SOURCES OF DATA FOR SYSTEMATICS

INTRODUCTION

The principal aim of systematics is to provide a system of classification based on evolutionary relationships. The natural systems take into account external vegetative and reproductive exomorphic characters. But Phylogenetic systems take into account most of the characters of the plant. Plant taxonomy is most synthetic approach and it is very essential to have comprehensive knowledge of concerned taxa from various aspects and various branches of Botany from morphology to molecular biology, from chemistry to cytological aspects of the plants and modern taxonomy takes advantage of computer based studies to solve typical problems of taxonomy.

Plant taxonomy deals with the classification or systematic study of plants on the basis of morphological, anatomical, floral and evolutionary characters. But these Characters have some limitations, therefore, it is necessary to use more and more detailed characters from different sources like morphology, anatomy, cytology, embryology, phytochemistry, molecular biology etc. These sources of data for plant systematic helps in solving various taxonomic problems. Maximum characters plays an significant role in the plant systematics.

MORPHOLOGY AND SYSTEMATICS

Morphological characters of plants have been commonly used for plant classification and for diagnostic purposes. These characters have provided the foundation and framework for taxonomy. The comparative external morphological characters is indispensable tool for systematics. Morphology is excellent source for systematics because-

1) They are easily observable direct evidences, innumerable variants, they help in delimitation and identification.
2) To analyze morphological characters by lenses, dissection or cpmpound microscopes is enough to confirm morphological details.
3) There is well developed terminology in morphology and time required to confirm taxonomic details is easy.

4) It is well known fact that plants have huge details and diversity in morphology. e.g.

1) Habit : It is concerns such features as size, branching, spread, density, rooting system, means of propagation.

i) Characters of bark such as colour, texture, thickness etc. are commonly used in the identification of ***Pinus*** and ***Betula.***

ii) Plants are classified on the basis of habit into herbs, shrubs and trees.

2) Underground parts : It also provide valuable taxonomic characters.

i) The form of the root structure is commonly used in the taxonomy of the genus ***Rananculus.***

ii) The shape of the main root either globose, ovoid, elongated, cylindrical or fusiform is used the identification of species of ***Aristolochia***.

iii) The rhizome character is good source for identification of various species of genus **Iris**.

iv) Bulb structure is an important taxonomic criterion in the genus **Allium**.

3) Leaf characters :

i) Leaf characters extensively employed for the recognition of species in many genera such as ***Almus*** and ***Betula.***

ii) The species of ***Dalbergia, D. latifolia, D.sissoo*** and ***D. nimmo*** can be easily distinguished by their leaflet size, shape and arrangement on the rachis.

iii) Stipular morphological character used for classifying species of ***Trifolium*** and ***Viola.***

iv) Leaf venation is more carefully studied by a palaeobotanist and used in the description of the fossils as well as in identification of **Olmus** and **Tilia**.

v) The character of leaf is important in the identification of various palms, **Salix** and **Populus**.

4) Reproductive sources :

i) Inflorescence is prominent features useful in the classification and identification of plants. Basically there are two types of inflorescence i.e. racemose and cymose and also having some special type of inflorescence which is found in some group of plants e.g. **verticillaster** (Lamiaceae), **hypanthodium** (Moraceae), **cyathium** (Euphobiaceae), **spike** (Amaryllidaceae).

ii) The characteristics of floral disc and nectaries are an diagnostic feature in ***Tamarix*** and **Brassicaceae**.

iii) The characteristics of bracts and their shape clearly distinguishes species of the **Convolvulaceae**.

iv) In some families presence of calyx modification are important feature. e.g. **persistent calyx** (Solanaceae), **pappus calyx** (Asteraceae), **petaloid calyx** (Rubiaceae and Caesalpiniaceae).

v) Corolla is an significant character for plant identification, **infundibulliform** (Solanaceae), **bilabiate** (Lamiaceae), **cruciform** (Brassicaceae), **papilionaceous** (Papilionaceae).

vi) The genus ***Eucalyptus*** has been classified on the basis of anther characters.

