific level. He studied the cuticular and epidermal structures in six species of Eranthemum and Pseuderanthemum. In 1975, Ahmad studied cuticular structure in some species of Lepidagathis and Barleria. In 1976, Ahmad studied the foliar epidermis and cuticle of five species of Hygrophila and three species of Dyschoriste.

Vesque (1889) proposed the first classification of stomata and he recognized four morphological types, named after the families in which they were first observed. Later Metcalfe and Chalk (1950) also classified the stomata on the same plant with some modifications in terminology. Stebbins and Kush (1961) suggested that the stomata with many subsidiary cells are most primitive. Stomatal abnormalities are of great diagnostic value in Solanaceae. Stomatal frequency, stomatal index, position of stomata and other epidermal features have been emphasized upon as of significant value not only in classification and phylogeny, but also in segregating various cytotypes as evidenced by the work of Solereder (1908); Paliwal (1966); Inamdar and Patel (1969), Van cothem

Tognini (1987); Pant and Banerji (1965); Shah (1967) Stace (1984) and Patel and Inamdar (1971) has identified the diversity of stomata on the same surface in the Convolvulaceae. On the basis of their stomatal study, it is suggested that epidermal characters such as stomatal types, nature of the epidermal cell, average size of stomata and guard cells can be of definite value in supplementing the conclusion based on external morphology. Takhtajan (1966 and 1980); Frynsclassens and Van cotthem (1973); Cronquist (1988) and Guyot, (1971) in their study reported that the primitive nature of paracytic stomata in angiosperm has been useful in several systematic studies. Based on the uniform occurrence of paracytic stomata in the Magnoliales, Baranova (1972 and 1992) has advocated the paracytic type as primitive among the angiosperm from which other types of stomata have evolved. Metcalfe and Chalk (1950) studied a general account of stomata in the family Cucurbitaceae.

Vancotthem (1970) proposed an elaborate classification based on the number and position of subsidiary cells and its ontogeny. Stomata along with other epidermal features have been employed in the identification of fragmentary materials in the pharmacognosical studies (Krishnamurthy and Kannabiran 1970). In their studies on the cuticular morphology of certain species of Ludwigia (Onagraceae), Pant (1932) has shown the utility of stomata in the systematics of Gramineae. Stebbins and Kush (1961) suggested that, the stomata with many subsidiary cells are the most primitive. The other types with minimum number of subsidiary cells, distribution, size and frequency of stomata have been reported to be specific for a species (Miller 1938) and hence these
characters are potential tools in taxonomy and phylogeny (Ahmad 1979 and Rajagopal 1979). The pattern of stomatal structure and their distribution is an important criterion in Epacridaceae (Watson, 1962).

Solereder (1908); Paliwal, (1966); Vancotthem (1970) and Bir et al., (1979) in their studies revealed that the stomatal index, frequency, ontogeny and position of stomata as also the various epidermal features have been emphasized that of significant value not only in classification and phylogeny, but also in segregating various cytotypes. Rao and Ramayya (1977) investigated the stomatal distribution in the vegetative and floral parts of ten species of *Hibiscus*. This was followed by a more comprehensive study on the distribution of stomata in relation to plant habit in the order Malvales by Rao and Ramayya (1981) in which the distribution of stomata in the stipules and leaves of *H. rosasinensis* were reported to be amphistomatic. Edeoga and Amayo (2001) observed that the distribution of stomata could be used to establish taxonomic decision and suggest close relationship within the genus *Ludwigia*. Solereder (1908) emphasized that trichomes can be used to distinguish taxonomic groups up to species level. It has been suggested by several investigators that the trichomes can be utilized as an effective taxonomic tool to distinguish between genera and species (Bachman 1886; Cooper 1932; Bremekemp 1938; Inamdar 1967; King and Robinson 1970). Trichomes form an excellent criterion on sub generic and species levels in Rhododendron (Cowan 1950; MetCalf & Chalk 1957). Goodspeed (1954) has reported that types of trichomes and their distribution are correlated with subgeneric and specific distinction in *Nicotiana*. On the basis of the structure and ontogeny of trichomes, Inamdar (1967) confirms the position of *Nyctanthes* in Oleaceae.
Various workers like Metcalfe and Chalk (1950); Rendle (1959); Carlquist (1961); Bates (1967); Rao and Ramayya (1976) and Inamdar and Chauhan (1969) have reported stellate and tufted hairs or glandular and non glandular hairs in the family Malvaceae. Rao and Ramayya (1977 b) studied the organographic distribution of sixteen trichome types in the Indian species of Malvastrum. They also observed that stellate trichomes are characteristic of the order Malvales, other forms like tufted hairs, small scales, simple bristles and glandular hairs were also observed in addition to this in this family Malvaceae by many taxonomists (Metcalfe and Chalk, 1950; Rendle, 1959; Bates, 1967; Rao and Ramayya, 1976). 

