PLANT SYSTEMATICS

Plant systematics is fundamental for understanding and interpreting the living diversity of the world. In recent years, plant systematics has made rapid progress and has witnessed impressive advances in floristic inventorying, incorporation of new types of comparative data, quantitative concepts, methods of phylogeny reconstruction and classification. In order to disseminate this vast data, there is a need to make available the exciting new developments in the field of plant systematics to the undergraduate and post-graduate students. This book is designed to introduce the students with the fundamentals of systematics in a simple, concise and balanced manner. The book aims to equip the students with the basics of plant taxonomy and at the same time also update them with the most recent advances in the field of plant systematics.

The book has been organized into 21 chapters that introduce and explain different concepts in a stimulating manner. The text is supplemented with relevant illustrations and photographs. Relevant literature has been added to provide a better picture of the most recent updates in the field of plant systematics. The language is simple and all the chapters are supplemented with a short summary. A glossary has been added to help the students to understand some important scientific terminology.

The book will not only be helpful for the students but also for teachers in training students in a vast subject like taxonomy that requires a detailed understanding of nomenclature, identification, classification, phenetics, cladistics, molecular phylogeny and DNA barcoding.

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CONTENTS

PREFACE

Plant systematics is fundamental for understanding and interpreting the living diversity of the world. In the past few years, the field of plant systematics has made considerable progress and copious amount of new data has been generated. With the advent of updated information in the form of APG IV classification (2016), the Shenzhen code (2018) and several new viewpoints published in various journals, there is an urgent need to introduce the Undergraduate and Post graduate students with the exciting new developments in the field of plant systematics.

Systematics as a science plays an important role in appropriate examination of the biodiversity, naming of taxa, construction of classification, interpretation of phylogenetic relationships and explanation of evolutionary processes. The book has been organized into several chapters that introduce and explain these concepts in a stimulating manner. Most recent case studies where these concepts have been used to resolve taxonomic problems have been incorporated in the text for the benefit of the students. The text is supplemented with relevant line drawings and figures to aid in the process of understanding various concepts. New literature up to the year 2021 has been added to give a better picture of the most recent updates in the field.

All the chapters are supplemented with a short summary to provide a gist of each chapter. A glossary has been added to help the students to understand some important scientific terminologies. Further reading would provide the students with relevant information for an in-depth study of a particular topic.

We are especially indebted to Dr. Kanchi N. Gandhi (Harvard University) for critically going through Chapter 7 (Plant Nomenclature) and providing valuable inputs which greatly improved the text. We tender our grateful thanks to the reviewers Dr. S. Rama Rao (Chapter 12), Dr. M.K. Janarthanam (Chapter 1), Dr M.Sabu (Chapter 4), Dr. Priyanka Agnihotri (Chapters 3 & 5), Dr K.S. Rajput (Chapter 9), Dr Ritesh Chowdhary (Chapters 14 & 18) and Dr Anzar A. Khuroo (Chapter 2) for their constructive suggestions.

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As practicing plant systematists, we have tried to present the information in a meaningful and conceptual framework. We have emphasized on presenting a lucid account of plant systematics to encourage students to appreciate this dynamic branch of biology and to understand the importance of the biotic world. We hope that this book will be useful to the students and teachers. We would most warmly welcome constructive criticism and suggestions for the improvement of this book.

Arun K. Pandey

Shruti Kasana

CHAPTER-1

INTRODUCTION

Systematics is the science of organismal diversity. It involves the discovery, description, and interpretation of biological diversity, as well as the utilization of this information in the form of predictive classification systems. **Systematics** is therefore the study of the biological diversity that exists on earth today and its evolutionary history. Systematics also provides the framework, or classification, by which other biologists communicate information about organisms.

Systematics is essential to our understanding of the natural world and for communicating about it. The basic activities of systematics involve classification and naming which are the ancient human methods of dealing with information about the natural world. We depend on many species for food, shelter, fibre, clothing, paper, medicines, tools, dyes, etc. Knowledge of systematics guides the search for plants of potential commercial importance.

Systematics provides a reference system for the whole of biology and therefore can be seen as both the most basic and the comprehensive area of biology. Systematics is basic because organisms cannot be discussed in a scientific way until some classification has been achieved to recognize them and give them names. Systematics is most wide-ranging because it gathers together and summarizes everything that is known about the characteristics of organisms, whether geographical, morphological, physiological, genetic, ecological or molecular.

TAXONOMY

Taxonomy is that branch of science which deals with the principles and practices of classification. This biological discipline involves identification, description, classification and naming of taxa based on certain similarities and differences. The term ‘taxonomy’ was coined by de Candolle (1813) from the Greek words, *taxis* (meaning arrangement) and *nomos* (meaning law, rule). The literal meaning of taxonomy is lawful arrangement of things or arrangement by rules. Taxonomy mainly comprises of four components: **D**escription, **I**dentification, **N**omenclature and **C**lassification (often memorized as **DINC**). Often, taxonomy is considered synonymous to systematics, though the latter is much more inclusive.

THE COMPONENTS OF TAXONOMY

1. **Description:** Description is the written account of features or attributes of a taxon. The features are called characters. The characters can be qualitative or quantitative. Two or more forms of a character are known as character states. For example, petal color (red and white), leaf shape (ovate, elliptic, lanceolate), and fruit type (achene, capsule, berry).
2. **Identification:** Identification is the process of associating an unknown taxon with a known one. In other words, identification is the determination of a taxon as being identical with or similar to another and already known element. Identification is the process of finding the taxon to which a specimen belongs, like identifying the medicinal plants, edible and poisonous mushrooms. Identification is a primary function in taxonomy and by applying nomenclature it performs an essential role as a means of communication. A taxonomic key is used for identification of plants. Taxonomic keys are dichotomous, i.e., consists of a series of two contrasting statements. Each statement is a lead. Two leads constitute a couplet.
3. **Nomenclature:** Nomenclature is the formal naming of taxa according to prescribed rules. The naming of groups of organisms and the rules governing the application of these names together form the nomenclature. Plant nomenclature is concerned with the determination of the correct name of a known plant according to an internationally accepted system, i.e., International Code of Nomenclature for Algae, Fungi and Plants (ICNafp). Once the plant has been identified, it becomes necessary that it has a scientific name that provides universal applicability. The rules of ICNafp determine the application of name of the taxa.
4. **Classification:** Classification is a two-step process. Step 1: grouping objects based on similarities and differences and Step 2: ranking these groups into a hierarchy (nested series of categories) based on some criteria. Classification is thus the placement of a plant (or group of plants) in categories based on their similarities and differences. These groups are then arranged according to their levels into categories in a nested manner. Thus, similar individuals may be grouped under a "species", similar species under a "genus", similar genera under a "family" and so on.

Classification is the production of a logical system of categories, each containing any number of organisms, which allows easier reference to its components. Classification is the arrangement of groups of plants with particular circumscriptions by rank and position according to artificial criteria, phenetic similarities, or phylogenetic relationships.

WHAT DO WE MEAN BY "SYSTEMATICS"?

