POLYPLOIDY IN PLANTS

Disclaimer

All the content material provided here is only for teaching purpose.

Contents

What is polyploids ?

- Polyploids are organisms with multiple sets of chromosomes in diploid number .

- Polyploidy is common in nature and provides a major mechanism for adaptation and speciation.

- Approximately 50-70% of angiosperms, which include many crop plants, have undergone polyploidy during their evolutionary process.

Classification of polyploids

- based on their chromosomal composition

  euploids

  aneuploids.

- Euploids constitute the majority of polyploids.

Euploidy

- are polyploids with multiples of the complete set of chromosomes specific to a species.

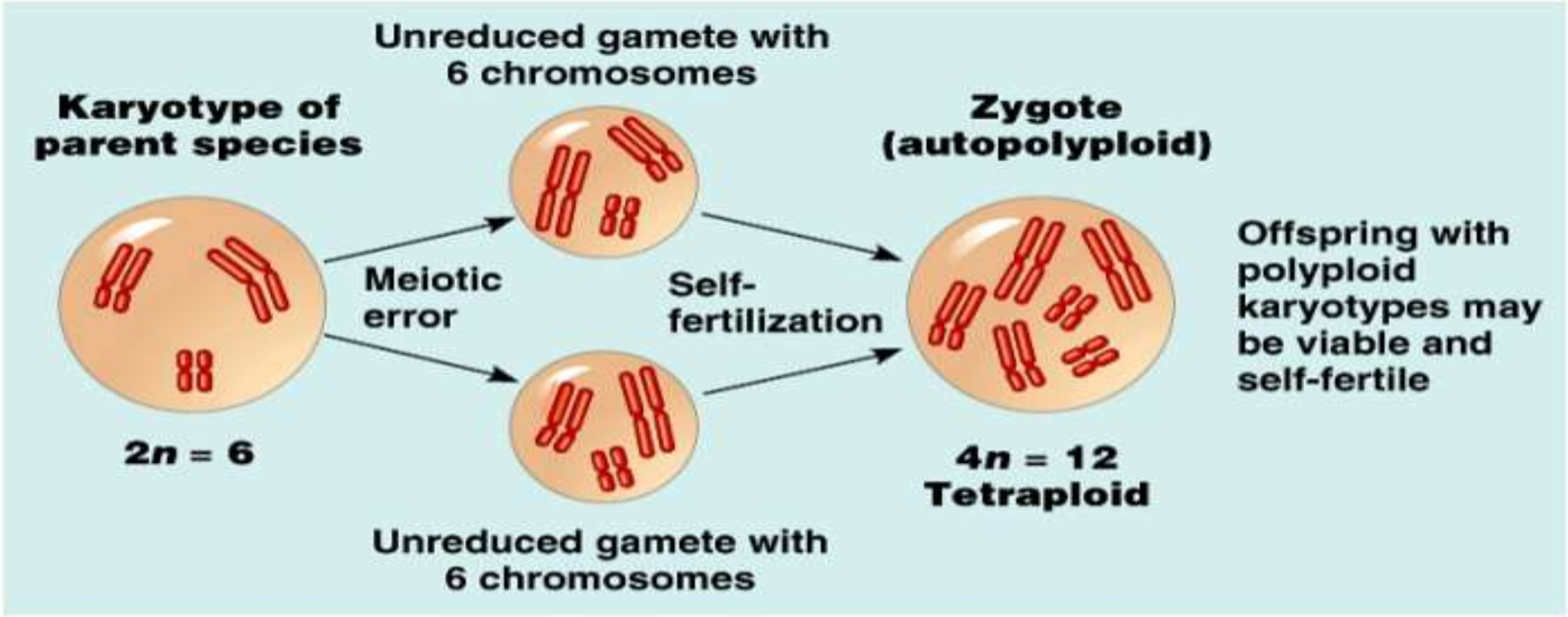
- Depending on the composition of the genome, euploids can be further classified into

autopolyploids

allopolyploids.

Autopolyploidy

- Containing of multiple copies of the basic set (x) of chromosomes of the same genome .



