Evidences from Cytology-1

Unit 3: Systematics- An Interdisciplinary Science

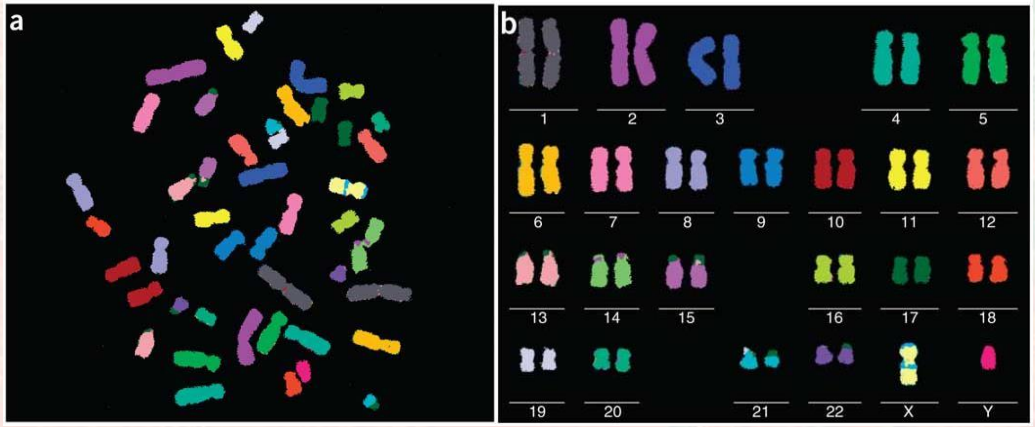
B. Sc (Hons.) Botany II year Semester IV

CC-10: Plant Systematics

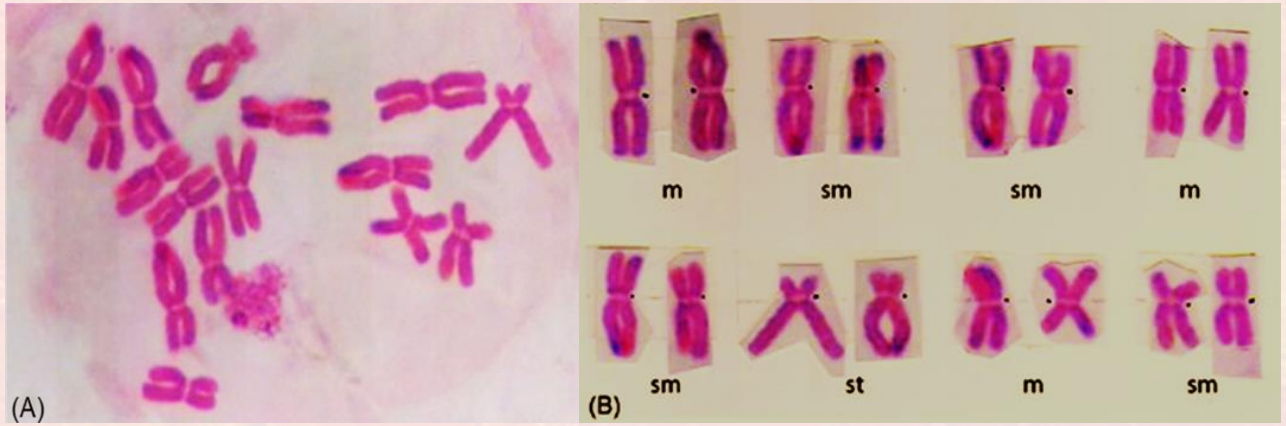
Dr Madhu Rani

Department of Botany, DBC, DU

madhupriya1999@gmail.com



Human chromosome painting (FISH)
a. Metaphase-chromosome spread. b. Karyotype
Source: http://www.nature.com/nprot/journal/v1/n3/images/nprot.2006.160-F4.jpg



(A) Diploid metaphase chromosome. (B) its karyotype from the root cells of onion (Allium cepa L.) containing 2n = 16.