Systematics is the branch of science that includes and encompasses traditional taxonomy (description, identification, nomenclature and classification of organisms) and phylogeny (evolutionary history) (Fig. 1.1). Plant systematics is studied by acquiring, analysing, and synthesizing information about plants and plant parts.

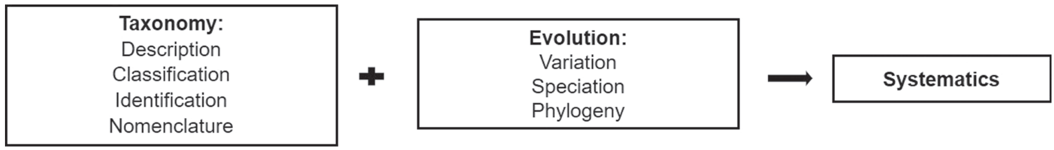

Fig. 1.1. Systematics includes taxonomy and evolution

DEVELOPMENTS AND SCOPE

Our knowledge of the biological world has changed greatly since Linnaeus, who first published his sexual system of classification in the *Systema Naturae* (1735). Since the publication of *Species Plantarum* by Linnaeus (1753) thousands of new species have been described and named every year. The availability of new tools and techniques has helped in new discoveries.

In the past few decades, there has been a renewed focus on the discovery of new taxa, publication of checklists, revisions, monographs and Floras. More floristic and inventory activities have been initiated than at any point in the history of taxonomy. Many collaborative research programs have been developed and training programs have been organized. The past half-century has also witnessed impressive advances in floristic inventorying, incorporation of new types of comparative data, and methods of phylogeny reconstruction and classification. Molecular data, tree-building algorithms, and statistical evaluations have revolutionalized the field of systematics.

Taxonomy is extremely modern, constantly changing and adapting, yet it has strong historical roots that always keep it connected to its past. In addition to inventorying during the past half-century, new types of comparative data of utility for plant systematics have been developed. In the 1950s, cytological data, especially chromosome number and basic karyotype, were emphasized. In the 1960s, secondary plant products (especially flavonoids), numerical taxonomy or phenetics reigned supreme. The 1970s and 1980s had focus on population - level questions with use of isozymes, that still provide good answers for solving particular types of systematic problems (e.g., hybridization). The application of computer techniques, which allowed more flexibility to handling data, were introduced in the early 1980s.

A key change in the field of taxonomy occurred with the development of cladistic theory and reconstruction of phylogenies, using cladograms, which greatly help to infer the evolutionary history of taxa. But the exciting new data came with analyses of DNA sequences and fragments in the 1990s and that has revolutionized the field of systematics. Molecular systematics and the development of methods in phylogenetic analyses have revolutionized our current understanding of relationships among plants and their patterns of diversification across time, space and form.

Current taxonomy represents a body of work that has accumulated over the past ~270 years, since the introduction of the binomial naming system by Linnaeus in the 1750s. The past half-century has witnessed impressive advances in floristic inventorying, incorporation of new types of comparative data, and quantitative concepts and methods of phylogeny reconstruction and classification. Innovations in use of molecular data, tree-building algorithms, and statistical evaluations have changed the field of systematics. The excessive amount of taxonomic information is now being digitized and is made available by various global initiatives.

The systematists have added different data sources to evaluate relationships, and have analysed the data using advanced computer software. When molecular systematics began its successful ascent, computer software were rapidly refined, because much larger data sets had to be processed. The new programmes were then used in morphology with more efficiency than before. Thus, morphological cladistics too has benefited from molecular cladistics. The use of several disciplines (e.g., cladistics, phylogenetics, genomics) helps taxonomy go beyond the naming of species to understand the evolutionary processes.

Next Generation Sequencing (NGS) has revolutionized molecular systematics as well as population and conservation genetics. Only a decade ago, phylogenetic matrices of three and four genes and several hundred taxa were considered large, with current NGS technologies, phylogenetic matrices based on hundreds of genes and involving thousands of species are readily feasible.

Significance of Systematics

- Plays a crucial role in inventorization of the earth's biota.
- Provides a means of communication about the plants.
- Helps in identification of the vast flora.
- Plays important role in distinguishing different taxa.
- It is an integral part of other fields of biology.
- Makes it easy to relate one organism with another and hence helps in classification.
- Helps in testing various evolutionary hypothesis.
- Helps in preservation of germplasm for future breeding experiments.

AIMS AND OBJECTIVES OF SYSTEMATICS

The fundamental aim of systematics is to discover all the branches of the evolutionary tree of life, document all the changes that have occurred during the evolution of these branches, and describe all species-the tips of these branches. The major objectives of systematics are:

1. To name and describe the world's organisms, thus completing our inventory of earth's biota.
2. To provide a classification of these organisms that expresses evolutionary relationships among them.
3. To understand the patterns and processes of evolution that have created this enormous diversity of organisms.
4. To provide an integrating and unifying focus, a means of communication, for all fields of biology by safeguarding and disseminating this knowledge.

PHASES OF TAXONOMY: ALPHA TO OMEGA

The discipline of taxonomy is often divided into four phases:

1. **Alpha taxonomy**: The classical or alpha taxonomy relies mainly upon morphology and is descriptive. It is concerned with the collection, identification and description of taxa. The term was coined by Turrill (1935).
2. **Beta taxonomy**: The beta taxonomy focuses on arrangement of taxa into taxonomic groups or categories of classification. It is concerned with the identification of natural groups based on certain similarities and differences and uses this information for the purpose of classification. The term was coined by Ernst Mayr (1969).
3. **Gamma taxonomy**: The gamma taxonomy includes study of intraspecific populations, speciation, and evolutionary rates and trends. The purpose of this type of study is to interpret the biological diversity.
4. **Omega taxonomy**: The omega or modern taxonomy uses the data obtained from various biological disciplines like cytology, palynology, phytochemistry, etc. and gives information about the relationships among organisms. It is often referred to as a 'perfected taxonomy' as it focuses on having a broad information base for interpreting the relationships. The term was coined by Turrill (1938).

As taxonomy makes use of data from other fields like anatomy, embryology, palynology, phytochemistry, cytology, molecular biology, it is often referred to as a synthetic science. However, every biological discipline needs some level of basic understanding about the taxonomy of organisms and the information provided by taxonomic research forms the basis for all other fields of biology. It is therefore, aptly said by May (2004) that taxonomy is the brick with which the house of biodiversity is made.

BIOSYSTEMATICS

The term biosystematics was introduced by Camp and Gilly (1943) to understand the natural relationships of plants, particularly those of the rank of genus and below. Biosystematic studies include a thorough sampling of the taxon and its populations, and counting of chromosomes of many populations within geographic races, species, and genera. Differences in chromosome number, their morphology, and behaviour at meiosis usually indicate genetic differences of taxonomic significance. Another aspect included in the biosystematic study is the determination of the ability of the different populations to hybridize which provides data on the presence or absence of breeding barriers between groups.