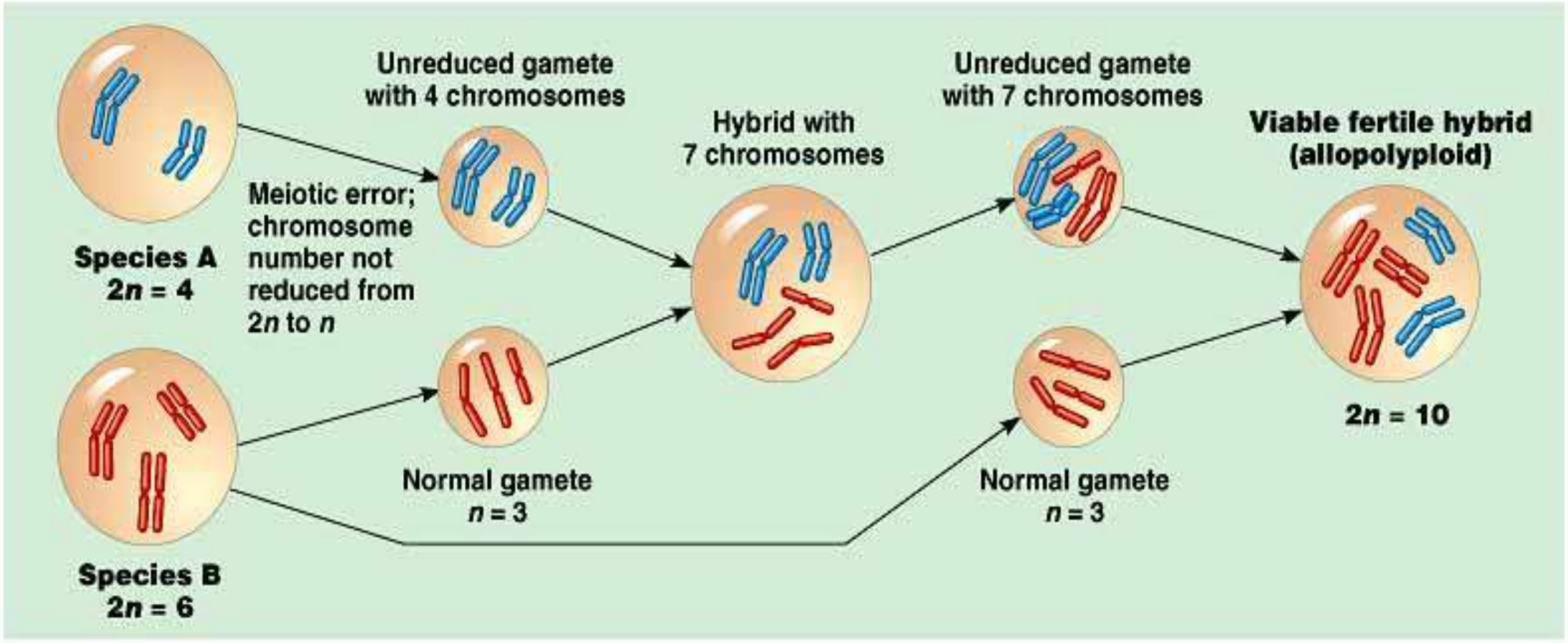
Autopolyploids

- occurs in nature through union of unreduced gametes.

- Natural autoploids include tetraploid crops such as alfafa, peanut, potato and coffee and triploid bananas.

Allopolyploidy

- A combination of genomes from different species .



- They result from hybridization of two or more genomes followed by chromosome doubling or by the fusion of unreduced gametes between species .

- This mechanism is called non-disjunction . These meiotic aberrances result in plants with reduced vigor.

- Economically important natural alloploid crops include strawberry, wheat, oat, upland cotton, oilseed rape, blueberry and mustard .

Aneuploidy

- are polyploids that contain either an addition or subtraction of one or more specific chromosome(s) to the total number of chromosomes that usually make up the ploidy of a species.
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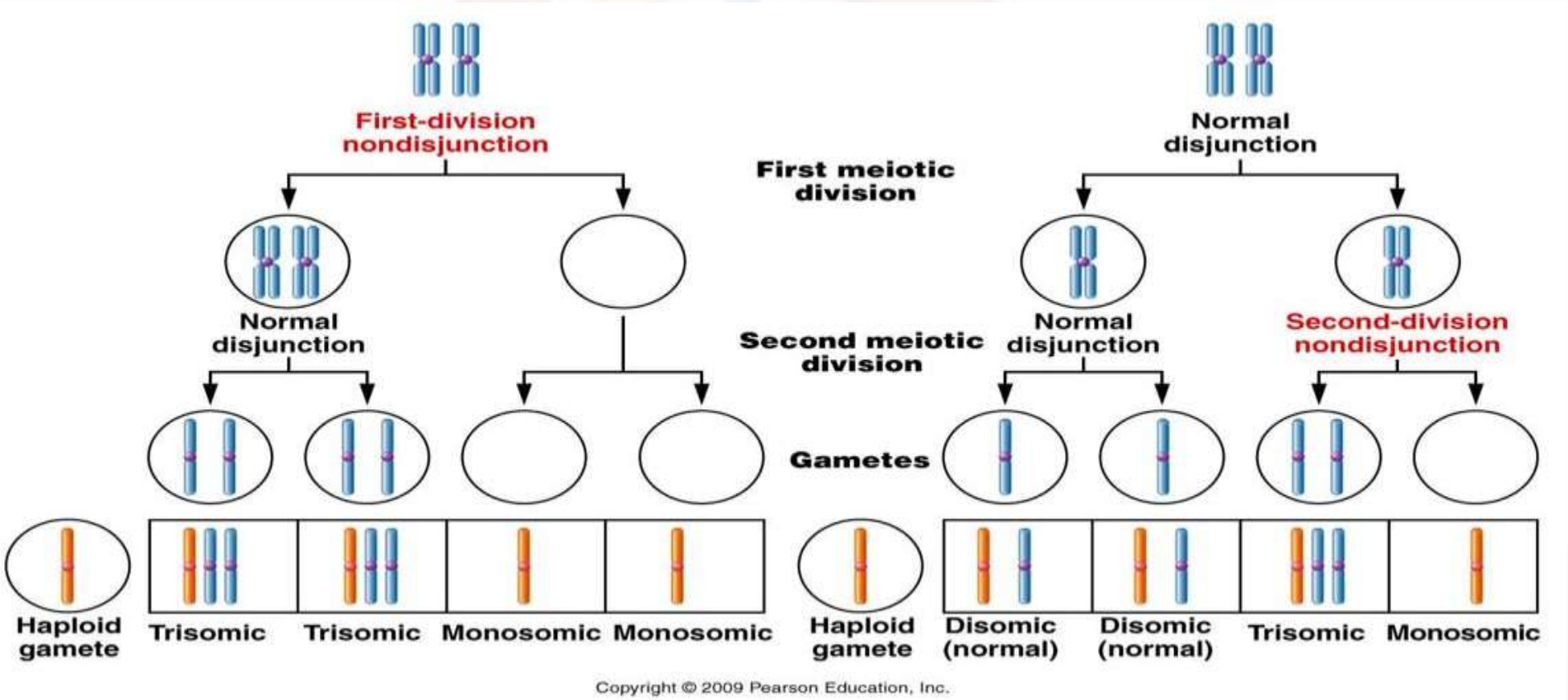