vii) Adhesion and cohesion of stamen are important source of taxonomic study e.g. epipetalous stamen in gamopetalae (***Datura***) presence of **gynostegium and staminal corona** in Asclepidiaceae, gynobasic style in Lamiaceae.

viii) Generally fruits are classified into three groups i.e. simple, aggregate and composite and they are important in plant identification.

ix) The external characters of seeds are of great value in separating closely related genera and species. Marking of testa have been commonly used in classification of ***Chenopodium, Euphorbia*** and ***Hypericum*****.**

x) The morphology of fruit helps in identification of Indian genera of compositae. The shape of cypsela, presence or absence of pappus and whether the pappus is represented by hairs scales or bristles, the presence or absence of beak and its length, the number of ribs on cypsells are important characters in identification.

ANATOMY AND SYSTEMATICS

Anatomy is the study of internal characters of plants. Anatomical characters are most important for the identification of plant. Since last few decades' diversified and extensive knowledge regarding structural details, behavior and cell types and tissues like xylem, phloem parenchyma and sclerenchyma, epidermal structure etc. provides important evidences with the help of light and electron microscope.

1) **Trichomes :**

Trichomes are the epidermal outgrowth on stem and leaf. The two major categories of trichomes are, glandular and non-glandular.

i) Trichomes are an excellent criterion on subgeneric and specific levels in **Rhododendron**. Trichome is useful character in the large genus **Astragalus** (with more than 2000 species)

ii) Occurrence of sessile glandular trichomes in **Typhaceae** and **Sperganiaceae** provides a link between these families.

iii) ***Parthenium argentatum***, the trichomes are T shaped whereas ***P. incanum*** they are whip like with long thread.

2) **Stomata :**

Stomatal morphology and spatial relationship to the neighbouring cells and number and arrangement of subsidiary cells are the main feature of stomata which is useful in plant systematics.

i) Dumbel shaped guard cells are characteristics of **grasses**.

ii) The ontogenetic studies of the stomata of **Curcurbitaceae** and **Caricaceae** suggest close affinity between these families.

iii) **Anomocytic** stomata in Ranunculaceae, **Anisocytic** stomata of Brassicaceae, **Diacytic** stomata in Caryophyllaceae, **Paracytic** stomata of Rubiaceae, **Graminaceous** stomata occur in family Poaceae are excellent characters in plant identification.

3) **Epidermis :**

The shape of the epidermal cells, thickness and characteristics of their wall, nature of sculpturing on their walls and inclusions of epidermal cells provide useful taxonomic criteria.

i) Division of epidermal cells and occurrence are also of some diagnostic value in certain families like **Poaceae.**

ii) Extremely narrow cells are characteristic of the epidermis of **Stylidiaceae**.

iii) On the basis of epidermal cells, structure of stomata and type of hairs the various species of ***Pyrus*** and ***Prunus*** are classified.

iv) Bladder like epidermal cells are characteristics of some families.

v) Details of silica body distribution on leaf also provide good taxonomic criteria in **Cyperaceae.**

4) **Leaf anatomy :**

i) The leaf anatomy is one of most reliable characters useful in **grass** systematic

ii) The distribution pattern of sclerenchyma in the leaves of ***Festuca*** is of great value in the separation of various species.

iii) Vascular structure of petiole is of much diagnostic significance in the genera ***Phlomis*** and ***Eremostachys*** (Labiatae).

5) **Stem anatomy :**

Internal structure of the primary stem may provide key role in many cases.

i) Stem endodermis shows much variation in the structure of their cells is an important criteria in families like **Piperaceae, Asteraceae** and **Lamiaceae**.

ii) Occurrence of bicollateral vascular bundles in two alternate rings is a characteristic of the stem of **Cucurbitaceae**.

iii) Conjoint, collateral and open type of vascular bundle occurs in dicot stem where as closed and scattered vascular bundle occurs in monocot stem.

iv) Tracheids and vessels in wood provide important characters in wood identification. Vessels are absent in gymnosperms but present in angiosperms. On the basis of wood anatomy amentiferae group is considered as advanced angiosperms and Gymnosperms order gnetales as ancestor of angiosperms.