The major objective of the biosystematic studies is to delimit the natural biotic units and to apply to these units a system of nomenclature adequate to the task of conveying precise information regarding their defined limits, relationships, variability, and dynamic structure. The four most widely accepted biosystematic categories are: ecotype, ecospecies, cenospecies (or coenospecies) and comparium.

Ecotype is the basic unit in biosystematics. It is adapted to a particular environment but capable of producing fully fertile hybrids with other ecotypes of the same ecospecies. **Ecospecies** is a group of plants comprised of one or more ecotypes. **Cenospecies** (Coenospecies) is a group of plants representing one or more ecospecies. **Comparium** is the biosystematic unit that often is comparable to the genus. It includes one or more cenospecies (more details in chapter 6).

Biosystematics is considered as the taxonomic application of the disciplines known as genecology. It is the study of the genotypic and phenotypic variation of species in relation to the environments in which they occur.

INTEGRATIVE TAXONOMY

A multisource approach that takes advantage of complementarity among disciplines, i.e., different fields of study, has been called combined, multidisciplinary, multidimensional, collaborative, or integrative taxonomy. Using multiple disciplines to solve taxonomic problems helps avoid failure inherent to single disciplines and increases rigor in species delimitation. Continuous progress is being made despite several impediments because species taxonomy is resurging as a solid scientific discipline that includes technological advances, such as virtual access to museum and herbarium collections, rapid methods of DNA sequencing, geographical information systems, and numerous functions of the internet. Integrative taxonomy has yielded a better and more robust biodiversity inventory.

DNA TAXONOMY

DNA taxonomy is defined as the analysis of genetic variation for the circumscription and delineation of species. It uses the evolutionary species concept and provides a new scaffold for the accumulation of taxonomic knowledge. In simple words, it is the use of DNA to delineate species. It is a convenient tool for species identification and rapid assessment of biodiversity.

CYBER TAXONOMY (E-TAXONOMY)

Taxonomic data is enormous and hence is being widely digitized to make it convenient for people to access this information globally. Cyber taxonomy involves the use of standardised electronic tools to access information (databases, e-publications). The internet is being used as the primary medium for taxonomic teaching and research. It has provided more accessible and universal platform for the deposition and retrieval of taxonomic information. Cyber taxonomy has greatly speeded up communication and made species diagnoses and new descriptions more accessible. The future has been envisioned to be an interactive "cyber taxonomy" having fast access to online description and publication of new species, and where updated taxonomic information is accessible for almost anybody from anywhere. Digital image-based morphometrics is also being widely used in evolutionary biology and systematics.

REVERSE TAXONOMY

DNA analysis and naming of the organism without studying its morphology is termed as reverse taxonomy. In this method, the molecular data is analysed first and based on it the taxon is assigned to a particular group and then described at genus/species level. It is helpful in cases where a taxon cannot be clearly defined to any taxonomic group by using traditional methods.

RELEVANCE TO SCIENCE AND SOCIETY

The greatest contribution of taxonomy to science and humanity is that taxonomists have discovered, described and classified over 2 million species and the process is still continuing. Understanding the biological richness, their variability and protecting them is vital to human survival. Systematics plays a vital role in society for the identification of organisms which is important for proper assessment and characterization of biodiversity.

Taxonomists identify species in the wild, notice the risk of extinction or the arrival of invasive species and follow the changes in biodiversity over time. They undertake inventories to survey the flora and fauna of various areas and provide advice for their protection.

Systematics helps in delineating taxa and establishes the correct relationship among organisms. It not only provides an insight into the origin of life on earth but also preserves the information about existing biodiversity through proper storage and documentation. It provides an effective means of dealing with the large amount of information that exists on the earth.

With the increasing threat of climate change and global warming, the biotic flora is also under extreme pressure of extinction. The increased competition among species for resources is making their survival difficult. Activities like deforestation and cultivation pose a constant threat to various undescribed species. Systematics thus plays a vital role in conservation biology. It helps in identifying the rare and endangered taxa, thereby enabling us to develop strategies for their conservation.

Systematic studies also give an overview of the incredible diversity of life on earth. Biogeography data help in understanding the distribution of species on the planet and the ecological interactions among the species. It also aids in identification of the biodiversity hotspots and help in making strategies for their preservation in the natural condition (*in situ*) or in artificially created habitats (*ex situ*). In areas with high risk of destruction, the floristic biota can be collected and inventoried.

Systematics is also important for the correct utilization of economic resources. Understanding the wild species that are closely related to economically important crop plants can help to improve the available germplasm and develop resistant varieties. Land use pattern can also be improved through the knowledge of ecological impact on the organisms.

Proper identification of taxa can help reduce pest infestation and damage due to increased population of weeds. It also advances our understanding of important processes like coevolution of pests–pathogens and plants–pollinators. Dispersal mechanisms, ecological shifts in the plants due to change in climatic conditions and habitat preferences can be easily understood with the assistance of systematic studies.

Systematics also helps in understanding the process of speciation and thus provides insights into the evolutionary pathways. This provides data about the ancestral – descendent relationship and the changes that occur over time. These phylogenetic studies provide insight into the evolutionary path for the origin of organisms on earth.

SUMMARY

- Systematics is the study of biological diversity that exists on earth and its evolutionary history.
- Taxonomy is that branch of science which deals with the principles and practices of classification.
- Taxonomy mainly comprises of four components: Description, Identification, Nomenclature and Classification.
- When multiple disciplines are used to solve taxonomic problems, it is called integrative taxonomy.
- Systematics is crucial in conservation biology as it helps in identifying the rare and endangered taxa, thereby enabling us to develop strategies for their conservation.
- Systematics helps in understanding the process of speciation and thus provides insights into the evolutionary pathways.

FURTHER READING

Alston, R.E. 1967. Biochemical systematics. *Evolutionary Biology* 1: 197–305.

Alston, R.E. and Turner, B.L. 1963. Natural hybridization among four species of *Baptisia* (Leguminosae). *American Journal of Botany* 50(2):159-173.

Angiosperm Phylogeny Group 2016. An update of the Angiosperm Phylogeny Group Classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnaean Society* 181: 1-20.

Arber, E.N. and Parkin, J. 1907. On the origin of angiosperms. *Botanical Journal of the Linnean Society* 38(263): 29-80.

Baldwin, B.G., Sanderson, M.J., Porter, J.M., Wojciechowski, M.F., Campbell, C.S. and Donoghue, M.J. 1995. The ITS region of nuclear ribosomal DNA: a valuable source of evidence on angiosperm phylogeny. *Annals of the Missouri Botanical Garden* 82: 247-277.

Bateman, R.M., Hilton, J. and Rudall, P.J. 2006. Morphological and molecular phylogenetic context of the angiosperms: contrasting the 'top-down'and 'bottom-up'approaches used to infer the likely characteristics of the first flowers. *Journal of Experimental Botany* 57(13): 3471-3503.

Baum, D. A. and Shaw, K. L. 1995. Genealogical perspectives on the species problem. In: Hoch, P. C. and Stephenson, A. G. (eds.), *Experimental and Molecular Approaches to Plant Biosystematics*. pp. 289–303. Missouri Botanical Garden, St. Louis.