- Aneuploids result from the formation of univalents and multivalents during meiosis of euploids .

- With no mechanism of dividing univalents equally among daughter cells during anaphase I, some cells inherit more genetic material than others .

- Similarly, multivalents such as homologous chromosomes may fail to separate during meiosis leading to unequal migration of chromosomes to opposite poles.

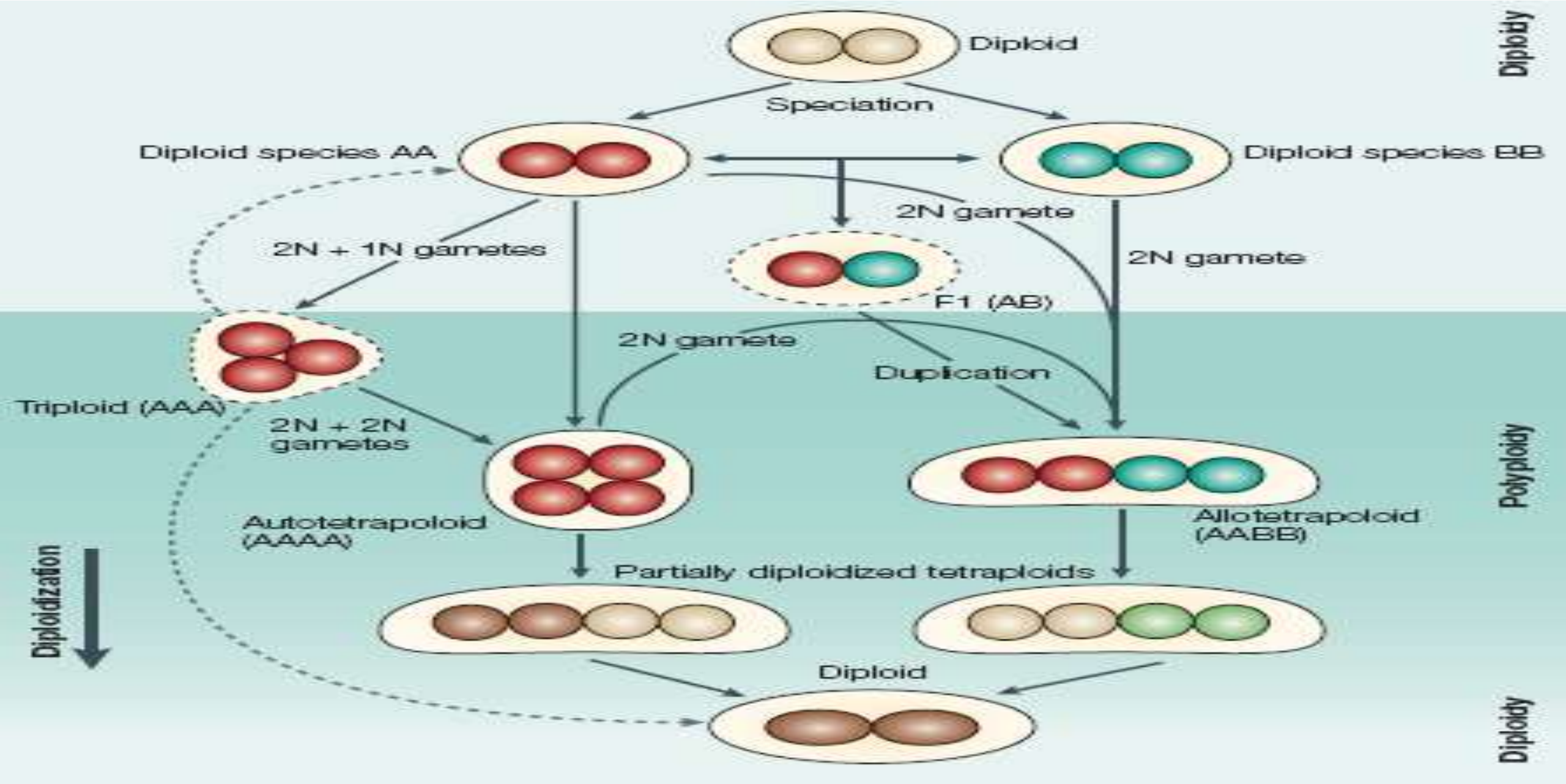
Classification of aneuploids

Term	Chromosome number
Monosomy	2n-1
Nullisomy	2n-2
Trisomy	2n+2
Tetrasomy	2n+2
Pentasomy	2n+3

Examples for polyploids

Common name	Ploidy	Name	Propagation
Maize	2x=20	Diploid	Outcrossing
