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Polyploidy Breeding: A Viable Method for Crop Improvement

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Introduction

A polyploid organism or individual is one that has more than two basic or monoploid sets of chromosomes; this situation is referred to as polyploidy. The term polyploidy was introduced by Winkler (1916). Thirty to forty-five percent of angiosperm species are polyploid. About one-third of flowering plant species and 70% of the family of wild grasses are polyploid. Certain families, such as the *Rubiaceae*, *Compositae*, *Iridaceae*, *Gramineae*, etc., are relatively common in having polyploids (Grant, 1981). Blakeslee and Avery (1937) created the colchicine method of chromosomal doubling, which has since become a crucial tool for the experimental investigation of polyploidy.

What are the two main types of polyploidy?

Autopolyploidy: "Self" duplication - complete duplication of the genome in a single species.

Allopolyploidy: "Other" duplication - complete genome duplication along with two-species hybridization.

How can we identify auto and allopolyploids?

In general, autopolyploids have multivalent pairing. The majority of chromosomes are identical due to polysomic inheritance. Variable-bivalent pairings with higher genetic divergence (disomic inheritance) are found in allopolyploids. multivalent combination in close relation

A) Autopolyploidy

Autopolyploids are polyploids that emerge from a hybrid between races of the same species, or from doubling the number of chromosomes in a diploid species. This phenomenon is known as autopolyploidy.

Origin of autopolyploids

- Spontaneous

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- Colchicine treatment
- Physical agents
- Regeneration *in vitro*
- Production of adventitious buds

Morphological features (Autopolyploids)

- Large cell size than diploid
- Larger pollen grains
- Slower growth and late flowering
- Large sized leaves, flower and fruits but generally lower in number
- Reduced fertility due to meiotic irregularities
- Increase vigour and vegetative growth but yield is low
- Lower dry matter.

Advantage of autopolyploidy:

- Due to polysomic inheritance, they have significantly higher levels of heterozygosity than their diploid progenitors.
- Preservation of more than two alleles per locus, which makes them more capable than diploids of producing a wider range of allozymes.
- Greater effective population sizes compared to diploids, which makes selecting processes far more efficient than chance-based genetic drift.

Disadvantages of autopolyploidy:

- Prolonged cell division time
- Volume of the nucleus increases
- The number of chromosome disjunctions during meiosis increases
- Genetic imbalances
- Interference with sexual differentiation when the ratio of the number of autosomes to the number of sex chromosomes determines the sex of the organism (as in Drosophila).

Limitation of Autopolyploid

1. Autopolyploids typically have higher water contents in conjunction with their larger sizes.
2. Poor seed set and high sterility are observed in autopolyploids.

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3. Autotetraploids have complex segregation, which causes delayed progress under selection.
4. It is only possible to retain triploid through clonal propagation.
5. Raw polyploids, or new polyploids, are always identified by one or more undesired traits. Examples of such traits are watermelon's inconsistent fruit size and grapes' weak stem strength.
6. Autopolyploidy has unpredictable effects.

B) Alloploypoidy

- Chromosome doubling after hybridization of two species.
- Interspecific polyploidy caused by hybridization followed by chromosome doubling e.g., AABB, AABBCC
- To restore fertility in inter-specific crosses by spontaneous doubling of chromosome (*Begonia*, *Impatiens*, *Kalanchoe*)

Origin of allopolyoloids

- Chromosome doubling occurs primarily in F_1 hybrids (remote hybrids) between two distinct species that are either members of similar or different genera.
- Allopolyploid's productions involve two steps as,
    1. production of F_1 distant hybrids, and
    2. chromosome doubling

Applications of allopolyploids

- Bridging cross:
- Creation of new crop species
- Interspecific gene transfer
- Tracing the origin of crop species:

Limitations of allopolyploids

1. Limited use
2. Difficulty in Maintenance
3. Undesirable Characters
4. Effect is unpredictable.
5. Newly synthesized allopolyploids have many defects
6. Only a small portion of allopolyploids are promising.

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7. Some other defects- low fertility, genetic instability, slow growth rate, etc.

Effect of polyploidy

- Increased fruit weight, fruit size, seed size, crop load, flower size etc.
- Reduction in fertility.
- Change in growth pattern.
- Can be used to create higher diversity
- Greater ability to colonize new habitats than diploid ancestors.
- Increase blooming period (marigold, *Begonia*)

The role of polyploidy in crop improvement

- Gene buffering
- Dosage effect
- Increased allele diversity and heterozygosis
- Novel phenotypic variation:
- Mutation breeding
- Seedless fruits
- Disease resistance through aneuploidy

Cotton

Gossypium herbaceum and *Gossypium raimondii* were crossed to create American cotton (*Gossypium hirsutum*). With 2n = 26, both of these species are diploid. The latter is a New World wild diploid, and the former is an Old World cultivated diploid.

Triploid Sugar Beets

- The roots of triploid sugarbeet are larger in size than diploids.
- They maintain the sugar content & yield more sugar per unit area.
- Triploids are highly sterile and do not produce seed.
- When tetraploid and diploid cells cross, or when meiosis goes awry and unreduced gametes are formed that combine with gametes bearing n chromosomes, triploid gametes are created.

Triploid Watermelons

- Seedlessness would be advantageous in watermelons. Diploid watermelons (*Citrullus lanatus)* have 22 chromosomes per somatic cell.

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- Kihara (1951) give technique of producing seedless, triploid watermelons.
- In isolation, diploids and autotetraploid lines—which are created by doubling a diploid's chromosomal number-are planted alternately.
- Seed parents are tetraploids. On tetraploids, a viable triploid seed is produced. Meiotic abnormalities lead the triploid seed production programme to fail when diploid is utilized as the female.

Difficulties in triploid Watermelon production

- Triploid fruits generate small, white, primitive structures resembling cucumber seeds, however triploid seeds are absent due to meiotic abnormalities.
- Because fruit formation on triploids depends on the stimulant supplied by the pollen, interplanting diploid varieties is crucial to growing a good commercial crop of seedless triploid watermelon.
- The primary challenge in producing triploid watermelon seeds is preserving the tetraploid seed parent.
- Triploid seed is quite expensive since tetraploid flowers need to be manually pollinated in order to generate triploid seed. Triploid plants are inviable because the gametes they produce are largely imbalanced non terms of chromosomal number. Triploid plants might be valuable if they could be vegetatively propagated, that is, through cuttings.

Rhaphanobrassica

- In 1928, Karpechenko worked with the radish (*Raphanus sativus*, 2n=18, n =9) and cabbage *(Brassica oleracea*, 2n =18, n =9). When these two plants are crossed, an F_1 results with n =18.
- The traits of this allodiploid plant are halfway between those of its two parent species. During an event of somatic doubling, the plant becomes an allopolyploid (an allotetraploid of 4n) and its chromosome count doubles to 36.
- This allotetraploid is also known as an amphidiploid since every chromosome has a homologue. In the absence of any prior knowledge, this plant would be categorised as diploid with 2n=36. In this instance, the progeny are sterile triploids, hence the new amphidiploid is unable to reproduce with either parent.
- As a result, *Raphanobrassica* has been assigned to it as a new species. That was not a successful agricultural experiment, though, as it did not combine the best qualities of

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radish and cabbage.

Conclusion

- As a result, *Raphanobrassica* has been assigned to it as a new species. That was not a successful agricultural experiment, though, as it did not combine the best qualities of radish and cabbage.
- Polyploidization is one of the best know tool for breeders for the crop improvement. Ex.- Triticale

Reference:

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