Baum, D.A. and Smith, S.D. 2012. *Tree Thinking: An Introduction to Phylogenetic Biology.* Roberts and Co., Greenwood Village, CO.

Beentje, H. 2016. *The Kew Plant Glossary: An Illustrated Dictionary of Plant Terms.* 2nd ed. Royal Botanic Garden, Kew.

Bell, C.D., Soltis, D.E. and Soltis, P.S. 2010. The age and diversification of the angiosperms re revisited. *American Journal of Botany* 97(8): 1296-1303.

Bentham, G. and Hooker, J. D. 1862–1883. *Genera Plantarum*. Reeve & Co., London.

Bessey, C.E. 1915. The phylogenetic taxonomy of flowering plants. *Annals of the Missouri Botanical Garden* 2: 109-164.

Brickell, C.D., Alexander, C., Cubey, J.J., David, J.C., Hoffman, M.H.A., Leslie, A.C., Malécot, V. and Xiaobai, J. 2016. *International code of nomenclature for cultivated plants (ICNCP or Cultivated Plant Code), incorporating the Rules and Recommendations for naming plants in cultivation* adopted by the International Union of Biological Sciences and the International Commission for the Nomenclature of Cultivated Plants. 9th Edition. International Society for Horticultural Science (ISHS), Leuven, Belgium. Scripta Horticulturae Number 18.

Bureau, L. E. 1894. Révision du genre *Catalpa*. Nouvelles Archives du Muséum d'Histoire Naturelle, sér. 3, 6: 169–208.

Burger, W. C. 1977. The Piperales and the monocots. Alternate hypotheses for the origin of the monocotyledonous flowers. *Botanical Review* 43: 345-393.

Burleigh, J.G., Hilu, K.W. and Soltis, D.E. 2009. Inferring phylogenies with incomplete data sets: a 5-gene, 567-taxon analysis of angiosperms. *BMC Evolutionary Biology* 9(1): 61.

Cain, A. J. and Harrison, G. A. 1960. Phyletic weighting. *Proceedings of the Zoological Society of London* 135:1–31.

Camp, W. H. and Gilly, C. L. 1943. The structure and origin of species with a discussion of intraspecific variability and related nomenclatural problems. *Brittonia* 4:323–385.

Candolle, A.D. 1813. *Théorie élémentaire de la Botanique*. Paris.

Cantino, P.D., Doyle, J.A., Graham, S.W., Judd, W.S., Olmstead, R.G., Soltis, D.E., Soltis, P.S., and Donoghue, M.J. 2007. Towards a phylogenetic nomenclature of Tracheophyta. *Taxon* 56: 822-846.

CBOL Plant Working Group and Janzen, D.H. 2009. A DNA barcode for land plants. *Proceedings of the National Academy of Sciences of the United States of America*: 12794-12797.

Chase, M.W., Cowan, R.S., Hollingsworth, P.M., Petersen, G., Seberg, O., Jorgsensen, T., and Carine, M. 2007. A proposal for a standardised protocol to barcode all land plants. *Taxon* 56: 295– 299.

Chennaveeraiah, M.S. 1960. Karyomorphologic and cytotaxonomic studies in *Aegilops*. *Acta Hortus Gotoburgensis* 23: 85-178.

Christenhusz, M.J.M. *et al.,* 2015. Results from an online survey of family delimitation in angiosperms and ferns: recommendations to the Angiosperm Phylogeny Group for thorny problems in plant classiûcation. *Botanical Journal of the Linnean Society* 178: 501–528.

Clausen, J., Keck, D. D. and Hiesey, W. M. 1940. *Experimental studies on the nature of species I. Effect of varied environments on western North American plants*. Carnegie Institute of Washington, Washington.

Coissac, E., Hollingsworth, P.M., Lavergne, S. and Taberlet, P. 2016. From barcodes to genomes: extending the concept of DNA barcoding. *Molecular Ecology 25*(7): 1423-1428.

Cracraft, J. 1983. Cladistic Analysis and Vicariance Biogeography: Evolutionary biology gains a new dimension from the reconstruction of systematic and biogeographic patterns. *American Scientist* 71(3): 273-281.

Cronquist, A. 1978. Once again, what is a species? In: L. V. Knutson (ed), *Biosystematics in Agriculture*. Pp. 3–20. Allenheld Osmun, Montclair, NJ.

Cronquist, A. 1981. *An integrated system of classification of flowering plants*. Columbia University Press, New York.

Cronquist, A. 1988. *The Evolution and Classification of Flowering Plants*, ed. 2. The New York Botanical Garden, Bronx.

Cunha, J.B. 2003. Application of image processing techniques in the characterization of plant leafs, *IEEE International Symposium on Industrial Electronics* 1(1), 9-11 June, pp. 612 – 616.

Dahlgren, G. 1989. An updated angiosperm classification. *Botanical Journal of Linnean Society* 100:197–203.

Darlington, C.D. 1937. *Recent advances in cytology*. P. Blakiston's son and Co., Philadelphia.

Darwin, C. 1859. *The origin of species.* 6th Vol. John Murray, London.

Darwin, F. and Seward, A.C. 1903. *More letters of Charles Darwin*. John Murray, London.

Davies, T.J., Barraclough, T.G., Chase, M.W., Soltis, P.S., Soltis, D.E. and Savolainen, V. 2004. Darwin's abominable mystery: insights from a supertree of the angiosperms. *Proceedings of the National Academy of Sciences* 101(7): 1904-1909.

Davis, C.C., Xi, Z. and Mathews, S. 2014. Plastid phylogenomics and green plant phylogeny: almost full circle but not quite there. *BMC Biology* 12(1): 1-4.

Davis, P.H. and Heywood, V.H. 1963. *Principles of angiosperm taxonomy*. D. VanNostrand Co. Inc., Princeton, New Jersey.

De Bodt, S., Maere, S. and Van de Peer, Y. 2005. Genome duplication and the origin of angiosperms. *Trends in Ecology and Evolution* 20(11): 591-597.

De Queiroz, K. and Donoghue, M.J. 1988. Phylogenetic systematics and the species problem. *Cladistics* 4(4): 317-338.

De Queiroz, K. and Gauthier, J. 1992. Phylogenetic taxonomy. *Annual Review of Ecology and Systematics* 23(1): 449-480.

Doyle, J. A. 1998. Molecules, morphology, fossils, and the relationship of angiosperms and Gnetales. *Molecular Phylogenetics and Evolution* 9: 448-462.

Doyle, J. A. and Hickey, L. J. 1976. Pollen and leaves from the mid-Cretaceous Potomac Group and their bearing on early angiosperm evolution. In: Beck, C. B. (ed.), *Origin and Early Evolution of Angiosperms*. pp. 139-206. Columbia University Press, New York.

Doyle, J.A. 2006. Seed ferns and the origin of angiosperms. *The Journal of the Torrey Botanical Society* 133: 169-209.