CYTOLOGY AND SYSTEMATICS

Cytology has made an outstanding contribution to plant systematics. Cytological characters such as chromosome number, shape, size, behavior, and structure at meiosis and mitosis provides most significant data in the field of plant systematics.

1) **Chromosome number :**

i. Normally chromosome number is constant in a species, it is an important taxonomic character the lowest chromosome number is recorded in ***Haplopappus gracilis*** (2n = 4) and the highest in ***Poa litorosa*** (2n = 265). The **Ophioglossum** (Pteridophyte) has highest

chromosome number in the plant kingdom (2n=1240). In several plants, polyploidy is found in various members of a group. The basic number of chromosome in ***Piper*** is 2n = 26, ***P. nigrum*** 2n = 52, ***P. betle*** 2n = 78 and in wild species 2n = 104. Whereas the number is variable in different species to species.

ii. Monocotyledons usually have larger chromosome number than dicotyledons.

2) **Chromosome morphology :**

i) Chromosome are variable in form, size, volume and in the amount of hetero-chromatin.

ii) In general, woody plants have smaller chromosomes than in their herbaceous members. The individual chromosomes of some taxa show marked difference in shape and size at mitotic metaphase.

iii) The karyotype of different plant species differ mainly in their chromosome number, size, relative length of arms, position of centromere etc. All these characteristics have significant role in plant systematics.

iv) In addition to the position and size of the centromere, the karyotypes can be differentiated on the basis of secondary constrictions and satellites.

3) **Chromosome behaviour of meiosis :**

i) Valuable taxonomic information observed in the behavior of chromosome during the process of meiosis. Abnormalities in meiosis such as non pairing, chromosome size, crossing over, translocations, bridge formation etc. all are proved to be great significance.

ii) Close relationship between the members of family **Cyperaceae** and **Juncaceae** observed on the basis of chromosome with non-localised centromeres and have show inverted meiosis.

4) **Cytological variation at family level:**

Cytological evidence is of most important in interpreting a classification and establishing relationships.

1. Taxonomic value of cytological data varies from group to group, they provided logical basis for improved arrangement of tribes and genera in families like **Ranunculaceae** and **Poaceae**.
2. The major sub-divisions of the family **Gramineae** as recognized currently on the basis of number and size of the chromosome.
3. On the basis of 5 long and 25 short chromosomes, the genera ***Agave*** and ***Yucca*** were placed in the separate families in **Amaryllidaceae** and **Liliaceae.**

5) Cytological variation at generic level :

There are several examples where chromosome number supports generic status.

i) The genus ***Cystus*** was previously included in ***Helianthemum*** on the basis of former chromosome number 8 and latter 9 this support the recognition of **Cystus** as a separate genus.

ii) The two genera, ***Physaria*** and ***Lesquerella*** of the Brassicaceae were recognized as a single genus. On the basis of cytological evidence, these two genera should remain separated.

iii) A great deal of cytological variation occurs at specific and infra-specific level.

PHYTOCHEMISTRY AND SYSTEMATICS

Chemical features of the plant are used in developing classification or solving taxonomic problems is also called Chemotaxonomy. Data from chemistry of plant products is termed as phytochemistry. It is also called chemical systematics that takes into account chemical variations in the plant. This helps to improve existing systematics. It adds knowledge about phylogeny and evolutionary relationships of plants. Chemical characters are particularly of high taxonomic value when they are stable, unambiguous and not easily, if at all, changeable.

i) Chemical characters of plants have long been of practical value. For example, in the families **Umbelliferae** and **Labiatae**, a fragrant smell arise from crushed leaves and stem due to presence of essential oils is a quick means of identifying them.

ii) In the family **Asteraceae**, the two tribes **Tubiflorae** and **Liguliflorae** are classified on the basis of presence and absence of latex in them.

iii) Presence of various chemical compounds useful for taxonomic evidences. The various chemical compounds are most important in phytochemistry. For example, **Sesquiterpenoids** (Compositae), **Carotenoids** (Algae), **Cyanogenic compounds** (Ranunculaceae), **Free amino acids** (Leguminosae and Liliaceae), **Acetylenes** (Compositae and Umbelliferae) etc.

iv) There are a total of nearly 33 different groups of chemical compounds. Some of the important taxonomic sources are

1) Flavonoids :

These are largest group of naturally occurring phenolics and are most important in chemical systematics. Flavonoids present in cell sap various types of flavonoids like flavones, flavonones, isoflavones, flavonols, chalcones and biflavonyls etc help in taxonomy.