Wheat	6x=42	Hexaploid	Outcrossing
Rice	2x=24	Diploid	Selfing
Potatoes	4x=48	Tetraploid	Outcrossing; Vegetative
Soybeans	2x=40	Diploid	Selfing
Barley	2x=14	Diploid	Selfing
Tomatoes	2x=24	Diploid	Selfing
Bananas	3x=33	Triploid	Vegetative
Watermelon	2x=22	Diploid	Outcrossing
Sugarcane	8x=80	Octoploid	Outcrossing; vegetative
Sugar beet	2x=18	Diploid	Outcrossing
Cassava	2x=36	Diploid	Outcrossing; Vegetative

How polyploids occur?



Inducing polyploids……

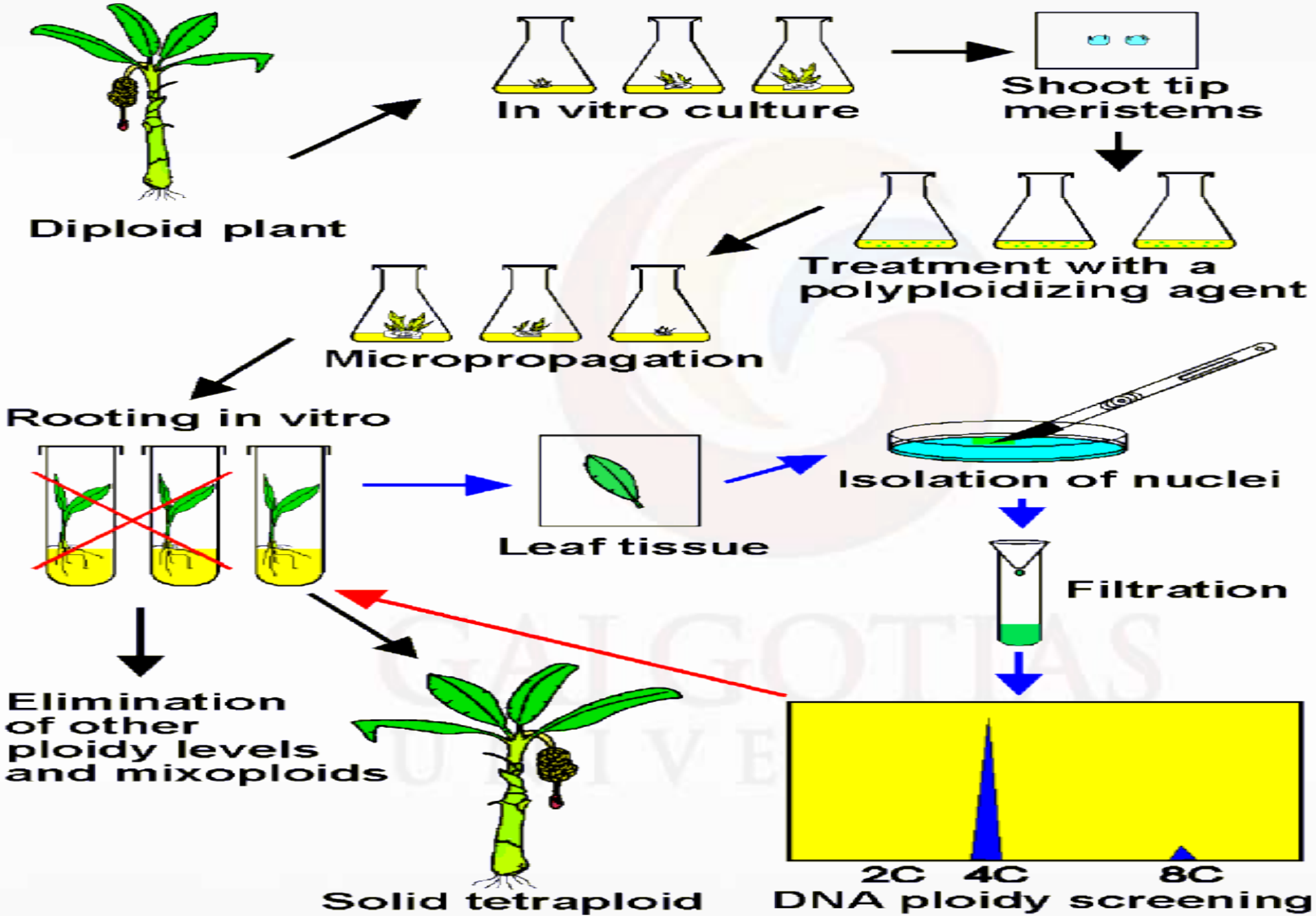
- They occur spontaneously through the process of chromosome doubling.
- Spontaneous chromosome doubling in ornamentals and forage grasses has led to increased vigour.
- Examples tulip