Source: Peter Firbas & Tomaž Amon (2014) Chromosome damage studies in the onion plant Alliumcepa L., Caryologia: International Journal of Cytology, Cytosystematics and Cytogenetics, 67:1, 25-35, DOI:10.1080/00087114.2014.891696
https://www.researchgate.net/publication/263610179_Chromosome_damage_studies_in_the_onion_plant_Allium_cepa_L

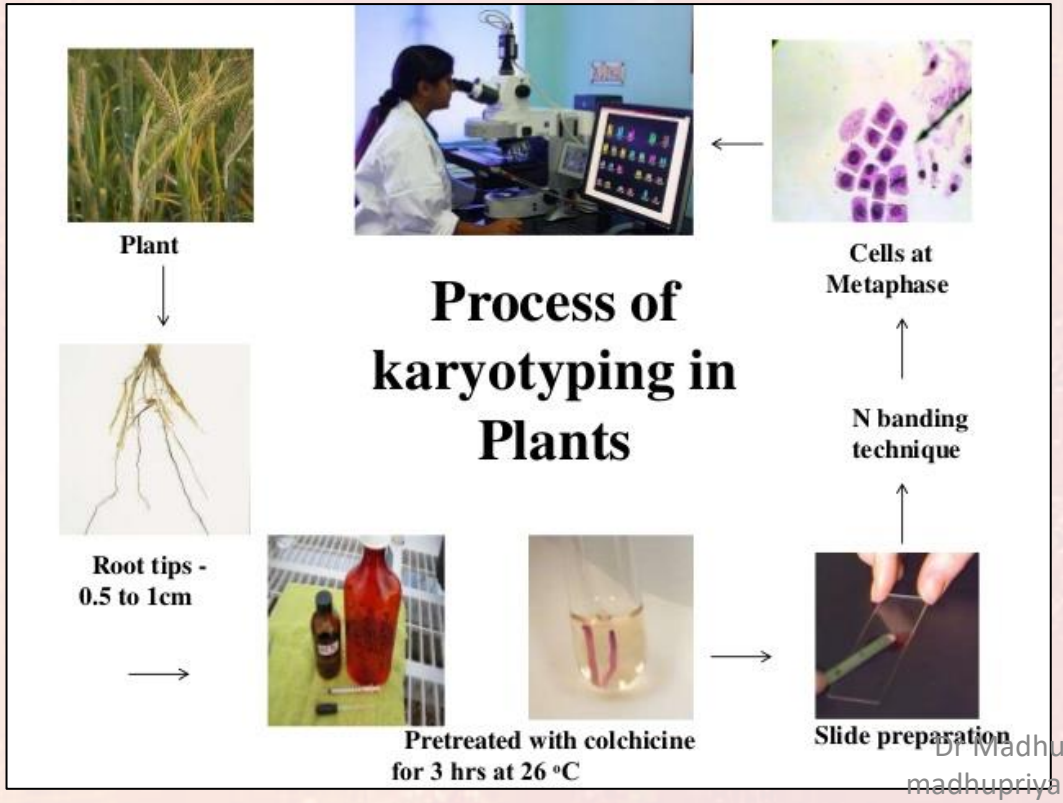
Remember this flower?