Flavonoids from vegetative parts and seeds provide more taxonomic evidence. The presence of leucoanthocyanin is occur in woody habits.

2) Amino acids :

The presence or absence of free amino acids and their quality and quantity are of great importance in chemical systematic.

Distribution of non-protein amino acids is significant in the family **Leguminosae**. In the genus ***Acacia***, the section **Gummiferae** has an unique amino acid content.

3) Alkaloids :

These are groups of heterogenous and highly complex organic nitrogen containing basic chemical compounds. Alkaloids are commonly occurs in plant families specially from **dicotyledons**. Abundant alkaloid content observed in the families like **Berbridaceae, Ranunculaceae, Legumonosiae** and **Solanaceae.** e.g Nicotine in Solanaceae, ephedrine in Ephedraceae (Gymnosperms), Morphine in Papaveraceae (i.e. **Papaver**) etc. The study of alkaloids are useful in taxonomic studies in **Papaver** and **Argemone** of Papaveraceae.

4) Betalins :

Betacyanins and Betaxanthins are the two important Betanils. They differ from Flavonoids and other phenolic compounds in that they contain nitrogen in them. The betalins are

functionally equivalent to phenolics. Thay are known as nitrogenous anthocyanins. These two pigments are commonly distributed in 10 families belonging to the order **Centrospermae.**

5) Terpenoids and carotenoids:

These are heterogenous groups of compounds. Carotenoids, an important terpenoids observed in the families **Leguminosae** and **Asteraceae.** Terpenes like Camphor (**Cinnamomum**), menthol (**Mentha**). **Carotenoids** are also of taxonomic value in the families **Carryaceae** and **Cornaceae**. Petal carotenoids may be helpful in the taxonomy of **Fabaceae**.

6) Other Chemical substances :

Chemical substances like starch grain and raphides character as tools of taxonomy. Starch grains is used for the classification of **Poaceae** whereas, presence or absence of raphides as an important character for the classification of the **Rubiaceae**.

EMBRYOLOGY AND SYSTEMATICS

Embryology is the study of micro and megasporogenesis, gametophytic development, fertilization, development of endosperm, embryology and seed coats. Embryology has played a significant role in systematic consideration. Embryological characters are of useful in classification, particularly of the larger taxonomic genera and tribes and in finding the relationship of families. There are several embryological features like number and arrangement of loculi in anther, nature of tapetum, development and organization of the pollen grains, development and structure of ovule, form and extent of nucellus, wall formation in megasporogenesis, arrangement of megaopore, type of embryo sac, pollination and fertilization, type of endosperm form of mature embryo, polyembryony etc.

There are numerous families and genera which are specially marked out by their prominent embryological features as below:-

i. **Cyperaceae:** Only one functional microspore is formed in each pollen mother cell instead of normal four microspores.

ii. **Onagraceae :** A characteristic embryological feature of this family is the **Oenothera** type of embryo sac.

iii. **Podostemonaceae :** Presence of pseudoembryo sac, bisporic type of embryo sac and occurrence of pollen grains in pair is distinct characters.

iv. **Epacridaceae :** Pollens are shed at two celled stage.

v. **Loranthaceae :** Pollens are triradiate, embryosac is monosporic and of polygonum type.

vi. Angiosperms divided into two classes i.e. monocotyledons and dicotyledons on the basis of distinguishing feature of embryo.

vii. Genus ***Paeonia***, in earlier systems of classification has been included in the family **Ranunculaceae**. However, Hutchinson, 1959, has removed it from **Ranunculaceae** and placed in separate family **Paeoniaceae** on the basis of embryological characteristics.

