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Role of Apomixis in Crop improvement

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Apomixis is a mode of asexual reproduction that occurs through seeds, where embryos develop without fertilization. It is observed in more than 300 species across 30 angiosperm families, with higher occurrence in Compositae, Rosaceae, and Graminae families. Initially considered an obstacle for plant breeding, apomixis was responsible for Mendel's failure to prove genetic principles in Hieracium. However, in recent years, apomixis has gained importance as a means to preserve superior genotypes as clones of seeds, making it a major area of investigation in plant genetics. Genetically, apomixis involves suitable modifications/failures during megasporogenesis and initiation of mitosis in the unfertilized 2n egg cell or other 2n cells of the embryosac. Dominant genes or a few closely linked genes on the same chromosome control gametophytic apomixis. For instance, apospory in Ranunculus species is due to a dominant gene, while nuclear adventive in citrus is controlled by a single dominant gene. Savidan reported dominant monofactorial control of apomixis in Panicum maximum. Typically, apomixis lines are developed using basic approaches, such as gene transfer from wild species sources, induced mutations, and selection for apomictic genotypes in the segregating generation of interspecific hybrids. Due to its potential for improving crops and enhancing global agricultural production, apomixis has become the subject of increased attention from both scientific and industrial sectors. A major goal in applied plant genetic engineering is to harness apomixis and efforts are currently focused on genetic and breeding strategies in various plant species. Additionally, molecular methods are being used to analyze apomictic and sexual modes of reproduction, as well as to identify key regulatory genes and mechanisms that underlie these processes.

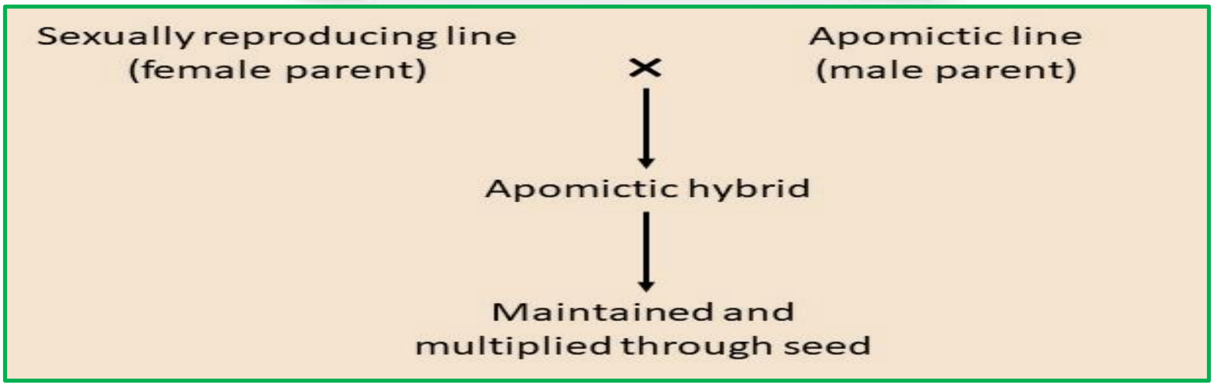

Figure 1. Steps of apomixis

Applications of Apomixis

1. Fixation of heterosis - When obligate apomixis is present, the heterosis fixation is complete, meaning that all the desirable traits are fully fixed. However, if apomixis is facultative, the fixation of heterosis can only be partial, as is the case with Bahia grass (*P. notatum*) and Buffle grass (*P. ciliare*).
2. Production of homozygous lines can be achieved through the parthenogenetic development of reduced egg cells. This is then followed by the development of embryos from secondary diploid cells of the embryonic sac, which are formed through fusions. This process can lead to the production of homozygous lines with favourable characteristics. E.g., rubus and sorghum
3. Production of vybrids - A vybrid refers to the offspring resulting from a cross between two plants that exhibit facultative apomixis. The vybrids themselves reproduce through facultative apomixis and can be sustained by collecting seeds exclusively from F1-like apomictic plants in each successive generation. e.g., sorghum.
4. Adventive embryony is a method utilized for the production of uniform rootstock and virus-free scion in citrus plants. It is also applied in the case of the Merion variety in *Poa pratensis*. Through adventive embryony, genetically identical plants can be produced in large numbers, thereby ensuring uniformity in rootstock. Furthermore, by producing virus-free scions, adventive embryony can help in the production of healthy plants.

Types of apomixes-based on the origin and development of cell in which embryo develops

1. Adventitious embryony refers to a type of agamospermy in plants where the embryo develops directly from the vegetative cells of the ovule, such as the nucellus, integument, and chalaza. This process is considered to be a sporophytic form of agamospermy.
2. Gametophytic apomixis is a reproductive process in plants where embryos are developed without fertilization from the egg cell or other cells of the embryo sac. The embryo sacs themselves are produced from unreduced gametophytes, resulting in the production of genetically identical offspring.
   - i. Apospory – In plants exhibiting gametophytic apomixis, the megaspore mother cell usually undergoes degeneration, leading to the formation of an unreduced embryo sac. This embryo sac is formed from a somatic cell, such as a nucleus or integument cell in the ovule, through a series of mitotic divisions.
   - ii. Diplospory – The formation of unreduced embryo sacs in gametophytic apomixis involves the circumvention of meiosis in megaspore mother cells. Instead of undergoing meiosis, the cells divide mitotically to produce unreduced embryo sacs.

Advantages of Apomixis

1. In obligate apomixis, heterosis can be fixed completely in hybrids. This enables farmers to re-sow seeds produced by apomictic hybrids and maintain the desirable traits.
2. The new hybrid variety could be multiplied from a few hybrid seeds in the same manner as a pure line.
3. Apomixis offers a way to commercially produce F_1 hybrids in crops that lack a CMS/fertility restoration system.

Disadvantages of Apomixis

1. The process can be tedious and time-consuming, particularly in the case of facultative apomixis.
2. Environmental factors can influence the proportion of sexual progeny in cases of facultative apomixis.
3. The genetic basis of apomixes is often unclear in many cases.

4. Without morphological markers linked to apomictic development, maintaining apomictic stocks can be challenging.

Techniques for screening Apomixis

1. Examination of embryo sac development using cytological analysis.
2. Detection of diplospory through callose fluorescence combined with clearing of ovules.
3. Observation of uniformity in progenies from cross-pollinated parents, as well as screening based on maternal phenotype in F_1 progeny, limited genetic variation in F_2 progeny, rapid fertility in aneuploidy, triploid, and wide crosses, and multiple seedlings per seed.
4. DNA marker analysis.

Conclusion

In conclusion, apomixis is a fascinating mode of asexual reproduction that has been observed in many plant species. Initially considered an obstacle for plant breeding, apomixis has gained importance in recent years as a means to preserve superior genotypes as clones of seeds. The genetic basis of apomixis involves modifications or failures during megasporogenesis and initiation of mitosis in the unfertilized 2n egg cell or other 2n cells of the embryo sac. Efforts are currently focused on genetic and breeding strategies in various plant species to harness apomixis and enhance global agricultural production. The identification of key regulatory genes and mechanisms that underlie these processes is a major area of investigation in plant genetics. Overall, apomixis has the potential to revolutionize plant breeding and improve food security for a growing world population.