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Polyploidy Breeding

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Polyploidy breeding is recognized as a fundamental tool in crop improvement, involving the multiplication of complete sets of chromosomes [1]. The evolution of approximately 70% of angiosperms is attributed to natural polyploidization events [2]. Higher genetic diversity and phenotypic plasticity are provided by polyploidy, enabling plants to adapt to diverse ecological niches [3]. The manipulation of ploidy levels is utilized by researchers to create novel germplasm with enhanced economic value [4].

Classification and Biological Basis

Autopolyploidy

Autopolyploidy is originated from the duplication of a single genome belonging to the same species [5].
The 'gigas' effect, characterized by an increase in cell volume and organ size, is frequently observed in autopolyploid plants [3].
Seedless varieties of fruits, such as triploid watermelons, are successfully developed through autopolyploidy breeding [6].
The formation of multivalents during meiosis is identified as a primary cause of reduced fertility in these lines [5].

Allopolyploidy

Allopolyploidy is resulted from the hybridization of two or more distinct species followed by chromosome doubling [7].
Meiotic stability is often achieved in allopolyploids due to the presence of non-homologous genomes which favor bivalent pairing [8].
Significant crops such as bread wheat (hexaploid), upland cotton (tetraploid), and canola are classified as allopolyploids [2].
The combination of divergent gene pools within a single nucleus is facilitated by allopolyploidy, leading to heterosis [7].

Induction Methods and Agronomic Applications

Chemical Induction Techniques

Colchicine is extensively employed as a spindle inhibitor to induce chromosome doubling in actively dividing tissues [9].
Specific concentrations of colchicine are applied to seeds, axillary buds, or callus cultures to generate polyploid sectors [10].
Alternative anti-microtubule agents, including oryzalin and trifluralin, are increasingly used due to their lower toxicity [11].

Impact on Crop Quality and Resistance

Increased concentrations of essential nutrients and secondary metabolites are reported in polyploid medicinal plants [12].

Enhanced resistance to abiotic stresses, particularly drought and salinity, is frequently exhibited by polyploid genotypes [13].
The vegetative growth phase is often extended in polyploids, which is beneficial for biomass production in forage crops [1].

Suggestion

The integration of flow cytometry for rapid ploidy determination is suggested to enhance selection efficiency in large breeding populations [14].
More focus should be directed towards the induction of polyploidy in underutilized legumes to improve their yield potential [13].
The use of tissue culture-based induction methods is proposed to minimize the occurrence of chimeric plants [10].
Polyploidy breeding should be combined with CRISPR/Cas9 technology to precisely target gene duplications for crop improvement [4].

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