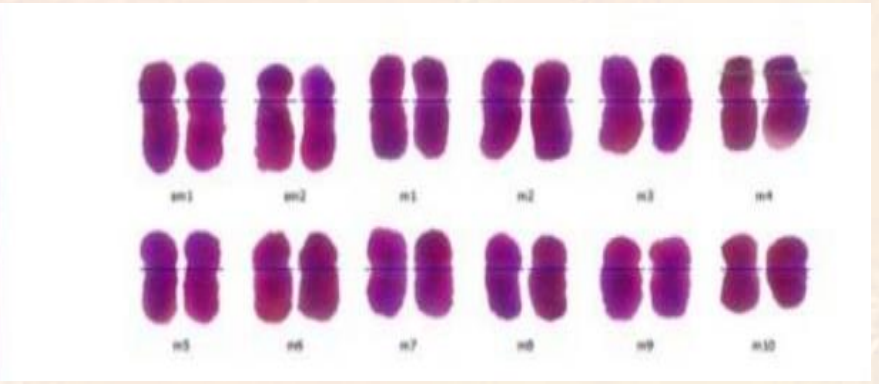
Answer at last slide

Taxonomic Evidences from Cytology

- Taxonomy deals with identification, nomenclature and classification of objects.
- The classical taxonomists advocate that this can be achieved by studying mainly the comparative morphology and geographic distribution.
- In the 20th century it has been established that the alpha classification based on **exomorphology** is not adequate.
- As a result, taxonomy has entered the `Synthetic phase' and evidences from various fields have been taken into consideration in addition to exomophology.
- One such field which has influenced taxonomy to a great extent during the past few decades is **cytology**.
- The application of cytological data in elucidation of taxonomic problems includes the study of various attributes of chromosomes, like-
  - ❖ Chromosome number
  - ❖ Chromosome size
  - ❖ Chromosome morphology
  - ❖ Behavior of chromosomes at meiosis
  - ❖ Chromosomal aberrations in reproduction
  - ❖ Banding pattern

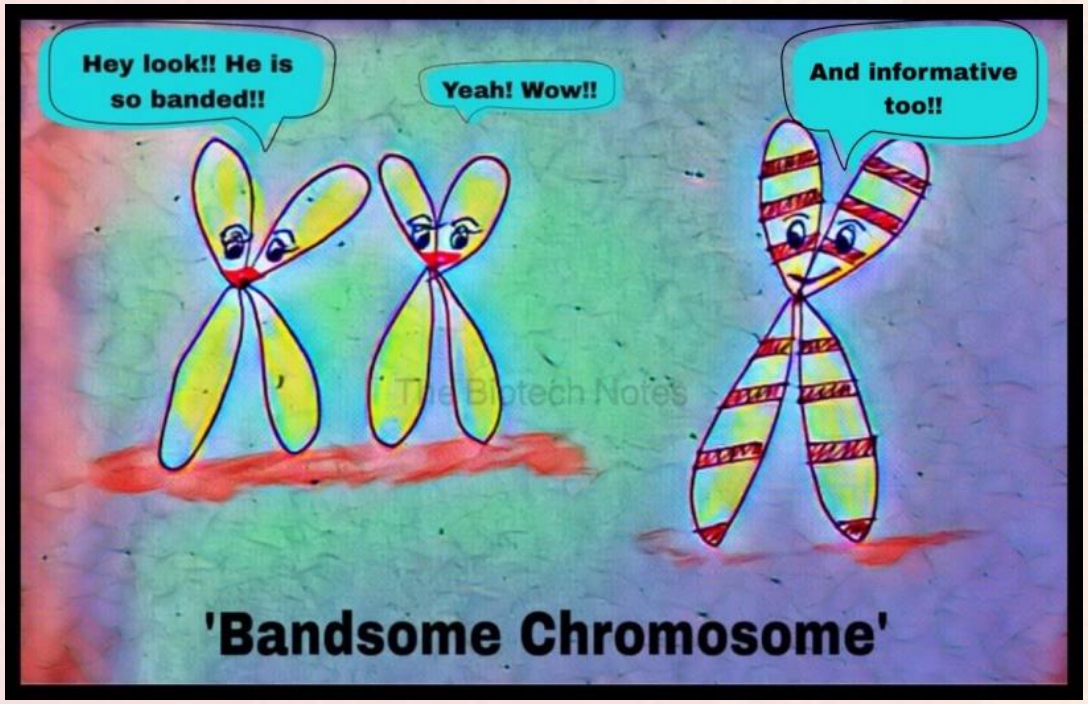
- To study cytological parameters of a species, or more specifically the Karyology of a species, the somatic chromosome spread at metaphase is studied.
- The appearance of somatic chromosomes at mitotic metaphase is termed as the **Karyotype.**
- A **Karyotype** can be defined as – "**the phenotypic appearance of the somatic chromosomes** (Levitsky, 1924)" or simply "**the basic chromosome set of a somatic cell (under metaphase) as seen under the light microscope**".
- A part of the plants such as root-tips, young leaves etc. are easily prepared for cytological examination by routine techniques such as acetocarmine squashes.