Doyle, J.A. 2008. Integrating molecular phylogenetic and paleobotanical evidence on origin of the flower. *International Journal of Plant Sciences* 169(7): 816-843.

Eichler, A. W. 1876. Syllabus der Vorlesungen iiber spezielle und medizinisch-pharmazeutische Botanik, ed. 1. Borntraeger, Berlin.

Eisen, J.A. 1998. Phylogenomics: improving functional predictions for uncharacterized genes by evolutionary analysis. *Genome Research* 8(3): 163-167.

Eldredge, N. and Cracraft, J. 1980. *Phytigenetic patterns and the evolutinary process; methods and theory in comparative biology*. Columbia University Press, New York.

Endress, P.K. 2001. The flowers in extant basal angiosperms and inferences on ancestral flowers. *International Journal of Plant Sciences* 162(5): 1111-1140.

Endress, P.K. and Doyle, J.A. 2015. Ancestral traits and specializations in the flowers of the basal grade of living angiosperms. *Taxon* 64(6): 1093-1116.

Engler, A. 1897. Nachtrige. In: Engler, A. & Prantl, K. (eds.), *Die Natürlichen Pflanzenfamilien*. pp. 364-369. Engelmann, Leipzig.

Engler, A. and Prantl, K. 1887–1915. *Die Natürlichen Pflanzenfamilien.* Engelmann, Leipzig.

Erdtman, G. 1969. *Handbook of palynolgy: Morphology, taxonomy, ecology. An introduction to the study of pollen grains and spores*. Hafner, New York.

Falistocco, E. 2020. Insight into the Chromosome Structure of the Cultivated Tetraploid Alfalfa (*Medicago sativa* subsp. *sativa* L.) by a combined Use of GISH and FISH Techniques. *Plants* 9(4): 542.

Fazekas, A.J., Kuzmina, M.L., Newmaster, S.G. and Hollingsworth, P.M. 2012. *DNA* barcoding methods for land plants. In: W. J. Kress and D. L. Erickson (eds), *DNA barcodes,* pp. 223-252. Humana Press, Totowa, NJ.

Feild, T.S. and Arens, N.C. 2005. Form, function and environments of the early angiosperms: merging extant phylogeny and ecophysiology with fossils. *New Phytologist* 166(2): 383-408.

Francis, C.M., Borisenko, A.V., Ivanova, N.V., Eger, J.L., Lim, B.K., Guillén-Servent, A., Kruskop, S.V., Mackie, I. and Hebert, P.D. 2010. The role of DNA barcodes in understanding and conservation of mammal diversity in Southeast Asia. *PloS one 5*(9): e12575.

Funk, V.A. 2003. The importance of herbaria. *Plant Science Bulletin* 49: 94– 95.

George, T.N. 1956. Biospecies, chronospecies and morphospecies. In: Sylvester-Bradley, P.C. (ed.), *The species concept in paleontology*, pp.123-137. Systematics Association, London.

Gholami, A., Malik, S., Dhabe, A.S., Pandey, A.K. and Babbar, S.B. 2020. DNA barcoding of Indian *Alysicarpus* (Fabaceae): ITS alone distinguishes species. *Vegetos* 33(3): 592-600.

Gholave, A.R., Lekhak, M.M. and Yadav, S.R. 2019. Comparative karyological analysis of Indian *Amorphophallus* (Araceae). *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*: 1-8.

Gogoi, B. and Bhau, B.S. 2018. DNA barcoding of the genus *Nepenthes* (Pitcher plant): a preliminary assessment towards its identification. *BMC Plant Biology* 18(1): 153.

Gohil, R.N., Rathar, G.M., Tahir, I. and Farooq, S. 1983. Comparative cytology, growth and grain composition of west Himalayan buckwheats. In: *Proceedings of the Second International Symposium on Buckwheat at Miyazaki*, pp. 87-101.

Golenkin, M. I. 1927. The Victors in the Struggle for Existence. In: *An Investigation of the Causes and Conditions of the Conquest of the Earth by Angiosperms in the Mid-Cretaceous*, Moscow.

Gosavi, K.V.C., Jadhav, N.A. and Yadav, S.R. 2016. Cytological studies in four endemic Genera of Apiaceae from India. *Taiwania* 61(4): 314-318.

Gostel, M.R., Zúñiga, J.D., Kress, W.J., Funk, V.A. and Puente-Lelievre, C. 2020. Microfluidic Enrichment Barcoding (MEBarcoding): a new method for high throughput plant DNA barcoding. *Scientific Reports* 10(1): 1-13.

Graham, S.W. and Iles, W.J. 2009. Different gymnosperm outgroups have (mostly) congruent signal regarding the root of flowering plant phylogeny. *American Journal of Botany* 96(1): 216-227.

Grant, V. 1992. Comments on the ecological species concept. *Taxon*: 310-312.

Greilhuber, J., Borsch, T., Müller, K., Worberg, A., Porembski, S. and Barthlott, W. 2006. Smallest angiosperm genomes found in Lentibulariaceae, with chromosomes of bacterial size. *Plant Biology* 8(6): 770-777.

Hajibabaei, M., Singer, G.A., Hebert, P.D. and Hickey, D.A. 2007. DNA barcoding: how it complements taxonomy, molecular phylogenetics and population genetics. *Trends in Genetics* 23(4): 167-172.

Hall, B.G. 2011. *Phylogenetic Trees Made Easy: A How-To Manual*. Sinauer Associates Inc., U.S.A.

Hebert, P.D., Cywinska, A., Ball, S.L. and Dewaard, J.R. 2003. Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 270(1512): 313-321.

Hennig, W. 1950. *Grundzüge einer Theorie der phylogenetischen Systematik.* Deutscher Zentralverlag, Berlin.

Hennig, W. 1966. *Phylogenetic Systematics.* Translated by D. D. Davis and R. Zangerl. University of Illinois Press, Urbana.

Heslop-Harrison, J. 1963. An ultrastructural study of pollen wall ontogeny in *Silene pendula. Grana* 4(1): 7-24.

Heywood, V.H. 1967. Variation in species concepts. *Bulletin du Jardin botanique national de Belgique/Bulletin van de National Plantentuin van België* 37(1): 31-36.

Hu, S., Dilcher, D.L., Jarzen, D.M. and Taylor, D.W. 2008. Early steps of angiosperm–pollinator coevolution. *Proceedings of the National Academy of Sciences* 105(1): 240-245.

Hutchinson, J. 1934. *The families of flowering plants. II. Monocotyledons. Arranged according to a new system based on their probable phytogeny.* Clarendon, Oxford.

Hutchinson, J. 1973. *The Families of Flowering Plants.* Oxford University Press.

Hynniewta M., Kharsandi, B., Pala, S., Malik, S. K. and Rao, S. R. 2018. Comparative Analysis in CMA Banding Patterns Between Wild and Cultivated *Citrus* species of North-East India *Acta Scientific Agriculture* 24: 45-49.

