Seed Production Methods in Cross-Pollinated Crops

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ABSTRACT

The seed production method in cross-pollinated crops is planned in a way that allows for the retention of excellent seed quality and genetic purity in species where pollination is by either wind, insects, or other vectors. The specialized production method is applied to lessen unnecessary cross-pollination and retain desirable characteristics because these crops are subject to extensive genetic blending. Isolated distances are applied to prevent contamination from other crops in nearby fields. Generally, the technology for seed production of cross-pollinated crops uses genetic, agronomic, and climatic principles to offer optimal and genetically stable seeds to support agricultural productivity and improved plant development.

INTRODUCTION:

Pollination is the process whereby the pollen from the male part of a plant is transferred to the female part in the same plant, or in the same plant from a different plant, for fertilization and seed production at a later date. Cross-pollination refers to cross-pollinated (allogamous) crops whereby the pollen from one plant is used for fertilization in the ovule of a genetically different plant belonging to the same species.

Examples for cross-pollination crop production include corn, sunflower, onion, carrot, and vegetable crops, including cucumber and watermelon, cotton, sorghum. **(Chassaigne-Ricciulli *et al.,* 2020; Gutierrez *et al.,* 2016).** "The aim of the seed production technology in cross-pollinated crops is to preserve genetic purity. Cross-pollinated crops are dependent on the services of natural pollinators such as wind and insects; thus, isolation distance, rouge, and synchronization of flowering are essential in them. Adequate field management and control of pollination are responsible for producing homogeneous seeds of high quality." **(Rai, Govindaraj, & Rao, 2012)**.

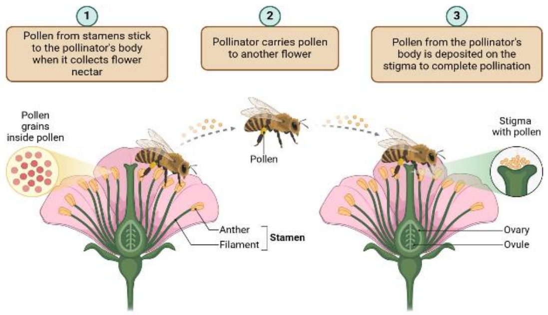

Fig. 1 – Process of Cross Pollination in Plants.
Source- (Sharma 2025)

Self-pollination, which is auto-gamy, is the transfer of pollen from the anther of a flower to the stigma either of the same flower or of the same plant, thus promoting uniformity of genetics. Cross-pollination, allogamy, is the transfer of pollen from the anther of a flower to the stigma of a different plant, thus promoting variability of genetics.

1. **Breeding Methods of Cross-Pollinated Crops:** The crops, self-pollinated and also cross-pollinated, such as cotton, sorghum, etc. in those plant species, the breeding techniques are not clear. Therefore, the breeding technology may also differ in cotton, sorghum, and maize, or in any other, respectively, according to **Abbas *et al.,* 2000**. All of these are defined as:

- Selection
- Hybridization.

1.1 Selection: In general, for cross-pollinated crops, three methods of selection are used, namely: Mass selection, Progeny selection, and Recurrent selection.

1.1.1 Mass selection: Mass selection is often referred to as the oldest procedure for improving self-pollinated species. The objective of mass selection is to improve the population by increasing the gene frequencies of desirable genes. Selection is on the basis of plant phenotype, and one generation per cycle is required. Cross-pollinated species are more focused on the improvement of the population rather than the improvement of individuals as is the goal for self-pollinated species. As for cross-pollinated species, these varieties are a mix of homo and heterozygotes. They are heterogeneous because they have a bunch of homo and heterozygous individuals.

1.1.2 **Progeny selection:** Progeny selection and recurrent selection are well-recognised methods for effective plant breeding in cross-pollinated crops using the existing variability in the population. It is not possible to follow traditional patterns of inheritance in cross-pollinated crops; hence, improvement strategies based on gene frequency are preferred in such populations.

1.1.3 **Recurrent selection:** In cross-pollinated crops, it is not possible to describe the process of genetic improvement properly based on classical genetics concepts due to the presence of heterozygosity and random mating; hence, the frequencies of genotypes obey the Hardy-Weinberg principle based on selection. As for direct selection, it is simple with adaptation but its rate is constrained by a lack of variation **(Chaudhry 2016)**.

1.2 Hybridization: Hybridization of offspring from genetically diverse parents facilitates the process of recombination desirable traits, as well as the production of superior pure lines through homozygosis. Although haploid breeding fosters homozygosis, the mutation process may hamper the selection of preferable combinations of genes in creating desirable traits **(Wright 1980)**. Hybridization can be Interspecific or Intervarietal:

1.2.1 **Interspecific hybridization:** The purpose of interspecific and intergeneric hybridization is the introduction of new genes that are not found in the domesticates. But the success of hybridization is dependent on the genetic relatedness of the species, and the lack of information about the chromosomal and genetic compatibility is a factor that makes it difficult to predict the performance of the breeding.

1.2.2 **Intervarietal hybridization:** Intervarietal hybridization, which involves crossing varieties within a species, has been widely employed in agriculture to merge desired traits. Simple or convergent hybridizations are effective in integrating genes from two or more parents to produce better hybrids. This involves breeding between different varieties or cultivars to produce improved offspring, which may give better yields.

1.2.3 **Utilization of hybrid Vigor:** Heterosis or hybrid Vigor leads to superior growth, yield, and productivity of F1 hybrids compared to their parents. Although the mechanism of heterosis is complex, the combined effects of dominance, overdominance, epistasis, and heterozygosity lead to an important role of heterosis being an important approach for improving crop performance.