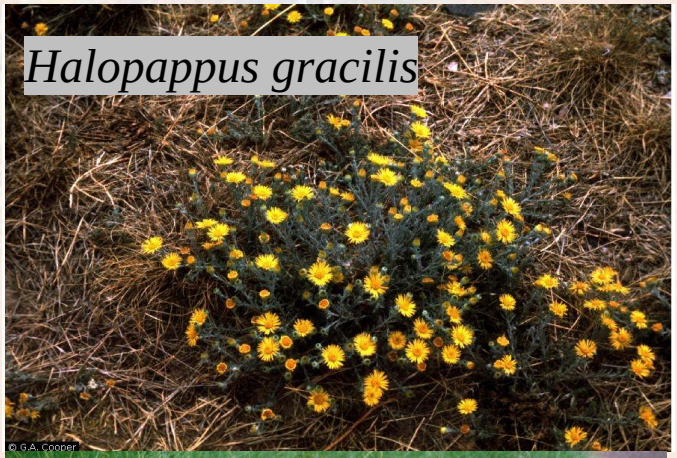
This is how chromosome spread appear in microscope. The view is captured through imaging system and printout is taken. The chromosome pics are cut and arranged according to size in homologous pairs to get a karyotype.

- The first step in cytotaxonomy is sampling of a taxon and study of chromosomes of many populations within geographic races or species.
- Differences in chromosome number, their morphology and behaviour at meiosis usually indicates genetic differences of taxonomic significance.
- Succeeding step includes the determination of the ability of different populations to hybridise.
- This reveals the presence or absence of breeding barriers between groups and is of great taxonomic importance as this indicates the limits of the taxa.



1. Chromosome Number

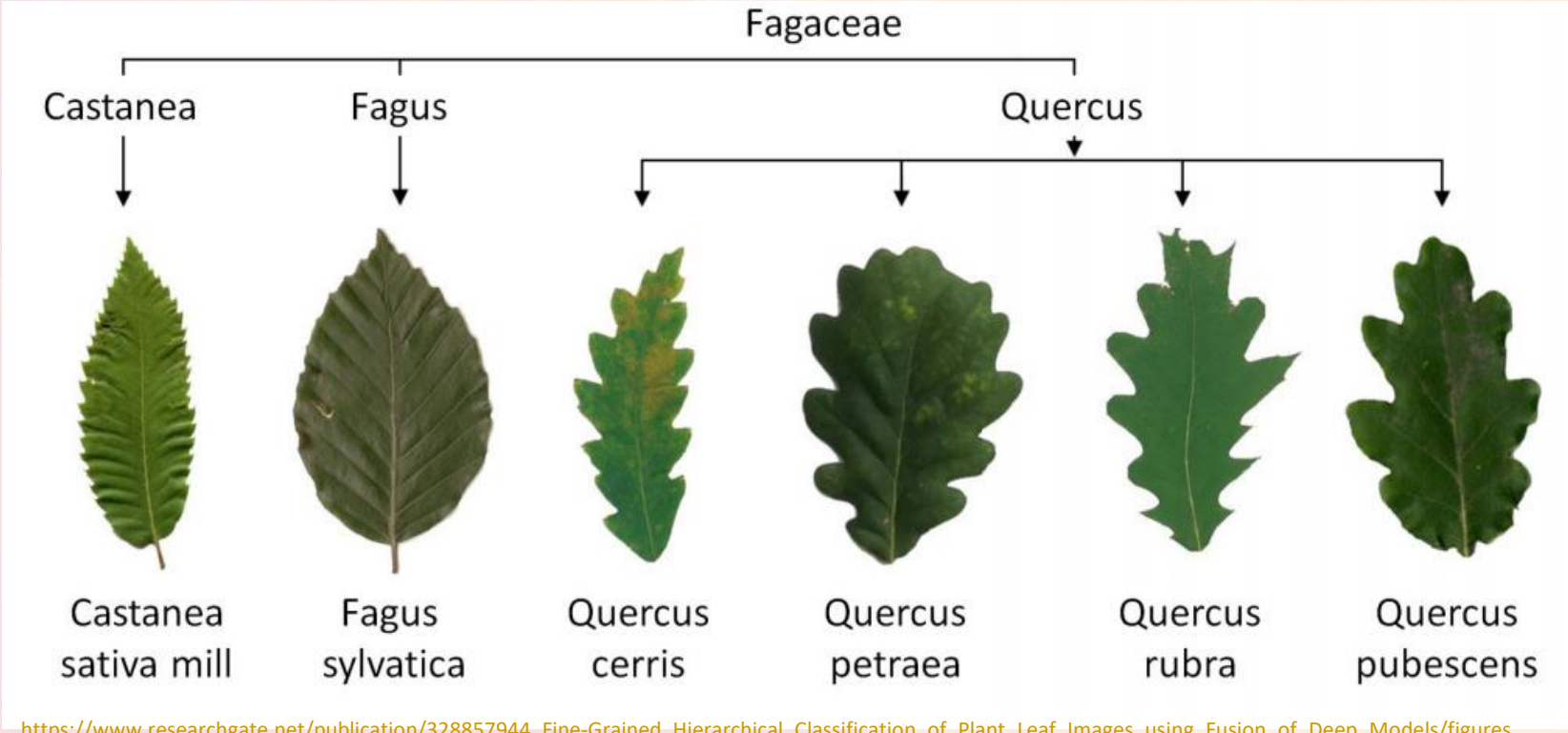
- The importance of chromosome number as a taxonomic character is that it is usually constant within a species. However, there are exceptions where chromosome numbers vary.
- The haploid number of chromosomes in Angiosperms ranges from n = 12 in *Halopappus gracilis* (Asteraceae) to about n = 132 in *Poa litorosa* (Poaceae).
- Most of the angiosperms have chromosome numbers ranging between n=7 and n=12. About 35 to 40% per cent of the flowering plants are polyploids.
- It is usually seen that closely related plants, like the different species of a genus, show chromosome numbers which reveal an arithmetic relation with one another – often in multiples of base number, characteristics of the genus.