Im, C. Nishida and H. Kunii, T.L. 1998. Recognizing plant species by laef shapes – A case study of the *Acer* family. *Proceedings of Fourteenth International Conference on Pattern Recognition*, 2, pp. 1171-1173.

Judd, W. S., Campbell, C. S., Kellogg, E. A., Stevens, P. F. and Donoghue, M. J. 2002. *Plant Systematics: a Phylogenetic Approach*, ed. 2. Sinauer Associates, Sunderland, Massachusetts.

Judd, W., *et al.* 2016. *Plant Systematics: A Phylogenetic Approach*. Sinauer Associates Inc., U.S.A.

Kaul, V., Koul, A. K. and Sharma, N. 2007. Genetic system of two rainy season weeds: *Commelina benghalensis* L. and *Commelina caroliniana* Walter. *Chromosome Botany* 2(3): 99-105.

Kozarewa, I. and Turner, D.J. 2011. Amplification-free library preparation for paired-end Illumina sequencing. In: Y.M. Kwon and S. C. Ricke (eds), *High-Throughput Next Generation Sequencing*. pp. 257-266. Humana Press, Totowa, NJ.

Kumar, A. and Rao, S.R. 2002. Cytological investigations in some important tree species of Rajasthan II. Male meiosis studies in the genus *Anogeissus* (DC.) Guill, Perr. & A.Rich. *Caryologia* 55: 63-73.

Lamarck, J. B. P. 1778. *Flore Francaise*. Imprimerie Royale, Paris.

Lamo, J.M. and Rao, S.R. 2017. Meiotic behaviour and its implication on species inter-relationship in the genus *Curcuma* (Linnaeus, 1753) (Zingiberaceae). *Comparative Cytogenetics* 11(4): 691.

Lawrence, G. H. M. 1951. *Taxonomy of Vascular Plants.* Macmillan, New York.

Legendre, P. and Vaillancourt, P. 1969. A mathematical model for the entities species and genus. *Taxon* 18(3): 245-252.

Levan, A. 1964. Nomenclature for centromeric position on chromosomes. *Hereditas* 52: 201-220.

Lewis, C.T. and Short, C. 1879. Harpers' Latin dictionary. A New Latin Dictionary Founded on the Translation of Freund's Latin-German Lexicon, edited by EA Andrews.

Lewis, H. 1957. Genetics and cytology in relation to taxonomy. *Taxon* 6:42–46.

Li, H.T. *et al.* 2019. Origin of angiosperms and the puzzle of the Jurassic gap. *Nature Plants*. 5(5): 461 - 470.

Linnaeus, C. 1736. *Fundamenta Botanica*. Amsterdam.

Linnaeus, C. 1753. *Species Plantarum,* 2 vols. Stockholm.

Liu, J., Shi, L., Han, J., Li, G., Lu, H., Hou, J., Zhou, X., Meng, F. and Downie, S.R. 2014. Identification of species in the angiosperm family Apiaceae using DNA barcodes. *Molecular Ecology Resources* 14(6): 1231-1238.

Lunau, K. 2004. Adaptive radiation and coevolution—pollination biology case studies. *Organisms Diversity and Evolution* 4(3): 207-224.

Lysak, M.A., Berr, A., Pecinka, A., Schmidt, R., McBreen, K. and Schubert, I. 2006. Mechanisms of chromosome number reduction in *Arabidopsis thaliana* and related

Brassicaceae species. *Proceedings of the National Academy of Sciences* 103(13): 5224-5229.

Lçve, A. 1960. Biosystematics and classification of apomicts. *Feddes Repertorium* 63:136–149.

Magnol, P. 1689. *Prodromus Historiae Generalis, in qua Familiae per Tabulas Disponutur*. Montpelier.

Maltoni, D., Maio, D., Jain, A.K. and Prabhakar, S. 2003. *Handbook of Fingerprint Recognition*. Springer-Verlag, NewYork, Inc.

Manilal, K.S. and Pandey, A.K. (eds.) 1996. *Taxonomy and Plant Conservation*. CBS Publishers and Distributors, New Delhi.

Marguerat, S. and Bähler, J. 2010. RNA-seq: from technology to biology. *Cellular and Molecular Life Sciences* 67(4): 569-579.

Mathews, S. 2009. Phylogenetic relationships among seed plants: persistent questions and the limits of molecular data. *American Journal of Botany* 96(1): 228-236.

Maurya, S., Darshetkar, A.M., Datar, M.N., Tamhankar, S., Li, P. and Choudhary, R.K. 2020. Plastome data provide insights into intra and interspecific diversity and *ndh* gene loss in *Capparis* (Capparaceae). *Phytotaxa* 432(2): 206-220.

May, R.M. 2004. Tomorrow's taxonomy: collecting new species in the field will remain the rate–limiting step. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 359(1444): 733-734.

Mayr, E. 1942. *Systematics and the Origin of Species from the Viewpoint of a Zoologist.* Columbia University Press, New York.

Mayr, E. 1964. The new systematics. In: C. A. Leone (ed.), *Taxonomic Biochemistry and Serology*, pp. 13–32. Ronald Press, New York.

Mayr, E. 1969. The biological meaning of species. *Biological Journal of the Linnean Society* 1(3): 311-320.

Mayr, E. 1982. *The Growth of Biological Thought: Diversity, Evolution, and Inheritance.* Belknap Press of Harvard University Press, Cambridge, MA.

Meena, D.S., Dwivedi, M.D., Chauhan, V. and Pandey A.K. 2021. Evolution of leaf forms in the genus *Indigofera* L. (Leguminosae, Papilionoideae) based on norphological and molecular sequence data. In: Singh, L.J. and Ranjan, V. (eds.) *New Vistas in Indian Flora*. Bishen Singh Mahendra Pal Singh, Dehradun.

Meeuse, A. D. J. 1975. Floral evolution as the key to angiosperms descent. *Acta Botanica Indica* 3: 1-18.

Moore, P.D., Webb, J.A. and Collison, M.E. 1991. *Pollen analysis*. Blackwell scientific publications Oxford.

Nei, M. and Kumar, S. 2000. *Molecular Evolution and Phylogenetics.* Oxford University Press, New York.

Nilsson, L.A. 1988. The evolution of flowers with deep corolla tubes. *Nature* 334: 147-149.

Pahalawatta, K., 2008. *Plant species biometric using feature hierarchies*. Thesis submitted to the Department of Computer Science and Software Engineering, University of Canterbury Christchurch.

Pandey, A.K. 1995. *Taxonomy and Biodiversity*. CBS Publishers and Distributors, New Delhi.

Pandey, A.K., Wen, J. and Dogra, J.V.V. 2006. *Plant Taxonomy: Advances and Relevance*. CBS Publishers and Distributors, New Delhi.

Passarelli, L.M. and Rolleri, C.H. 2010. Pollen grains and massulae in pollinia of four South American palustrine species of *Habenaria* (Orchidaceae). *Grana* 49(1): 47-55.

Paterson, H.E.H. 1985. The recognition concept of species. In: Vrba, E.S. (ed.), *Species and Speciation*. pp. 21–29. Transvaal Museum, Pretoria.