  forage grasses ryegrasses have yielded superior varieties following spontaneous chromosome doubling .

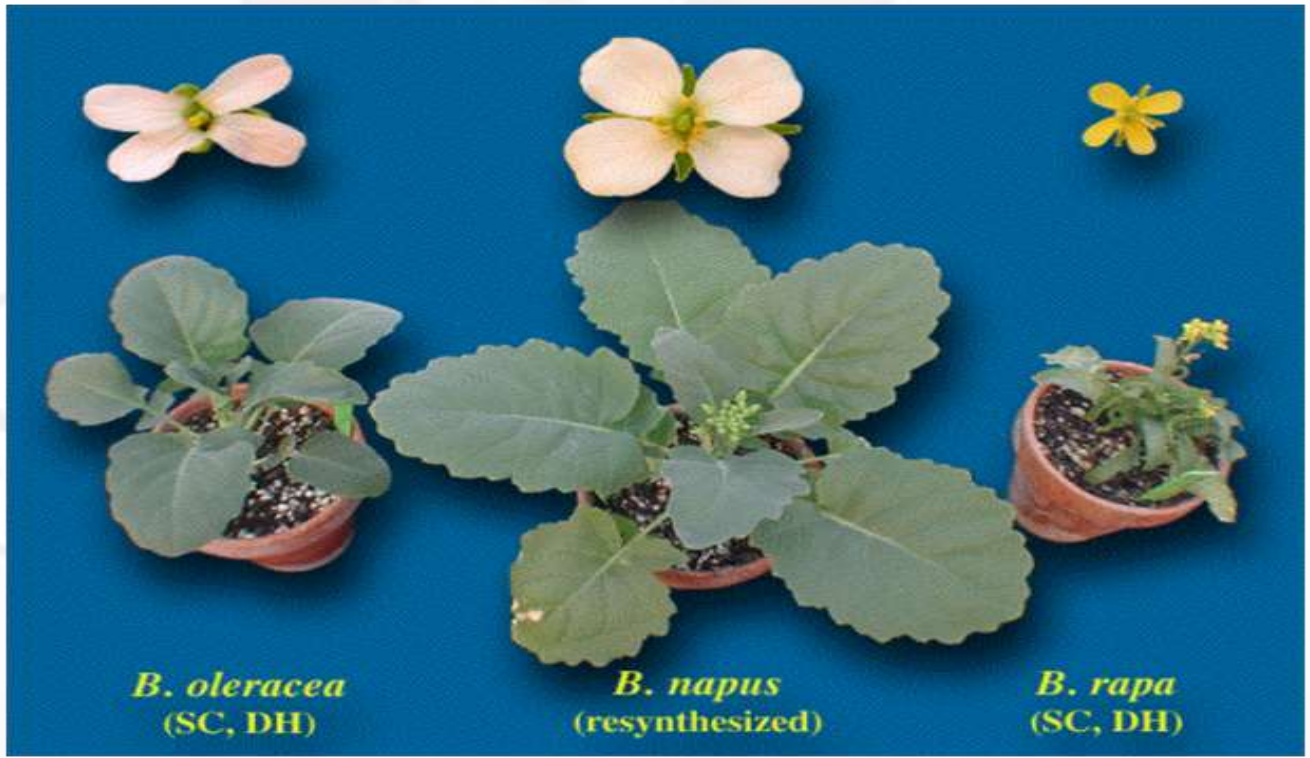
- breeders have harnessed the process of chromosome doubling *in vitro* through induced polyploidy to produce superior crops.

- For example, induced autotetraploids in the watermelon crop are used for the production of seedless triploid hybrids fruits.

- Such polyploids are induced through the treatment of diploids with mitotic inhibitors such as dinitroaniles and colchicine .