- For example- the different species of *Piper* show chromosome numbers in multiples of 26, like **2n = 52** in ***P. nigrum***, **2n = 78 in *P. betle***, and **2n = 104 in wild species of *Piper*** (Mathew, 1958).
- In *Morus nigra* has the highest chromosome number (2n = 308), in *M. cathyana* there are forms with 2n = 56, 84; 112.
- *Solanum nigrum* is a good example of the existence of a species complex, comprising diploid (n = 12), tetraploid (n = 24) and hexaploid (n = 36) forms.

The chromosome number relationship with taxonomic groups can be broadly classified into the following three classes

1. Constants number: in certain groups of vascular plants the chromosome number is constant throughout the whole group example *Quercus* and other member of the Fagaceae have the same basic number and is equal to 12. In such cases chromosome number is not of any help in distinguishing various taxa within the group.



https://www.researchgate.net/publication/328857944_Fine-Grained_Hierarchical_Classification_of_Plant_Leaf_Images_using_Fusion_of_Deep_Models/figures

2. Euploidy: when the chromosome numbers in various members of a taxon are in the proportion of exact multiples, the series is described as euploidy. For example, in family Malvaceae, the basic numbers in various species range from 10, 15, 20, 25, till 40; from 12, 18, 24 to 30; from 14, 28, 42, 56 to 84 and so on.

https://keyserver.lucidcentral.org/key-server/data/04030b04-0102-4b0c-8e07-0e0105010a0f/media/Html/Malvaceae.htm

Basic Chromosome number-

- In an euploid series, the various members may share a common basic number (x) which is the gametic number of diploid species.
- As in in family Malvaceae, the basic number x = 5. The other species in the series are described as triploids (3x), tetraploids (4x), hexaploids (6x), and polyploids (nx).
- The basic number is usually constant for a genus or higher taxa and has proved useful in supraspecific studies.