Paul, P. and Chowdhury, M. 2020. Pollen morphology of selected Indian species from subfamily Polygonoidae (Polygonaceae). *Biologia* 1-13.

Qiu, Y.L., Lee, J., Bernasconi-Quadroni, F., Soltis, D.E., Soltis, P.S., Zanis, M., Zimmer, E.A., Chen, Z., Savolainen, V. and Chase, M.W. 2000. Phylogeny of basal angiosperms: analyses of five genes from three genomes. *International Journal of Plant Sciences* 161(S6): S3-S27.

Ratnasingham, S. and Hebert, P.D.N. 2007. BOLD: The Barcode of life data system (www.barcodinglife.org). *Molecular Ecology Notes* 7: 355– 364.

Raven, P. H. 1975. The bases of angiosperm phylogeny: cytology. *Annals of the Missouri Botanical Garden* 62:724–764.

Remizowa, M.V., Sokoloff, D.D. and Rudall, P.J. 2010. Evolutionary History of the Monocot Flower. *Annals of the Missouri Botanical Garden* 97(4): 617-645.

Saitoh, T. and Kaneko, T. 2000. Automatic Recognition of Wild Flowers, *Proceedings of 15th International Conference on Patter Recognition*, Vol. 2, pp. 507–510.

Saitou, N. and M. Nei. 1987. The neighbor-joining method: a new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution* 4: 406–425.

Sanger, F., Nicklen, S. and Coulson, A.R. 1977. DNA sequencing with chain-terminating inhibitors. *Proceedings of the National Academy of Sciences* 74(12): 5463-5467.

Sauquet, H., von Balthazar, M., Magallón, S., Doyle, J.A., Endress, P.K., Bailes, E.J., de Morais, E.B., Bull-Hereñu, K., Carrive, L., Chartier, M. and Chomicki, G. 2017. The ancestral flower of angiosperms and its early diversification. *Nature communications* 8(1): 1-10.

Scutt, C.P. 2018. The origin of angiosperms. In: L. Nuno de la Rosa and G. Müller (eds) *Evolutionary Developmental Biology*, pp.1-20. Springer International Publishing, Berlin.

Sen, S. 1974. Nature and behaviour of B chromosomes in *Allium stracheyii* Baker and *Urginea indica* Kunth. *Cytologia* 39(2): 245-251.

Shamurailatpam A. 2014. *Molecular Cytogenetic Studies on Inter- and Intraspecific Variation in Vigna Species from North-East India*. PhD. Thesis, North-Eastern Hill University, Shillong.

Sharma, S., Kaushik, S. and Raina, S.N. 2019. Estimation of nuclear DNA content and its variation among Indian Tea accessions by flow cytometry. *Physiology and Molecular Biology of Plants* 25(2): 339-346.

Shaw, K.L. 2001. The genealogical view of speciation. *Journal of Evolutionary Biology*. 14(6): 880-882.

Shekhar, S. and Pandey, A.K. 2016. Pollen morphology in *Inula* L. (Asteraceae) and related genera. *The International Journal of Plant Reproductive Biology* 8(2): 202-207.

Simpson, G. G. 1961. *Principles of Animal Taxonomy.* Columbia University Press, New York.

Simpson, M.G. 2018. *Plant Systematics*. Elsevier Academic Press, San Diego, CA.

Singh, H.K., Parveen, I., Raghuvanshi, S. and Babbar, S.B. 2012. The loci recommended as universal barcodes for plants on the basis of floristic studies may not work with congeneric species as exemplified by DNA barcoding of *Dendrobium* species. *BMC Research Notes 5*(1): 42.

Singh, K., Sharma, Y.P., Sharma, P.R. and Gairola, S. 2020. Pollen morphology and variability of the *Rosa* L. species of Western Himalaya in India. *Genetic Resources and Crop Evolution:* 1-20.

Sneath, P.H.A. and Sokal, R.R. 1962. Numerical Taxonomy. *Nature* 193:855–860.

Sneath, P.H.A. and Sokal, R.R. 1973. *Numerical Taxonomy: The Principles and Practice of Numerical Classification.* W.H. Freeman and Company, San Francisco.

Sokal, R. R. and Michener, C. D. 1958. A statistical method for evaluating systematic relationships. *University of Kansas Science Bulletin* 38: 1409–1438.

Solereder H. 1908. *Systematic Anatomy of the Dicotyledons* (Vol I) pp 601–611, Clarendon Press, Oxford.

Soltis, D.E., Smith, S.A., Cellinese, N., Wurdack, K.J., Tank, D.C., Brockington, S.F., Refulio Rodriguez, N.F., Walker, J.B., Moore, M.J., Carlsward, B.S. and Bell, C.D. 2011. Angiosperm phylogeny: 17 genes, 640 taxa. *American Journal of Botany* 98(4): 704-730.

Soltis, D.E., Soltis, P.S., Bennett, M.D. and Leitch, I.J. 2003. Evolution of genome size in the angiosperms. *American Journal of Botany* 90(11): 1596-1603.

Soltis, P., Soltis, D., Judd, W., Majure, L., Manchester, S., Mavrodiev, E., Endress, P. and Chase, M. W. 2018. *Phylogeny and Evolution of the Angiosperms: Revised and Updated Edition*. University of Chicago Press, USA.

Sousa-Baena, M.S., Sinha, N.R., Hernandes-Lopes, J. and Lohmann, L.G. 2018. Convergent evolution and the diverse ontogenetic origins of tendrils in angiosperms. *Frontiers in Plant Science* 9: 403.

Stace, C.A. 1980. *Plant Taxonomy and Biosystematics.* Arnold, London.

Stace, C.A. 1989. *Plant Taxonomy and Biosystematics.* (2nd ed.) Edward Arnold, London.

Steele, P.R. and Pires, J.C. 2011. Biodiversity assessment: State of the art techniques in phylogenomics and species identification. *American Journal of Botany* 98(3): 415-425.

Straub, S.C.K., Parks, M., Weitemier, K., Fishbein, M., Cronn, R., and Liston, A. 2012. Navigating the tip of the genomic iceberg: Next-generation sequencing for plant systematics. *American Journal of Botany* 99: 349 – 364.

Stuessy, T. F., Crawford, D. J., Soltis, D. E., and Soltis, P. S. 2014. *Plant Systematics: The Origin, Interpretation, and Ordering of Plant Biodiversity*. Koeltz Scientific Books, Germany.

Stuessy, T.F. 2004. A transitional-combinational theory for the origin of angiosperms. *Taxon* 53(1): 3-16.

Stuessy, T.F. 2009. *Plant Taxonomy: The Systematic Evaluation of Comparative Data*. Columbia University Press, New York.

Stuessy, T.F. 2018. *Plant Taxonomy: The Systematic Evaluation of Comparative Data.* Cambridge University Press, UK.

Stuessy, T.F. 2020. Challenges facing systematic biology. *Taxon* 69(4): 655-667.