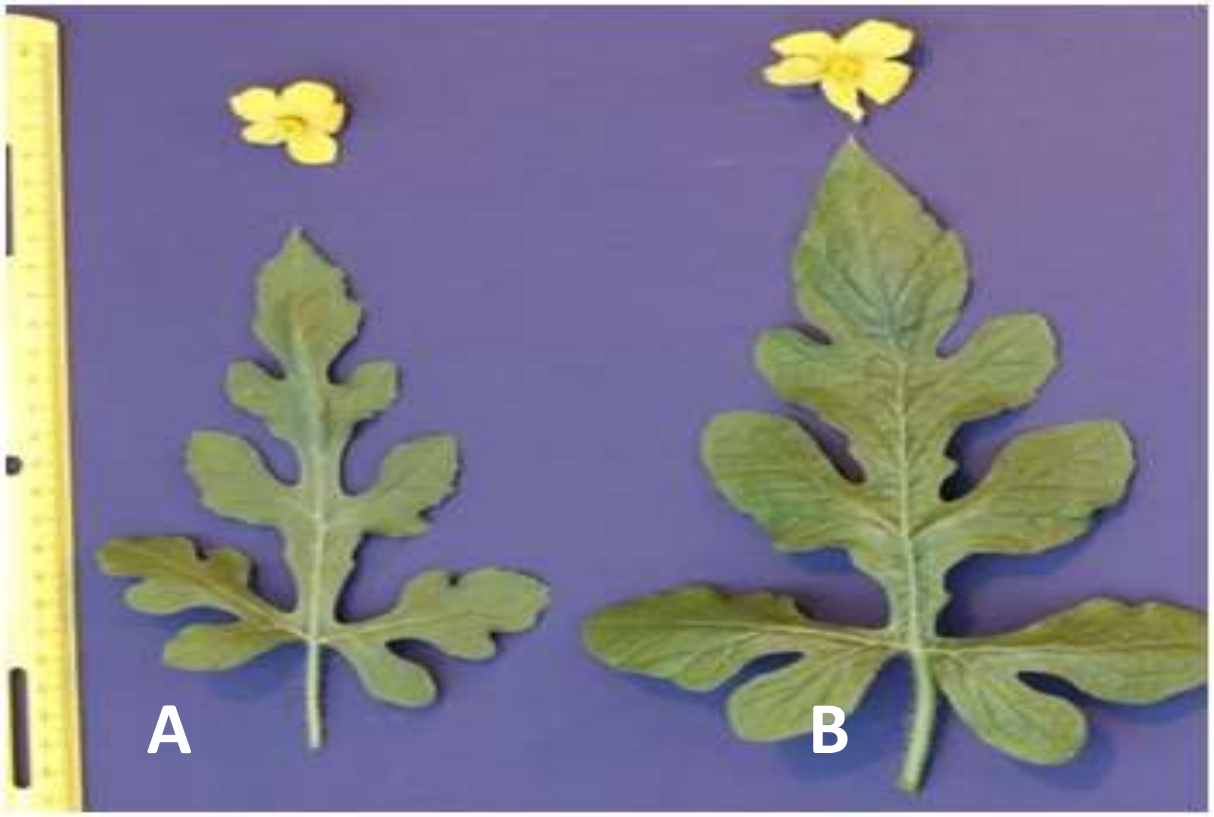

Diploid plant
In vitro culture
Shoot tip meristems
Treatment with a polyploidizing agent
Micropropagation
Rooting in vitro
Leaf tissue
Isolation of nuclei
Filtration
Elimination of other ploidy levels and mixoploids
Solid tetraploid
2C 4C 8C
DNA ploidy screening

- It is necessary to eliminate duplicated genes in a newly formed polyploid to avoid gene silencing as well as to stabilize fertility
- The increase in nuclear ploidy affects the structural and anatomical characteristics of the plant.
- Polyploidy results in increased leaf and flower size , stomatal density, cell size and chloroplast count



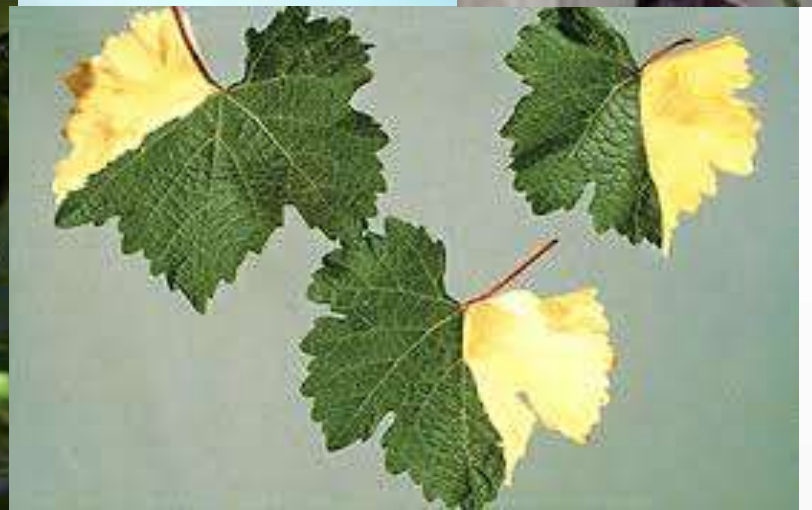
- Hybrid vigor resulting from interspecific crosses in allopolyploids is one of the most exploited advantages of polyploid in plant breeding.