2. Why is seed production of cross-pollinated crops

- The fact that control of pollination is required, purity needs to be maintained, as well as optimized pollination, makes seed production more complex compared with seed produced through self-pollination.
- The aim here is to produce seeds with a high probability to give a desired genotype/phenotype, and also to allow gene flow to promote Vigor.

3. Mechanisms of cross-pollination-

Cross-pollination can be achieved through wind, insects, water, and other natural agents that transfer pollen between genetically different plants; this therefore enhances genetic diversity and heterozygosity **(Barrett, 2010; Harder & Johnson, 2009).**

3.1 Dichogamy: The reproductive mode observed in flowering plants wherein the male and female reproductive structures of a flower grow at different times to avoid self-pollination or to promote cross pollination.

3.2 Herkogamy: A structural characteristic within bisexual flowers where the anthers and stigma are physically separated in order to inhibit self-pollination and facilitate cross-pollination.

3.3 Self-incompatibility: Genetic mechanism existing in plants that does not allow self-pollination by preventing the germination or growth of pollen from the same plant.

3.4 Male sterility systems: techniques used in plant breeding to avoid self-pollination, usually achieved by setting up plants with non-viable pollen but normal female reproductive organs (Artificially induced).

5. Hybrid Seed Classes: High-quality seeds are the primary as well as most crucial component for effective agricultural production. The **(Table 1.)** below describes the seeds required for plant breeding aimed at ensuring purity.

Table 1. Classification of Seeds Based on Generation.

Seed Class	Produced By	Genetic Purity (%)	Certification Tag Colour and Size	Main Characteristics / Purpose
Nucleus Seed	Plant Breeder	100%	Not tagged (maintained by breeder) Tag size: 15 cm x 7.5 cm	Original seed, highest genetic purity, base material for breeder seed
Breeder Seed	Breeder / Research Institute	The Genetic purity of the Breeder seed crop must be kept at 100%.	Golden Yellow Tag size: 12 cm x 6 cm	Direct progeny of nucleus seed, source for foundation seed
Foundation Seed	Seed Corporation / Authorized Agency	The genetic purity of the foundation seeds shall be maintained at 99.5 percent.	White Tag size: 15 cm x 7.5 cm	Produced from breeder seed Used for producing certified seeds
Certified Seed	Registered Seed Growers	This is the commercial seed which is available for farmers to purchase, and this should have genetic purity of 99 percent.	Blue Tag size: 15 cm × 7.5 cm	Distributed to the farmers for commercial crop production

6. Isolation distance- Isolation distance is the minimum distance required to be kept between two fields of the same crop and different varieties (or of the same variety and different seed classes) to avoid genetic impurities due to cross pollination, mechanical mixture, or volunteer pollen. Self-pollinated crops need small isolation distance (5-10 m), moderately cross-pollinated crops require moderate separation (100-200 m), whereas cross-pollinated crops need a larger distance (200-1000 m).

Table 2. Isolation Distances Required for Various Crops at the Foundation and Certified Seed Levels.

Crop	Pollination Nature	Foundation Seed Stage (m)	Certified Seed (m)
Rice	Self-pollinated	3	3
Wheat	Self-pollinated	3	3
Barley	Self-pollinated	3	3
Pulses (Gram, Lentil, Pea)	Self-pollinated	10	5
Soybean	Self-pollinated	3	3
Groundnut	Self-pollinated	3	3
Mustard (Brassica juncea)	Often cross-pollinated	100	50
Sunflower	Highly cross-pollinated	600	300
Maize	Cross-pollinated	400	200
Sorghum	Often cross-pollinated	400	200
Pearl millet (Bajra)	Cross-pollinated	1000	600
Cotton	Often cross-pollinated	50	30
Sesame	Often cross-pollinated	50	25
Castor	Cross-pollinated	600	300
Onion	Cross-pollinated	1000	500
Carrot	Cross-pollinated	1000	800
Tomato	Often cross-pollinated	50	25
Chilli	Often cross-pollinated	400	200

7. Hand pollination: Hand pollination is an artificial process of pollination wherein pollen is moved by human intervention from the anther of one plant to the stigma of another using a brush or even by hand. This is usually practiced in plant breeding and in seed production when fertilization is required according to a defined plan.

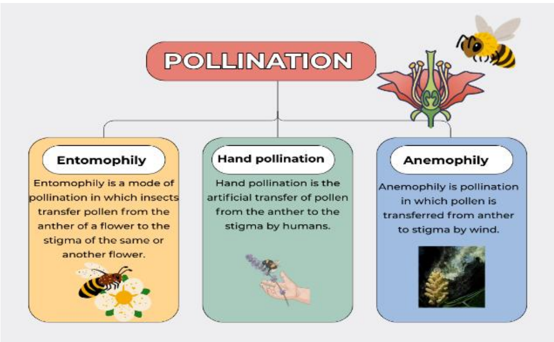

Fig. 3- Different methods of pollination.

CONCLUSION

In the case of cross-pollinated plants, the preservation of purity and assurance of effective performance of improved varieties require seed production technology. Skilful management practices, like proper isolation distance, rouging at the right time, synchronisation of blooming, and regulation of pollinators, are required to prevent adulteration, as such plants normally undergo high levels of pollen flow. Seed quality, viability, and storage life can also be enhanced by proper harvesting, certification, and field management.

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