Trichomes are one of the most important characters in taxonomy at the level of genus and species level. The study of trichome micro-morphology permits a better understanding of the relationship between species. In most cases character combinations could easily be used as a means of taxonomic identification at different intrageneric level as evidenced by the work of Cowan (1950); Carlquist (1958); Tomilinson (1969); Carolin (1971); Ellis (1976); Werker (2000); Carolin (1971); Navarro and Eloulidi (2000); Dickison (2000).

According to Maffei et al., (1989); Werker et al., (1993 and 2000); Perez Estrada et al., (2000) in many plant species, trichome density is very high in young leaves but decreases rapidly with leaf expansion. At later stages of leaf development, when the formation of the epidermis is completed, the functional role of the trichomes become less important and they often senescence and shed. In some cases, however, trichomes remain viable and functional in mature leaves. According to Navarro and Eloualidi (2000), trichome micromorphology permits a better understanding of the
relationship between species and genus. On the basis of a detailed study of the
morphology and ontogeny of trichomes in the tribe Heliantheae (Asteraceae),
Ramayya (1969) finds support to the views that this is the most primitive tribe of
Asteraceae.

Metcalfe and Chalk (1950) suggested that the shape of the epidermal cell provide
useful confirmatory evidence, if the identity of a leaf is already suspected. Epidermal
cells differ considerably in size, shape and outline in different plants, but external factors
such as light intensity and atmospheric humidity often have a marked effect on these
features. The thickness, shape of epidermal cells and characteristics of their wall provided
useful taxonomic criteria. Sclerification of the wall of epidermal cells is an important
feature of taxonomic importance in the tribe mutisieae of compositae (Carlquist, 1958)
and extremely narrow cells are characteristic of the epidermis of Stylidiaceae. Stomata
are usually evenly distributed in the epidermis of leaves, however, they have been
reported as clustered in discrete groups in the leaves in representatives of dicot families
(Metcalfe and Chalk, 1979).

The size and shape of pollen, number and position of furrows, number and
position of apertures and the details of sculpturing of the exine are of taxonomic value.
The form, number distribution and position of apertures are important palynological
criteria in assessing the relationships and phylogeny of plants. According to the position,
the aperture may be proximal, distal or zonal. In terms of evolution, the proximal position
is most primitive and zonal position as most advanced (Anderson and Gensel, 1976).
According to Walker and Doyle, (1975), pollen characters are of taxonomic and phylogenetic importance. The germinaperture character forms the stable fundamental basis and are primary importance in the interpretation of interrelations, while exine surface pattern is secondary and the other characters such as pollen size and shape are tertiary in the degree of significance (Erdtman, 1952; Erdtman, 1969; Nair, 1965 a; Walker, 1976a; Walker and Doyle, 1975). The aperture characters refer to their form, number and distribution and to a lesser extent the position. The show variation in different plants at various taxonomic levels so as to be of use in the identification of several species and sometimes even varieties. The exine surface pattern serves as supplementary character for reaching taxonomic and phylogenetic conclusions (Erdtman, 1952; Nair, 1970; Walker, 1974b). Features of exine ornamentation are particularly useful in stenopalynous taxa, while the tertiary characters such as exine strata, pollen size, and shape are insignificant characters in applied taxonomy.

