

POLYPLOIDY INDUCTION IN FORAGE CROPS

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I. INTRODUCTION

Chromosomal doubling occurs in plants naturally however its rate is very low and a slow process. Since time is important chromosomal doubling/polyploidization can be induced in a short period at a high rate by using antibiotic agents like colchicine, oryzalin etc. the concentration and duration for treatment of the explant differ with the crop and hence an efficient polyploidization protocol has to be developed for the concerned crop. The induced putative polyploids can be selected by various morphological parameters cytological and flow cytometric techniques. The exact chromosome complement can be obtained by studying the mitosis or meiosis.

As we know artificially is more than two basic sets of chromosomes. Artificially Plants are obtained through chemical, physical, and biological ($2n$) techniques. This review is useful for a wider range of gene expression, which affects phenotypic traits like yield and product quality. The time required to select high yielding superior polyploids after early chromosomal set doubling must be cut short. Nevertheless, these obstacles are removed particularly when using colchicine, plant breeders have effectively obtained polyploid bred-germplasm in a wide range of forages. Polyploidy can play a functional and effective role in the evolution of certain crops spp. If we need to improve ornamental varieties with desirable morphological traits, means plant size and vigor, leaf thickness, larger flowers with thicker petals, intense color of leaves and flowers, long-lasting flowers, compactness, and dwarfism, depends heavily on polyploidy in horticulture. Development of unreduced gametes by doubling the number of chromosomes in somatic cells, polyploidy can be artificially generated or can arise naturally. Artificially produce polyploidy are used when naturally polyploid plants are not accessible, mitotic inhibitors. Colchicine is a popular mitotic inhibitor it functions like preventing the segregation of chromosomes during cell division to cause polyploidy in plants. For induce polyploidy the following techniques such as dipping/soaking, dropping, or cotton swabbing is useful in various plant organs, including seeds, apical meristems, flower buds, and roots.

Research shows the natural substance colchicine, which has the capacity to impede spindle fiber development to stop the chromosome and result in a failure of chromatid disjunction. [2][3]. Angiosperms commonly experience polyploidy, which has been crucial to the evolution of plants. According to estimates, 40–70% of all plant species are polyploid, which suggests that hybridization is a common strategy for encouraging adaptability in plants. (Mason, 2017).

II. THE ORIGIN OF PLANT POLYPLOIDIZATION IN EVOLUTION

Polyploidy has a very large distribution in plant kingdom. All plant species are paleo-polyploids (Figure 1, B) because genomic comparisons based on sequenced genomes show that they all evolved from one or more episodes of polyploidization.[19]