Chlorophytum

Primary and secondary basic numbers –

- In many cases, more than one basic number can be present in a group.
- For example, in the living species of *Chlorophytum* of the family Liliaceae, the chromosome numbers vary from 14 to 28, 42, 56, 84, etc. and also from 16 to 32. This indicates that *Chlorophytum* has two basic numbers x=7 and x=8.
- In such cases, the inferred base numbers ranging between 2 and 13 may be referred to as a **primary basic numbers** in the absence of living deployed members. The remaining are termed **secondary basic numbers**.
- However, in case of *Chlorophytum*, detailed analysis of the meiotic behaviour of chromosomes in one of the species, *C. laxum*, has shown that the two base numbers 7 and 8 should be considered as secondary, most probably derived from the primary basic number x = 4.

Dr Madhu Rani, Department of Botany, DU e-mail-madhupriya1999@gmail.com, WhatsApp-9412209655

Polyploid pairs-

- Closely related species in certain groups of plants may be cytologically distinct, i.e one may be diploid while the other is a tetraploid. Such related pairs are termed polyploid pairs.
- For example- *Cardamine hirsuta* (2n=16) and *C. flexuosa* (2n= 32) of the family Cruciferae is a polyploid pair.

Dibasic polyploidy-

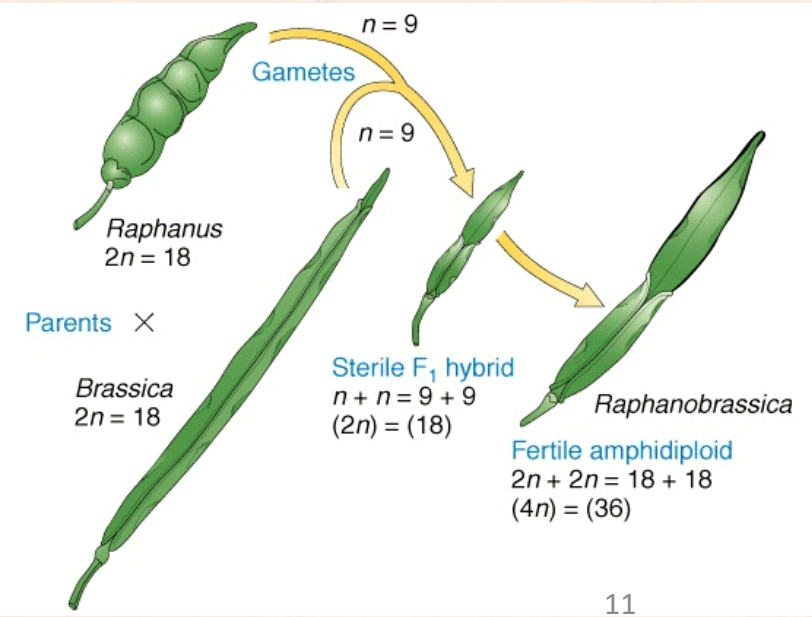
- It is now a well-known fact that hybridization has a dominant role in evolution and such hybridization may involve crossing of any two genetically unlike individuals, which have different base numbers of chromosomes.
- Such hybrids undergo polyploidy since each chromosome is doubled, and as a result the pairing at meiosis is restored. This type of polyploidy is termed as dibasic polyploidy.
- An excellent example of this type of polyploidy is artificially synthesized *Raphanobrassica*, which is a hybrid between *Brassica oleracea* (2n=18) and *Raphanus sativus* (2n=18) and has 2n = 36 chromosomes.

***Raphanus sativus* (2n=18)**

X

***Brassica oleracea* (2n=18)**

***Raphanobrassica* (2n = 36)**



Any deviation from the normal chromosome number of an organism at any stage in its life cycle is termed heteroploidy.