The taxonomic value of pollen size has been reported in some varieties of cereals like Sorghum vulgare and Zea mays by Nair, (1962) and in three cultivated varieties of Triticum aestivum by Sharma and Chatterji, (1957). Grain size as an index to ploidy level emergence of plant dioecism had been shown in Trichosanthes palmata. Erdtman, (1952) pointed out that a pollen survey of the sub-family Lamiaceae is essential for the better understanding of systematic relationships. On the basis of pollen morphology the family Lamiaceae has been divided into two sub families, the Lamioideae with tricolpate pollen grains and the Nepetoideae with hexacolpate pollen grains. Detailed pollen morphological studies have been undertaken in various tribes of the family Lamiaceae by Abu Asab and Cantino, (1993).
Govil, (1980) studied the embryology and seed coat development in Convolvulaceae and Cuscutaceae, in order to discuss the taxonomic position of Cuscutaceae, which was once a part of Convolvulaceae. The two families are characterized in having five epipetalous, dithecous, introrse stamens with 3-4 layered anther walls. The development of anther wall is dicotyledonous types in both the cases. Tapetum is archesporial in origin and multinucleate. However, the pollen in Cuscutaceae is smooth walled zonocolpate. According to Sampathkumar and Rangaswami Ayyangar (1980) the Solanaceae pollen is colpate, rugulate and psilate. The embryological and seed coat characters support the separation of Cuscuta into the family Cuscutaceae (Govil, 1980).

The pollen grains of several species of Solanum have been studied by Erdtman (1952) and Nair (1965). Nair (1965) reported the variation in the size of pollen in the species of Solanum and suggested that the pollen grain of S. macranthum are larger, when compared to other species of Solanum.

Life is sustained in all living organisms through the metabolism of universally distributed primary biochemicals like nucleic acid, carbohydrates, amino acids, coenzymes etc. Ayurveda has identified many medicinal properties in plants belonging to several families including Solanaceae against nosebleed and high blood pressure (Alexander and Banes 1961; Agurell and Ramstad 1962; Bush, Wilkinson and Schardl, 1997). In addition, reactions which often differ from species to species and may be considered as an expression of the chemical individuality of the organism is grouped under the term secondary metabolism and the products formed are termed as secondary metabolites or products. These secondary products though not essential for the survival
of the individual cell fulfill an important and even essential role in the life and survival of organism as a whole (Groeger and Floss, 1998; Keller and Tudzynski, 2002). Though metabolism has been grouped into primary and secondary, due to its restricted distribution, it is considered as a secondary constituent yet it is an important storage of energy involved in primary metabolism (Rehacek and Sajdl, 1990). Secondary metabolic pathways are interrelated with the pathways of primary metabolism.

Some primary metabolites provide the starting material for secondary metabolites. These primary pathways, either singly or in combination give to the major class of secondary metabolites such as terpenoids, phenols, alkaloids etc. Secondary metabolites are broadly classified into terpenoids, alkaloids and phenolics. They have a key role in protecting the plant from environmental pressures (Taber, Vining and Heacok, 1963). They also have an indirect effect on plant growth by mediating in the regulation of hormone synthesis as in the cases of phenolic compounds (Tudzynski et. al., 2001). Biochemical aspect differ from species to species and may be considered as an expression of the chemical individuality of the organism is grouped under the term secondary metabolism and the products formed are termed as secondary metabolites (Keller et. al., 2002). Secondary metabolic pathways are interrelated with the pathways of primary metabolism. Some primary metabolites provide the starting material for secondary metabolites. These primary pathways either singly or in combination give to the major class of secondary metabolites. Biochemical characters such as presence of alkaloid and quantity of protein and carbohydrate act as a remarkable marker for the identification of genera and species (Lowry et. al., 1951).
Presence of a specific alkaloid also very helpful in the identification of plant species. Plants by their nature are unable to run away from their predators. Consequently, they have evolved a large battery of toxic chemicals. Many of these chemicals are useful as drugs, because in smaller doses, they have useful pharmacological aspects. Many of the alkaloid toxins can be used as drugs. About a quarter of all the pharmaceutical chemicals sold in market are derivatives of chemicals found in plants. Natural products remains one of the main means of discovering bioactive compounds. Several recent reviews have provided data to document the importance of natural products as a source of bioactive compounds.