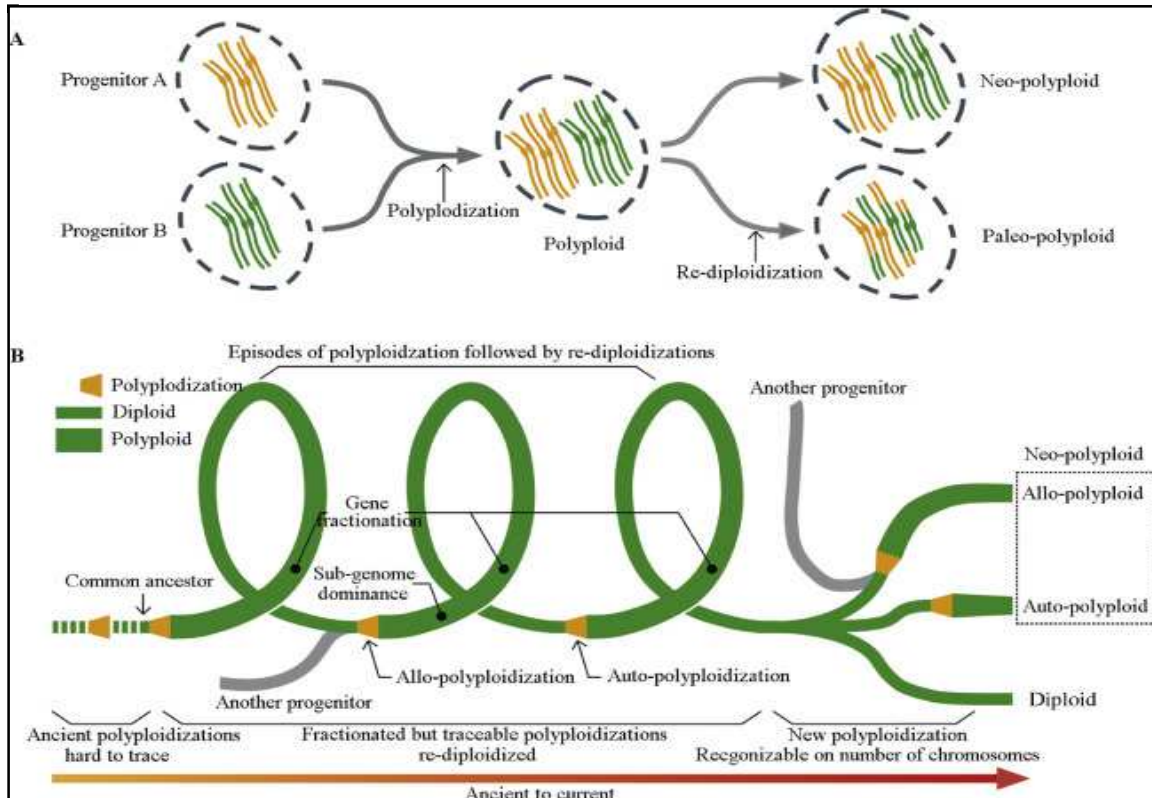


Figure 1: B Life cycles of plants experiencing recurrent polyploidization and re-diploidization events

It may be relations between the origin of plant paleo-polyploidy and significant historical occurrences. Researchers evaluated all known polyploidization occurrences in plant species' occurrence times (Van de Peer et al., 2017). [20]

- 1. Colchicine Treatment:** For chromosome doubling Colchicine treatment is the most effective and the most widely used treatment. Colchicine treatment all so great success in a both dicot and monocot plants. Colchicine is a poisonous chemical isolated from seeds (0.2-0.8%) and bulbs (0.1-0.5%) of autumn crocus (*Colchicum autumnale*).

Function

- It is readily soluble in alcohol, chloroform or cold water.
- But is relatively less soluble in hot water.
- Pure colchicine is $C_{22}H_{25}O_6N$.
- It blocks spindle formation.
- Thus inhibits the movement of sister chromatids to the opposite poles.

- The resulting restitution nucleus includes all the chromatids; as a result, the
 - chromosome number of the cell is doubled.
 - Colchicine affects only dividing cells, it should be applied to a shoot-tip meristem only when its cells are actively dividing. At any given time, only a small proportion of the cells would be in division; therefore, repeated treatments should be given at brief intervals to double the chromosome number in a large number of cells of the shoot apex.
- 2. Genetics of Polyploidy:** There is different between polysomic polyploid species and disomic polyploid (or amphidiploid) species because inheritance. Amphidiploid species exhibit strange disomic inheritance for loci that act like diploids. Quadrivalent (multivalent) pairing is present in polysomic tetraploid species, which calls for chromosome homology and may result in twofold reduction during meiosis II [15]. In polysomic polyploids Four copies of an allele are possible, and the two extra copies it is may be advantageous for evolution. Redundant alleles may mutate and then be selected in the course of evolution to achieve a new function of a gene related to a metabolic pathway [16].
- 3. Applications of Autopolyploid in Crop Improvement:** For the improvement of crop certain useful applications of autopolyploid.
- Triploids - Triploids are created when tetraploid and diploid strains hybridize.
 - Generally speaking, they are extremely sterile, with a few exceptions.
 - In order to produce watermelons without seeds, this function is helpful.
 - It may be more active than the typical diploids in some species sugarbeets.
 - There is a detailed description of these two examples. The reciprocal cross (2x x 4x) does not work, they are created by crossing tetraploid (4x, used as female) and diploid (2x, used as male) lines. The triploid plants almost exclusively generate little, white, primitive structures resembling cucumber (*Cucumis sativus*) seeds; they do not produce real seeds.[21]
 - However, a few normal-sized seeds that are often empty may appear. Pollination is essential for fruit ripening.
 - The ratio of 1 diploid to 5 triploid plants is used to plant diploid lines for this purpose.

III.ISSUES

- Including the genetic instability of 4x lines, irregular fruit shape.
- A propensity for hollow fruits, the production of empty seeds,
- The labor-intensive process of producing triploid seeds (by hand pollination). Watermelon "ice-box type" diploid hybrids that produce fruits without seeds (all of their seeds resemble cucumber seeds) have recently been produced.[21]
- Tetraploid sugar beet produces smaller roots and lower yields than diploid sugarbeet, while triploid sugarbeet produces larger roots and more sugar per unit area. In sugarbeets, 3x seems to be the ideal level of ploidy.