Sun, G., Dilcher, D. L., Zheng, S. and Zhou, Z. 1998. In search of the first flower: a Jurassic angiosperm: Archaeftructus from Northeast China. *Science* 282: 1692-1695.

Sun, G., Ji, Q., Dilcher, D. L., Zheng, S., Nixon, K. C. and Wang, X. 2002. Archaefructaceae, a new basal angiosperm family. *Science* 296: 899–904.

Svaèina, R., Sourdille, P., Kopecký, D. and Bartoš, J. 2020. Chromosome Pairing in Polyploid Grasses. *Frontiers in Plant Science*: 11.

Taberlet, P., Coissac, E., Pompanon, F., Gielly, L., Miquel, C., Valentini, A., Vermat, T., Corthier, G., Brochmann, C. and Willerslev, E. 2007. Power and limitations of the chloroplast *trn*L (UAA) intron for plant DNA barcoding. *Nucleic Acids Research* 35(3): e14-e14.

Takhtajan, A.L. 2009. *Flowering Plants.* Second Edition. Springer.

Taylor, D.W. and Hickey, L.J. 1990. An Aptian plant with attached leaves and flowers: implications tor angiosperm origin. *Science* 247: 701-704.

Taylor, D.W. 1991. Angiosperm ovules and carpels: their characters and polarities, distribution in basal clades, and structural evolution. *Postilla* 208: 1-40.

Templeton, A.R. 1989. The meaning of species and speciation: a genetic perspective. In: Otte, D. and Endler, J.A. (eds.), *Speciation and Its Consequences*. pp. 3–27. Sinauer, Sunderland, MA.

Than, M.M.M., Samaddar, T., Bhowmick, B.K. and Jha, S. 2017. Fluorescent Chromosome Banding and Genome Size Estimation in three species of *Swertia*. *Cytologia* 82(5): 513-520.

Thien, L.B., Bernhardt, P., Devall, M.S., Chen, Z.D., Luo, Y.B., Fan, J.H., Yuan, L.C. and Williams, J.H. 2009. Pollination biology of basal angiosperms (ANITA grade). *American Journal of Botany* 96(1): 166-182.

Thorne, R.F. & Reveal J.L. 2007. An Updated Classification of the Class Magnoliopsida ('Angiospermae'). *Botanical Review* 73(2): 67–181.

Tripathi, A.M., Tyagi, A., Kumar, A., Singh, A., Singh, S., Chaudhary, L.B. and Roy, S. 2013. The internal transcribed spacer (ITS) region and *trn*H-*psb*A are suitable candidate loci for DNA barcoding of tropical tree species of India. *PloS one* 8(2): e57934.

Turesson, G. 1922. The species and the variety as ecological units. *Hereditas* 3(1): 100-113.

Turland, N.J. 2019. *The Code Decoded*. Advanced Books, Pensoft Publishers.

Turland, N.J., *et al.* (eds.) 2018. *International Code of Nomenclature for algae, fungi, and plants* (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. Regnum Vegtabilis 157. Koeltz Botanical Books, Glashütten.

Turrill, W.B. 1935. The Investigation of Plant Species. *Proceedings of the Linnean Society of London* 147: 104–105.

Turrill, W.B. 1938. The Expansion of Taxonomy with Special Reference to Spermatophyta. *Biological Reviews* 13: 342–373.

Van Valen, L. 1976. Ecological species, multispecies, and oaks. *Taxon* 25: 233-239.

Vos, P., Hogers, R., Bleeker, M., Rijans, M., van der Lee, T., Hornes, M., Frijters, A., Pot, J., Peleman, J., Kuiper, M. and Zabeau, M. 1995. A new technique for DNA fingerprinting. *Nucleic Acids Research* 23: 4407–4414.

Wang, X. 2019. Origin of Angiosperms and their Diversification in the Cretaceous. *Open Journal of Geology* 9(10): 577-580.

Wang, Z., Chi, Z., Feng D. and Wang, Q. 2000. Leaf Image Retrieval with Shape Features, *Lecture Notes in Computer Science: Advances in visual information systems*, R. Laurini (Ed.), Springer-Verlag, pp. 477-488.

Waterhouse, R.M., Zdobnov, E.M., Tegenfeldt, F., Li, J. and Kriventseva, E.V. 2011. OrthoDB: the hierarchical catalog of eukaryotic orthologs in 2011. *Nucleic Acids Research* 39: 283-288.

Wen, J., Egan, A. N., Dikow, R. B., and Zimmer, E. A. 2015. Utility of transcriptome sequencing for phylogenetic inference and character evolution. In: Hörandl, E. and Appelhans, M. S. (eds) *Next-generation sequencing in plant systematics*, pp. 51–91. International Association for Plant Taxonomy (IAPT).

Wettstein, R. 1907. *Handbuch der svstematischen Botanik*. Deuticke, Leipzig.

Wettstein, R. 1924. *Handbuch der systematischen Botanik*, ed. 3. Deuticke, Leipzig.

Wickett, N.J., Mirarab, S., Nguyen, N., Warnow, T., Carpenter, E., Matasci, N., Ayyampalayam, S., Barker, M.S., Burleigh, J.G., Gitzendanner, M.A. and Ruhfel, B.R. 2014. Phylotranscriptomic analysis of the origin and early diversification of land plants. *Proceedings of the National Academy of Sciences* 111(45): E4859-E4868.

Wiley, E.O. and Lieberman, B.S. 2011. *Phylogenetics: Theory and Practice of Phylogenetic Systematics.* Second Edition. Wiley Blackwell.

Wiley, E.O. 1978. The evolutionary species concept reconsidered. *Systematic Zoology* 27(1): 17-26.

Wilkins, J.S. 2009. *Defining species: a sourcebook from antiquity to today*. Peter Lang, New York.

Wilmott, A.J. 1949. Intraspecific categories of variation. In: Wilmott, A.J. (ed), *British flowering plants and modern systematic methods.* Taylor and Francis, London.

Yadav, P.B., Manning, J.C., Yadav, S.R. and Lekhak, M.M. 2019. A cytotaxonomic revision of *Drimia* Jacq. (Hyacinthaceae: Urgineoideae) in India. *South African Journal of Botany* 123: 62-86.

Yang, L., Su, D., Chang, X., Foster, C.S., Sun, L., Huang, C.H., Zhou, X., Zeng, L., Ma, H. and Zhong, B. 2020. Phylogenomic Insights into Deep Phylogeny of Angiosperms Based on Broad Nuclear Gene Sampling. *Plant Communications* 1(2): 100027.

Zeng, L., Zhang, Q., Sun, R., Kong, H., Zhang, N. and Ma, H. 2014. Resolution of deep angiosperm phylogeny using conserved nuclear genes and estimates of early divergence times. *Nature Communications* 5(1): 1-12.

Zimmer, A., Lang, D., Richardt, S., Frank, W., Reski, R. and Rensing, S.A. 2007. Dating the early evolution of plants: detection and molecular clock analyses of orthologs. *Molecular Genetics and Genomics* 278(4): 393-402.