Plants have a strong biological and ecological rationable to produce these compounds. This is probably related in large measure to the fact that, they defend themselves by killing predators like insects, microorganisms or even other plants. Plants have thus evolved a complex chemical defense system and this can involve the production of a large number of chemically diverse compounds. A major advantage of the natural products approach to drug discovery is that is capable of providing complex molecules that would not be accessible by other routes also it can provide good quantity of drugs for our drug design. Alkaloids are one of the most important natural products in plants. The alkaloids are organic nitrogenous bases not only found in plants, but also to a lesser extend in microorganisms and animals. In plants alkaloids act as poisonous and stimulating agents. They also act as regulatory growth factors and reserve substances for nitrogen and other elemental supply and as end products of detoxification reactions.

The alkaloids may have a role in the defence of the plant against single oxygen, which is damaging to all living organisms and is produced in plant tissues in the presence
of light (Mohammed Ali, 2009). Chemical studies have shown the presence of various classes of compounds, such as triterpenoids, flavonoids, steroids and lipids (Pan et. al., 2011). The phytochemical analysis of several medicinal plants revealed that the presence of tannin, alkaloids, saponins, glycosides, terpenes, flavonoids and phenols (Rajurkar and Kunda, 2012). Bioactive polyphenols have attracted special attention, because they can protect the human body from the oxidative stress, which may cause diseases, including cancer, cardiovascular problems and ageing (Robards et. al., 1999). Flavonoids have been reported to possess many useful properties, including anti-inflammatory, enzyme inhibition, antimicrobial, antiallergic, antioxidant and antitumour activity (Harborne and Williams, 2000).

Primarily phenolic compounds are of great importance as cellular support material because, they form the integral part of cell structure by polymeric phenolics (Gupta et. al., 2010). Saponins have been extensively used as detergents, as pesticides, in addition to their industrial applications as foaming and surface active agents and also have beneficial health effects (Shi et. al., 2004). Tannin contribute the property of fasten the healing of wounds (Okwu and Josiah, 2006). Alkaloids are produced by large variety of organisms including bacteria, fungi, plants and animals. Some alkaloids have a bitter taste and others are toxic to other organisms (Gupta et. al., 2010). Steroid compounds are important in pharmacy due to their relationship with sex hormones (Santhi et. al., 2011). Knowledge of phytochemical constituents of plants is desirable, not only for the discovery of therapeutic agents, but also because such information may be of value in disclosing new sources of economic materials such as tannins, oils, gums, flavonoids, saponins, essential oils etc. (Akrout et. al., 2010).
Phytochemical constituents are secondary metabolites of plants that serve a defense mechanism against prediction by many microorganisms, insects and other herbivores (Bonjar et. al., 2004). The most common biological properties of alkaloids is their toxicity against cells of foreign organism and this property has led to the development of powerful pain killer medications (Kam and Liew, 2002). Flavonoids are hydroxylated phenolic substance known to be synthesized by plants in response to microbial infection. Tannins form an irreversible complex with proline rich proteins resulting in the inhibition of cell protein synthesis (Shimada, 2006). Phenolic compounds have also been known as antioxidant agents, which act as free radical terminators and have shown medicinal activity as well as exhibiting physiological functions (Omale and Okafor, 2007). The phenolic compounds of plants are known to have beneficial skin care effects such as the prevention of UV-induced skin damage (Svobodova et. al., 2003; Tanaka et. al., 2004). Plant steroids are known to be important for their cardiotonic activities and also possess insecticidal and antimicrobial properties. They are also used in nutrition herbal medicine and cosmetics.

Saponins are considered as a key ingredient in traditional Chinese medicine and are responsible for most of the biological effects. Saponins are known to produce inhibitory effect on inflammation. Saponin is used as mild detergents and in intracellular histochemical staining. In medicine, it is used as antioxidant, anticancer, antifungal, anti-inflammatory and hyperglycaemia. Saponin possesses specific physical, chemical and biological activities that make them useful as drugs. Some of these biological properties include anti-microbial, anti-inflammatory and hemolytic effects (Xu et. al., 1996; George et. al., 2002).