Distant Hybridization for Crop Improvement: A Review

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Abstract

Wide crosses plays important role in crop improvement as they become useful tool in transmitting genes into cultivated cultivars from wild forms and relatives for disease resistance and for improvement in quality parameters in various cultivated plant species. Apart from uses, wide crosses should contain certain issues like cross incompatibility, hybrid inviability, and hybrid breakdown and hybrid sterility. Certain techniques are used to overcome these issues like pollen mixture, bridge crosses, manipulation of ploidy level, embryo rescue.

Introduction

Hybridization is the crossing between two genetically dissimilar parents while hybridization among entities from diverse species of the same genus i.e. intrageneric hybridization and two diverse genus of same family i.e. intergeneric hybridization combinedly known as distant hybridization and such crosses are known as distant crosses or wide crosses. Thomas Fairchild (1717) was the pioneer who performed distant hybridization for the first time by developing a hybrid by crossing Carnation (*Dianthus caryophyllus*) and Sweet willian (*Dianthus barbatus*). First intergeneric hybrid, between *Brassica* (cabbages) and *Raphanus* (radish) was given by Karpechenko (1928) leading to the production of *Raphanobrassica*. Whereas Triticale was developed by crossing wheat with rye (Rimpu,1890) possessing higher potential than raphanobrassica (Allard 1960).

Problems associated with wide crosses

Problems related with performing distant crosses are:

1. Cross Incompatibility: It is illustrated as incompetence of fully matured pollen grains of one genera or breed to fertilize other genera or breed.

There are three main reasons of cross incompatibility viz.

I. Abscence of pollen germination,
II. Inadequate development of pollen tube to reach ovule and
III. Failure of fusion of microgamete with megagamete.

- These barriers are called as pre –fertilization barriers.
- Such barriers can be overthrown with the exploitation of various techniques like reciprocal and bridge crosses, utilization of pollen mixtures, pistil manipulations and growth regulators etc.

2. Hybrid Inviability: Condition in which zygote or embryo becomes inviable or fails to develop further or initial stages are completed but it gets aborted is described as hybrid inviability.

Major causes for this condition are:

1. Adverse interactions occurring among the chromosomes of the two species
2. Hostile interaction of the endosperm with the embryo.
3. Disharmony between cytoplasm and nuclear genes

- In order to overthrow these situation techniques like making reciprocal crosses, use of hormones required for growth and preventing embryo abortion through its rescue can be exploited.

3. Hybrid Sterility: It specifies the situation in which hybrid produces progeny which is non viable in nature. This is more prominent in the case of intergeneric crosses. The major reason for hybrid sterility is the lack of structural homology between the chromosomes of the two species.

- Sterility occurring due to difference in structural homology among the chromosomes of two species can be overpowered by the use of colchicine treatment.

4. Hybrid Breakdown: It is the major issue in interspecific crosses.
- The condition in which first filial (F1) hybrid plants of intrageneric cross are fertile and vigorous but their next generation i.e. F2 progeny looks like weak and finally becoming sterile is called as breakdown of hybrid.
- So hybrid breakdown hinders the progress of interspecific gene transfer.
- This may be due to the structural difference of chromosomes or problems in gene combinations (Singh 2010).

Different approaches for making distant crosses successful

1. **Plant Selection**
   Cross compatible plants should be selected as parents for doing crosses.
2. **Reciprocal crosses**
   Under the situation of failure of one parental combination, crosses in the reciprocal manner can be performed.
   e.g. Mung x udid- cross compatible and Udid x mung-cross incompatible
3. **Handling of ploidy**
   Copies of single genomes through colchicine treatment can be made to retain the fertility of a cross.
4. **Bridge crosses**
   When a cross is to be made between two cross incompatible species, a species which is compatible with both the other species is used as a bridge for achieving the cross. Such type of species is known as bridging species.
   e.g. Tobacco
   -*Nicotiana repanda* x *N.tabaccum*– cross incompatible
   -*Nicotiana repanda* x *N.sylvestris*- cross compatible
   -*Product* x *N.tabaccum*- cross compatible
5. **Utilization of mixtures of pollen**
   For overpowering the adverse interactions among pistil and pollen in distant crosses pollens from diverse plants can be utilized for pollination.
6. **Pistil Manipulations**
   For overpowering incompatibility beheading of style can be done.
7. **Applications of growth hormones**
   Development of pollen tube is increased with the use of IAA, NAA, 2,4-D and Gibberellic acid.
8. **Protoplast fusion**
   Fusion of protoplasts can be performed under the condition of failure of gamete fusion.
9. **Prevention of embryo abortion**
   Embryo rescue technique can be attempted to overcome embryo abortion.
- Ex. Hordeum. vulgare x Secale cereale.
- Degradation of endosperm cane be overpowered through rescue of embryo (Allard 1960).