Some fodder crop species show the great success. Tetraploid red clover (*Trifolium pratense*) and ryegrass (*Lolium perenne*) are the most successful examples. Tetraploids of the berseem (*Trifolium alexandrium*, variation Pusa *Giant Berseem*) and alsika clover (*Trifolium*

hybridum, variety Tetra) are two other instances. Compared to diploids, autotetraploid red clover and ryegrass are more robust, pleasant and digestible, and more resistant to nematodes. [22]

1. Production of Polyploid Plants: Colchicine, which may be obtained from *Colchicum autumnale* L., is the most often used chemical. It plays a role in inhibiting the formation of the spindle, which prevents anaphase disjunction and cytokinesis [2][3], leaving one cell with a doubled chromosome set. Method is successful when depending on the colchicine concentration and exposure time, plant tissues and its developmental stage, and method for chromosome set doubling. Following are the results of colchicine treatment

- Applying the colchicine solution to immature buds might cause unreduced reproductive cells, which will produce polyploid seed at various rates.
- The forage species, it may be administered to the pedicel of a developing immature bud or the inflorescence stalk may be dipped in a growth media solution with a low concentration of colchicine (0.01 to 0.1%). A polysomic tetraploid (12–40%) was effectively produced in guar accessions by dipping a cotton swab in a colchicine solution of 0.2% for 10 hours over the course of two days [6].
- Colchicine can also be injected into the callus, i.e., meristematic tissues can be cultured in cells to create chimera plants, or seeds can be sown in a colchicine solution and allowed to germinate [7].
- The first sign that colchicine has been used successfully is growth stop. After a lag period of colchicine administration, affected cells often resume cell division. In thale cress (*Arabidopsis thaliana* L. Heynh.), induced polyploidy resulted in slower growth, larger cell sizes, and fewer cells per leaf blade as compared to the euploid series (2, 4, 6, and 8). In the stem, polyploid cells showed greater pectin and hemicelluloses but reduced lignin and cellulose [8].
- A high colchicine concentration has been, however, toxic to cell and plant tissues. A low colchicine concentration (0.1%) treatment with relative long duration (48 h) has been effective in increasing the yield of polyploid cells in shoot tips in vitro [9]
- A direct application of colchicine by dipping the apical meristem of seedlings produced chimeric tissues where induced polyploidy was limited to a particular layer [10].

2. Impact of Polyploidy on Forage Yield and Contributing Traits: In forage species induced polyploidy is compared with diploidy in a variety, this advantage is observed.

- Larger leaves, herbage yield, and slow heterosis decay [11, 12]
- Increased plant height, persistence, faster regrowth after grazing,
- Increased branching [13].
- The polysomic tetraploid *Lolium* species had slow heterosis decay.
- The potential to produce more seed over several generations without significantly reducing their forage yield, allowing for their cultivation to be done with less expensive seed and overcoming the disadvantage of expensive F1 seed [14].
- Chromosome duplication, on the other hand, decreased the persistence in the induced 4 perennial ryegrass (*Lolium perenne* L.) [14].

3. Restoration of Fertility: Using induced polyploidy technique, we restored the fertility of interspecific hybrids with variable ploidy levels or unique genomes with similar levels, mostly homoploid and anorthoploids, e.g. Germination of the seed in medium supplemented with colchicine, the fertility of allotriploid hybrids between Napier grass (*Pennisetum purpureum* (L.) Brown) and pearl millet (*P. glaucum* (L.) Brown) was restored [17].

4. The Commercialization of Induced-Polyploid Cultivars

- Depends upon the polyploidy it maintains in succeeding generations, or artificial polyploids' fertility.
- Artificial polyploidy gave us economic benefit because their high biomass and digestibility.
- Reliable performance and stability generation after generation self-pollination, testing of fodder yield and quality of induced polyploid across agro-ecological zones may be required.

IV. FUTURE PERSPECTIVES

The primary plant research fields of plant speciation, diversification, genome evolution, adaptive selection, gene function innovation, and crop domestication are all strongly related to genome polyploidization. Despite significant advancements, a thorough knowledge of polyploidization is still lacking. There is contradicting information on many polyploidy species, hence it is impossible to provide a single theory to explain how polyploidy evolved in plants. But in the near future, improvements in experimental analysis, sequencing technology, multi-omics data accessibility, and the creation of more effective analysis tools are anticipated to materially increase our comprehension of polyploidization.

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