viii. The genus ***Trapa*** was classified in the family **Onagraceae** according to Bentham and hookers system of classification while in Englerian system of classification, ***Trapa*** classified in a separate family on the basis of cotyledons and spiny fruit character.

ix. All genera of **Butomaceae** except ***Butomus*** transferred to the **Alismataceae** on the basis of polygonum type of embryo sac in ***Butomus***, where as other genera have **Allium** type of embryo sac.

x. The genus ***Peganum*** has been included in the **Rutaceae** by Bentham and Hooker and in the **Zygophyllaceae** by Engler and Prantl (1897) on the basis of embryo development. On the basis of embryological characters it is now kept in the separate family Peganaceae near Linaceae.

xi. The family **Lemnaceae** are considered to have been derived either from the **Araceae** or from the **Helobiales.** Embryological study clearly indicates that the **Lemnaceae** are evolved from the **Araceae** and they are not related to **Helobiales**.

xii. Genus ***Pentaphragma*** classified under the family **Campanulaceae** by Bentham and Hooker. On the basis of vegetative character Airy Show (1941) has pointed out its relationship with various other families. But on the basis of embryological characters the genus ***Pentaphragma*** retain in **Campanulaceae.**

xiii. **Exocarpus** was removed from Santalaceae on the basis of naked and presence of pollen chamber and it was kept in family Exocarpaceae near Taxaceae in Gymnosperms. But on the basis of embryological characters like typical angiospermic flower, plygonum type of embryo sac, cellular endosperm etc like family santalaceae it has benn confirmed that it is angiosperm.

MOLECULAR BIOLOGY AND SYSTEMATICS

Molecular biology is understanding any species in the terms of biomolecules like DNA and RNA, Protein chemistry, DNA sequencing and molecular level RNA analysis. Molecular systematics deals exclusively with the utilization of nucleic acid data. Molecular biological features plays an significant role in plant systematics. The molecular systematic denotes the use of DNA and RNA sequences to interpret evolutionary relationships. Now a day's DNA molecule play vital role in plant systematic. The comparision of whole DNA molecule can be done for systematic studies. DNA sequencing , DNA fragments, genetic map of individual gene, polymerase chain reaction (PCR) are the various techniques used in plant systematic. e.g.

1. Recently many taxonomist searching for molecular data for taxonomic studies. Mostly nucleic acid data is used in taxonomic studies. As molecular data reflects gene level changes, it is believed to reflect true phylogeny better than data of morphological characters.
2. Now a day's molecular characteristics are available to the plant systematic for use in phylogenetic inference, including restriction site, analysis of DNA rearrangement etc.
3. Plant taxonomy based on phenotypic properties has encountered several problems. Molecular approaches have found a niche in plant systematic.
4. Measurement of DNA hybridization between species is the single most definite tool for defining a species. Data on DNA sequences and amino acids can be used to identify species. The molecular approach is most useful tool in systematic ranging from kingdom to species.
5. Molecular aspects like DNA sequencing, gene coding, chromosome analysis, nucleic acid sequence are now extensively used in systematic study of **Brassicaceae** and other families.

6. On the basis of molecular characterization the analysis indicates that tribes **Lepidieae, Arabideae** and **Sisymbriaeae** are not monophyletic.
7. Systematics use molecular data from three different locations within a plant cell-chloroplast, mitochondrion and the nucleus yielding three different types of genome (DNA). Chloroplast genome is smallest (120-2500 kbp) in higher plants while in algae like **Acetabularia** upto 2000 kbp (kilo base pairs), Mitochondrial genome (200-2500 kbp) and nuclear genome (million to more than billion kbp). Chloroplast and mitochondrial genome are maternal in origin while nuclear genome is biparental. It is noticed that mitochondrial and nuclear genome are highly stable not only within the same cell but also within a species and present useful taxonomic tool.
8. Genome analysis of cereals and grasse provide useful taxonomic information e.g. rice has the smallest genome (400 mb) maize genome (2500 mb) whereas the largest genome is in wheat (17,000 mb).

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