Various categories of heteroploidy are:

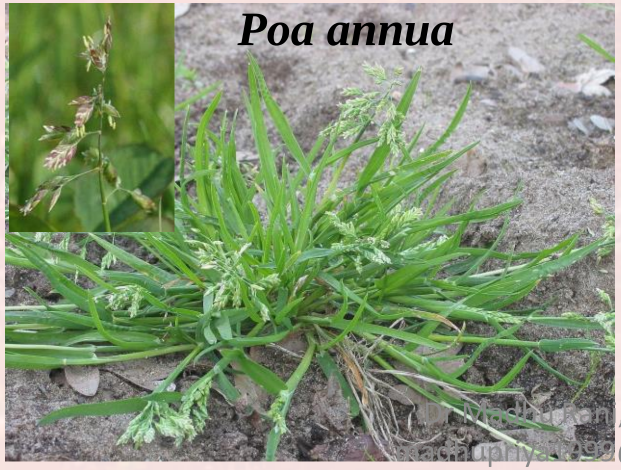
1. Euploidy: A change in chromosome number- either decreases or increases in the number by a complete genome is euploidy. Several types of euploidy are haploidy, polyhaploidy, diploidy and polyploidy.

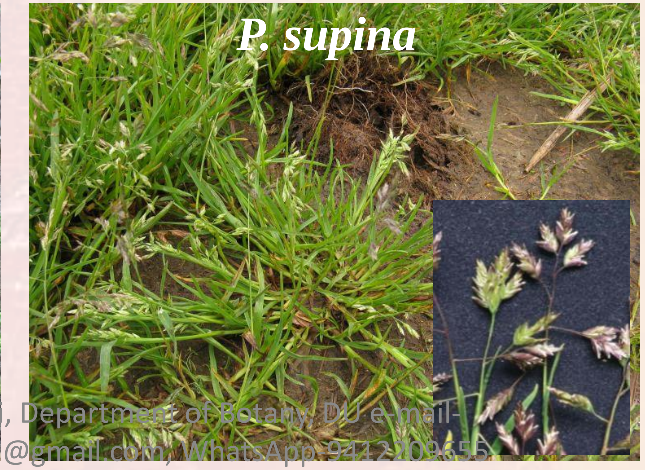
- **Haploidy**: (Monoploidy): This occurs when the normally diploid phase of an organism has only one genome. Haploidy has been reported for a number of economically important plants.

- **Polyhaploidy:** When a polyploid gives rise to individuals with half the chromosome number of the parent, the result is a polyhaploid, and is reported in some species of *Bromus*, *Dactylus*, *Dichanthium*, *Medicago* and *Parthenium*.

- **Polyploidy:** The most common variation in chromosome number involves polyploidy which is widespread in Angiosperms and has been reported for about 47% of Angiosperms.
- It plays an important role as an evolutionary mechanism as well as it poses problems for the taxonomist.
- Polyploidy is the occurrence of multiple chromosome sets in an organism, and mostly formed as a result of the doubling of chromosomes of hybrids formed between separate species, or at least between different races of the same species.
- Polyploidy is considered as a mechanism of abrupt species formation successfully.
- Although polyploid pairs are easily separable sometimes, it poses grave difficulty majority of time as reflected in their treatment as subspecies (varieties of a single species).
- For instance- in case of *Ranunculus ficaria*, which contains 2n, 3n, 4n, 5n and 6n races in Europe.
- Polyploidy is often a means by which sterile hybrids between distinct species overcome their sterility by chromosome doubling. *Poa annua* (2n=28) is derived from *P. supina* (2n=14) x *P. infirma* (2n=14).


Ranunculus ficaria


Poa annua


P. supina


P. infirma

Dr Madhu Rani, Department of Botany, DU e-mail- madhupriya1999@gmail.com, WhatsApp-9412209655

Aneuploidy:

- This involves an increase or a decrease in chromosome number by less than a complete genome.
- Increases in number have been referred to as **ascending aneuploidy**, while decrease in number have been termed **descending aneuploidy**..
- For example- Various species of *Carex* (family Cyperaceae) show a wide range of chromosome numbers from n=6 to 112 with multiples of 5, 6, 7 and 8 exhibiting aneulpoidy.

Aneuploidy may result due to following reasons:

1. **Change in the basic chromosome number-**
   - an increase or decrease in the number of chromosomes may occur, leading to a change in the basic chromosome number.
   - This phenomenon is important from the taxonomic and evolutionary point of view as change in the basic number result in new variations and their combinations leading to the evolution of new varieties and ultimately to new species.
   - The changes in the basic number of chromosomes can lead **polysomy**.
   - Such processes are common in nature and results in increased sets of genes- duplication of one chromosome or a pair of chromosomes.