A comparison between the leaf and flower of a (A) diploid and (B) induced tetraploid watermelon



Chimeras

- Plant or plant part composed of genetically different layers.



Type of chimeras

- **Mericlinal Chimera**
- A mutation occurs in one layer and along the side of the apex.🡪 Due to its position, the cell division products of those mutated cells occur as a layer on only one side of the plant and they are not stable
- only a section of one of the layers is mutated.🡪

- **Periclinal Chimera**
- A mutation occurs in one (or more) layer at the top of the apex.🡪 Due to its position, the cell division products of the mutated cells spread and cover the entire layer of the apex.
- The entire layer is mutated🡪 and they are stable and comprises the most common type chimeras in horticulture.

- **Sectorial Chimera** -A mutation occurs in multiple layers at the top of the apex.🔲 Due to its position, the cell division products of the mutated cells give rise to a section of mutated cells.🔲
- An entire section of the layer is mutated and stable and comprises the most common type chimeras in horticulture.

Applications in polyploids

- Mutation breeding
- Seedless fruits
- Bridge crossing
- Ornamental and forage breeding
- Disease resistance through aneuploidy
- Industrial applications of polyploidy

1 .Mutation breeding

- Mutation tolerance in polyploid crop improvement in two ways.

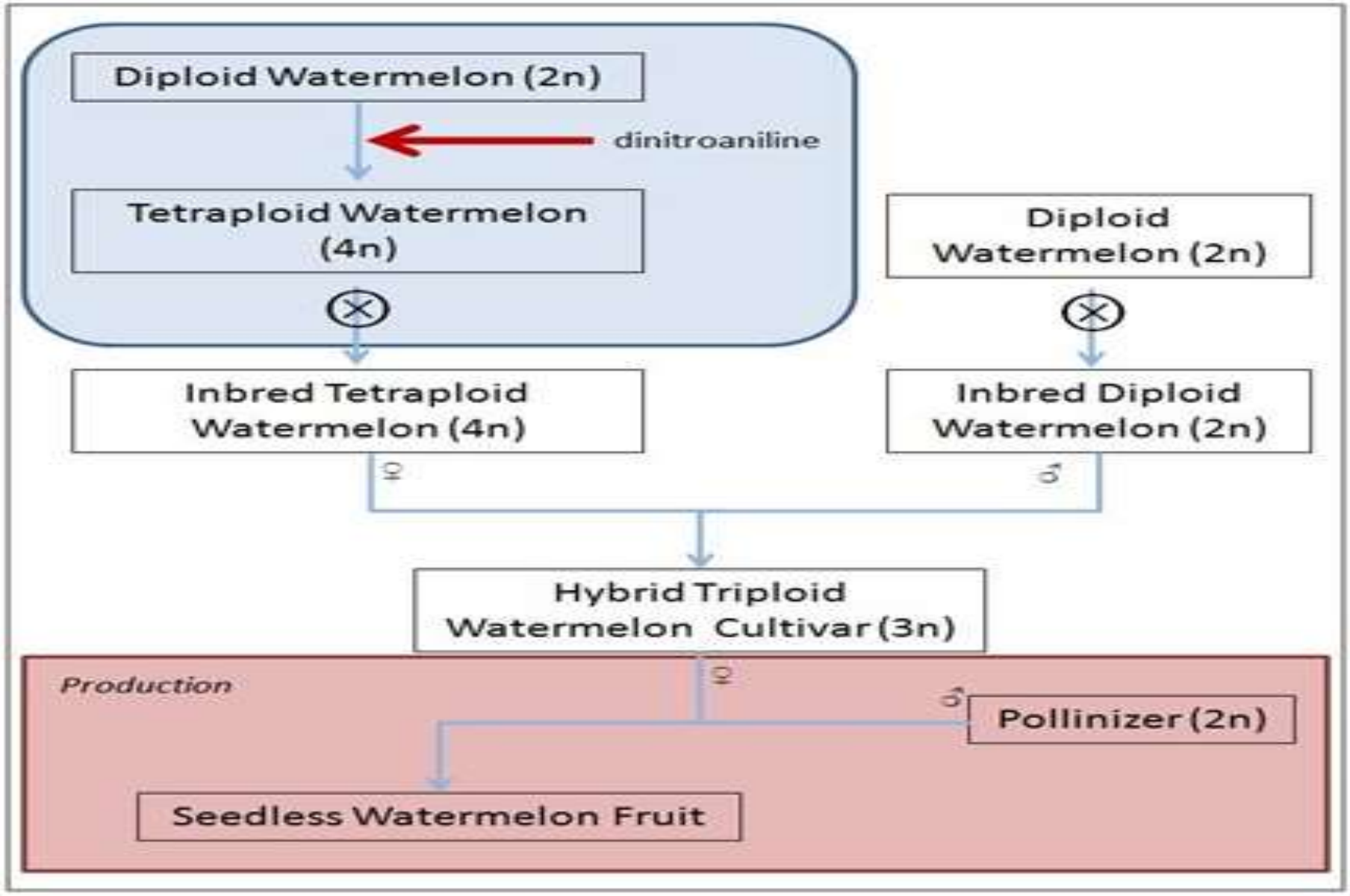
  1. polyploids are able to tolerate deleterious allele modifications post-mutation, and