(A) Cutting of proembryo within 3-5 days of pollination.
(B) Culturing of proembryo on media containing agar.
(C) Collection of plantlet obtained from the embryo
(D) Transplantation of the plantlet in soil.

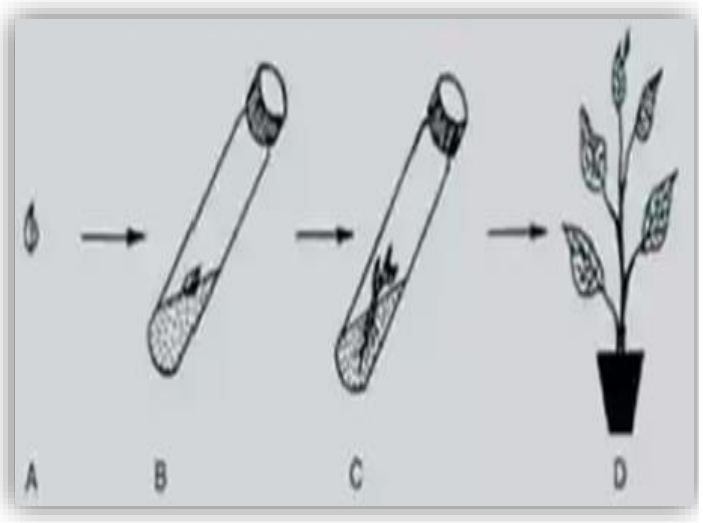

Fig. 1. Embryo rescue

Constraints in embryo rescue :

- Generation of new plantlets is not cost effective.
- Induction of mutations lethal in nature in invitro phase.
- Well equipped and established greenhouse and tissue culture lab are major requisite for distant hybridization.
- Skillful persons are required for performing all the operations.

Importance of distant crosses in overall crop enhancement

For the overall enhancement of crops by increasing the level of disease resistance, pest resistance, stress resistance, quality, adaptation and yield, distant Hybridization acts as an important tool for the same. Furthermore, they can be utilized for evolving new crop species.

Improving the crop plants for

1. Disease and insect resistance: Wide crosses can be used for transferring the disease resistance from wild species to cultivated species. The some examples are given below (Harlan 1976; Singh 2010; Knott and Dvorak 1976).

Crop	Character transferred	Species transferred from	Species transferred to
Cotton (Meyer 1974)	Jassid resistance Blackarm resistance	*G.Tomentosum* *G.arboreum*	*G.Hirsutum* *G.barbadense*
Okra	Resistance to YMV	*Abelmoschus manihot*	*A. esculenta*
Groundnut	Resistant to leaf chewing insect	*Arachis monticola*	*A.hypogea*
Wheat	Rust resistance	*Agropyron*	*T. aestivum*
Tobacco	Resistant to mosaic virus	*N.repanda*	*N. tabaccum*
Sugarcane	Sereh disease resistance	*Saccharum spontaneum*	*Saccharum officinarum*
Potato	Late blight and leaf roll resistance	*Solanum denissum*	*Solanum tuberosum*
Straberry	Resistance toward aphid	*Fragaria chiloensis*	*Cultivated strawberry*

2. Improvement in quality: Wide crosses can be used for improving the quality of cultivated plant species. The some examples are given below (Simmonds 1979; Stalker 1980).

Crop	Character transferred	Species transferred from	Species transferred to
Cotton	Fibre length Male sterility	*G. Thurberi &* *G. Raimondii* *G. harkenssii*	*G. hirsutum* *G. hirsutum*
Potato	Starch content Frost resistance	Wild species *Solanum acaule*	*Cultivated Spp.* *S. tuberosum*
Tomato	Carotenoid content	*Lycopersicon*	*L. esculentum*

		Wild Spp.	
Palm	Oil quality	Wild Spp.	Cultivated Spp.
Rice, Oat & Rye	Protein quality	Wild Spp.	Cultivated Spp.

3. Improvement in yield:

This also been achieved through the use of wild Spp. in some crops e.g. Oat, Vigna, Arachis, Potato, Tobacco.

Achievements

Hybrid varieties:

Upland cotton – MCU-2, MCU-5, Khandwa1, Khandwa2 etc are derivatives of interspecific hybridization.

Hybrid between Pearl millet x Napier gress- Hybrid Napier which is very popular for its high fodder yield and fodder quality e.g. Jaywant and Yashwant

Interspecific hybrids in cotton- Varlaxmi, Savitri, DCH-32, NHB-12, DH-7, DH-9 etc.

Prabhani Kranti variety of bhindi.

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