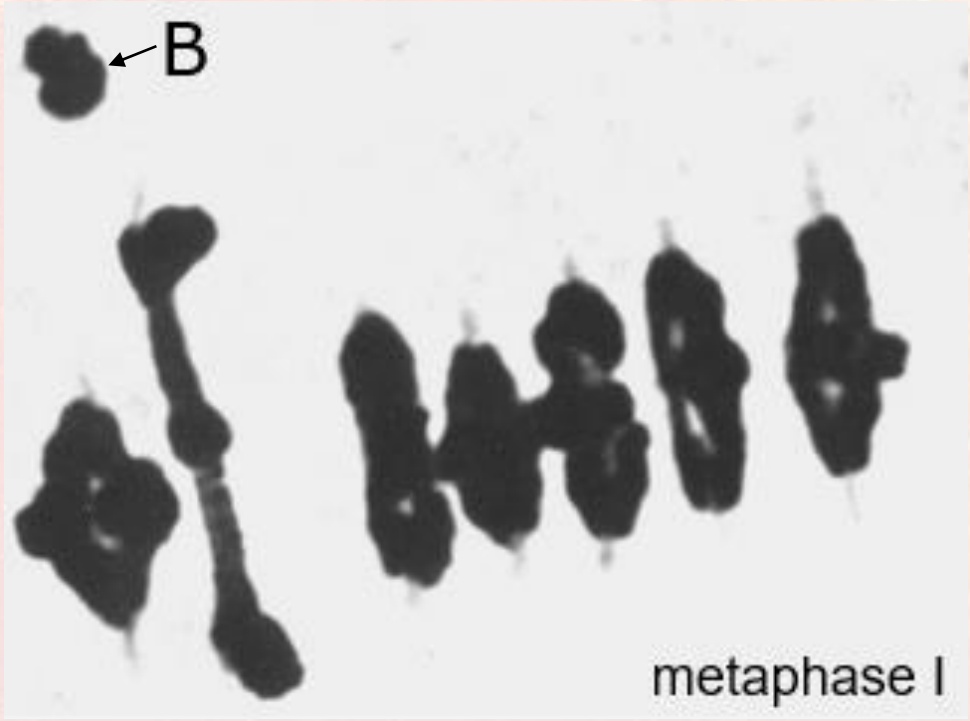
- Polysomics can be of various types:
  - Trisomics- Plants containing one extra chromosome, 2n + 1.
  - Tetrasomics- Plants containing 2 extra chromosomes, 2n + 2.
  - Monosomics- Plants with one chromosome less, 2n -1.
  - Nullisomics- Plants with two chromosomes less, 2n - 2.

- Polysomics are usually unstable.
- Since they are not isolated genetically from their relatives under natural condition, they would lose their identity during crossing with normal plants.
- This may be followed by natural selection for more viable, genetically balance normal disomic types.

In the family Poaceae different subfamilies, tribes and genera can be characterized to varying extents by their base numbers. For example, the allegedly primitive subfamily Bambusoideae has x=12 while the subfamily Pooideae has mostly x=7. But within the latter certain tribes (e.g. Glycerieae) or genera (e.g. *Anthoxanthum*) deviate consistently and illustrate the relative nature of the concept of base numbers. Glycerieae has x=10 and *Anthoxanthum* has x=5.

B chromosomes-

they are one or more accessory or supernumerary chromosomes in addition to normal chromosomes and have been detected in a large number of plants. These chromosomes are generally much smaller in size as compared to the normal chromosome complement and are of unknown origin, they reduce fertility or increase the vigor of plants. it has been found that they perpetuate in certain natural populations and may have some evolutionary significance.



https://nph.onlinelibrary.wiley.com/doi/full/10.1002/ppp3.16

Dr Madhu Rani, Department of Botany, DU e-mail-madhupriya1999@gmail.com, WhatsApp-9412209655

Be Calm and safe

Allium flower

Dr Madhu Rani, Department of Botany, DU e-mail-madhupriya1999@gmail.com, WhatsApp-9412209655