  2. they have increased mutation frequency because of their large genomes resulting from duplicated condition of their genes .

- The high mutation frequencies observed with polyploids may be exploited when trying to induce mutations in diploid cultivars that do not produce enough genetic variation after a mutagenic treatment.

- This approach has been used in mutation breeding of *Achimenes sp.* (nut orchids) by first forming autotetraploids through colchicine treatment followed by the application of fast neutrons and X-rays. In this study, the autotetraploids were found to have 20-40 times higher mutation frequency than the corresponding diploid cultivar due to the large genome (Broertjes, 1976).

2 .Seedless fruits production



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- Utilize the reproductive superiority of polyploids .

- When sexual incompatibilities between two species are due to ploidy levels, transitional crosses can be carried out followed by chromosome doubling to produce fertile bridge hybrids.
- This method has been used to breed for superior tall fescue grass (*F. arundinacea*) from Italian ryegrass (2n=2x=14) and tall fescue (2n=6x=42) by using meadow grass (*Fescue pratensis*) as a bridge species .

- The same principle has been applied in fixing heterozygosity in hybrids by doubling the chromosomes in the superior progeny .

4 .Ornamental and forage breeding

- Polyploidy in plants is an increase in cell size which in turn leads to enlarged plant organs.
- This phenomenon termed as gigas effect .

- The increase in cell volume however is mainly attributed to increased water and not biomass.

- Although chromosome doubling may result in significantly larger seeds and increased seed-protein content in cereal crops, this advantage is offset by low seed set .

- Ornamental crops such as snapdragons and marigolds have been bred through chromosome doubling to improve the quality and size of their blossoms.

- The slower growth rate of polyploids allows them to flower later and for a longer period of time than their diploid progenitors . This quality may be of interest especially in ornamental breeding.

5 .Disease resistance through aneuploidy

- Aneuploidy applied in breeding to develop disease resistant plants through the addition of an extra chromosome into the progeny genome.

- Ex -: The transfer of leaf rust resistance to *Tricum aestivum* from *Aegilops umbellulata* through backcrossing. In addition, other breeding strategies utilizing aneuploidy have been explored including chromosome deletion, chromosome substitution and supernumerary chromosomes

6 .Industrial applications of polyploidy

- Commercial synthesis of sex hormones and corticosteroids has been improved significantly by artificial induction of tetraploids from diploid *Dioscorea zingiberensis*, native to China .

- Other plants whose production of terpenes has increased following artificial chromosome doubling .It enhances production of secondary metabolites such as alkaloids and terpenes in polyploids may concurrently offer resistance to pests and pathogens.

Advantages of polyploids

- Enlargement and Increased Vigor
- Creation of Sterile Triploids
- Restoring Fertility in Hybrids
- Overcoming Barriers in Hybridization
- Enhancing Pest Resistance and Stress Tolerance

Drawbacks in Polyploidy in Plant Breeding

- Inbreeding in polyploids
- Effect of polyploidy on sterility
- Effect of polyploidy on inheritance and population genetics

References:

1. Wolfe, K. H. (2001). "Yesterday's polyploids and the mystery of diploidization". *Nature Reviews Genetics*. **2** (5): 333–341
2. Tate, J. A.; Soltis, D. E.; Soltis, P. S. (2005). "Polyploidy in plants". In Gregory, T. R. (ed.). The Evolution of the Genome. San Diego, California: Elsevier. pp. 371–426.
3. Jarald E.D., Jarald S.E.(2007), Test book of pharmacognosy & Phytochemistry, 1st edition, CBSPublishers & distributors, New Delhi, p.no. 129-140
4. T.E.Walis, Textbook of pharmacognosy, 5th edition, published by CBS Publisher & Distributor,p.no. 170-196
5. Parisod, C.; Holderegger, R.; Brochmann, C. (April 2010). "Evolutionary consequences of autopolyploidy". *The New Phytologist*. 186 (1): 5–17
6. Ramsey, J.; Schemske, D. W. (1998-01-01). "Pathways, Mechanisms, and Rates of Polyploid Formation in Flowering Plants". *Annual Review of Ecology and Systematics*. 29(1): 467–501