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Role of Wide Hybridization in Crop Improvement

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Introduction

- When individuals from two distinct species of the same genera are crossed, it is known as inter specific hybridization. Eg. *Oryza sativa* x *O. perennis*
- When individuals being crossed belong to two different genera, it is referred to as intergeneric hybridization. Eg. Wheat x rye (*Secale cereale*)
- Hybridization between individuals from different species belonging to the same genus or two different genera, is termed as distant hybridization or wide hybridization, and such crosses are known as distant crosses or wide crosses.
- Wide hybridization involving crop wild relatives and related taxa has gained momentum in the recent fruit crop improvement programs (*Anushma PL et al*.,2020).
- This dynamic process improves the momentum of recent agricultural advancements, enabling the introduction of beneficial traits that contribute to increased crop resilience, productivity, and adaptability in response to evolving environmental and economic challenges (Patnaik *et al*.,2021).

History

- The first distant hybridization; hybrid between carnation (*Dianthus caryophyllus) and sweet willian (Dianthus barbatus) by* Thomas Fairchild in 1717 and the hybrid is called as fairchilds mule.
- An interesting inter generic hybrid by Karpenchenko in1928 *Raphano brassica was an amphidiploid cross* between radish and cabbage but it was useless.
- Most of the interspecific hybrids were of no agricultural value many interspecific hybrids particularly in case ornamentals, served as commercial varieties.
- The first inter generic hybrid with a great potential was **TRITICALE by** Rimpu 1890.

Objectives

1.To transfer some desirable characters from wild relatives that are not available in cultivated varieties.

E.g. Many disease resistance and, insect resistance genes Wide adaptability: (i.e. drought-resistance, cold tolerance etc.) Quality improvement (Eg. Cotton (fibre) Tobacco (leaf)
Yield improvement (Eg. Oats, Tobacco, Maize, S. cane)
Other characters (Eg. CMS, Earliness, dwarfness morphological characters)

2. Exploitation of luxuriance (heterosis) in vegetatively propagated / ornamental crops.

Prolonged vegetative period, Prolonged blooming period

3. Creation of Novel genotypes :

New species or F1 hybrids hither to non – existent in Nature.

Barriers to the production of distant hybrids

1. Failure of zygote formation / Cross incompatibility
2. Failure of zygote development / Hybrid inviability
3. Failure of F1 seedling development / Hybrid sterility

A variety of mechanisms may be responsible for each of these three difficulties :

1. Failure of zygote formation / cross incompatibility:

Inability of the functional pollens of one species or genera to effect fertilization of the female gametes of another species or genera is referred to as cross incompatibility. It may be due to –

1. Failure of fertilization, because the pollen may not germinate.
2. Pollen tube is unable to reach to embryo sac and hence sperms are not available for fertilization –
3. Pollen tube may burst in the style of another species Eg. Datura.
4. The style of the female parent may be longer than the usual length of the pollen tube growth therefore the pollen does not reach the embryo sac. Eg. *Zea mays* and *Tripsacum* sp.
5. Pollen tubes of polyploidy species are usually thicker than those of diploid species.
6. When a diploid is used as female and a polyploidy as male, the polyploidy pollen tube grows at a slower rate in the diploid style than it would be in a polyploid style.

These barriers are known as pre-fertilization barriers.

Techniques to make wide crosses successful

a. Removal or scarification of stigma b. Using short styled parent as female.

c. Using the diploid species as the male parent

2. Failure of zygote development / hybrid inviability:

The inability of a hybrid zygote to grow into a normal embryo under the usual conditions of development is referred to as hybrid inviability. This may be due to :

1.Lethal genes : some species carry a lethal gene, which causes death of the interspecific hybrid zygote during early embryonic development. Eg. 1. *Aegilops umbellulata* carries a lethal gene with 3 alleles against diploid wheats.

2. Genetic Dishormony between the two parental genomes.

The genetic imbalance between the two parental species may cause the death of embryos.

Eg. Cotton - G.gossypioides x other G. sps., Brassica – *B.napus x B.oleracea*

3. Chromosome elimination : In some cases of distant hybridization, chromosomes are gradually eliminated from the zygote. This generally does not prevent embryo development, but the resulting embryo and the F1 plants obtained from such crosses are not true interspecific hybrids since they do not have the two parental genomes in full. Generally. Chromosomes from one are successively eliminated due to mitotic irregularities.

Eg. *Hordeum bulbosum x H. vulgare* , *Hordeum bulbosum x Triticum aestimum*
Triticum aestivum x Zea mays

4. Incompatible cytoplasm : Embryo development may be blocked by an incompatibility between cytoplasm of the species used as female and the genome of the species used as male. Such an interaction, more generally, leads to hybrid or cross weakness and male sterility in the hybrids or may some times leads to failure of embryo developments.

5. Endosperm Abortion : Seeds from a large number of distant crosses are not fully developed and are Shrunken due to poorly developed endosperm. Such seeds show poor germination, and may often fail to germinate. When the endosperm development is poor or is blocked, the condition is generally known as endosperm abortion.

Eg. a. Triticum x secale – Triticale . In this case the endosperm aborts at a much later stage so that a small frequency of viable seed is obtained.

b. Hordium bulbosum x H. vulgare – the endosperm aborts at an early stage so that viable seeds are not produced. In case of endosperm abortion - embryo rescue culture is practiced.

3. Failure of hybrid seedling development / hybrid sterility

Some distant hybrids die during seedling development or even after initiation of flowering. The mechanisms involved in the failure of seedling development most likely involve complementary lethal genes.
Eg. a. In cotton-certain interspecific hybrids appear normal, but die in various stages of seedling growth; some plants die at flowering.
b. Interspecific and intergeneric F1 hybrids of wheat show both chlorosis and necrosis;
Hybrid sterility : Hybrid sterility refers to the inability of a hybrid to produce viable off spring. The main cause of hybrid sterility is lack of structural homology between the chromosomes of two species.

Techniques for production of distant hybrids

a. Choice of parents : Genetic differences exist among parents in a species for cross compatibility. More compatible parents should be selected for use in wide crosses.
b. Reciprocal crosses : it is better to attempt reciprocal crosses when distant crosses are not successful.
c. Manipulation of ploidy: When two species of a cross differ in chromosome number, it is necessary to match their ploidy level by chromosome doubling of the species with low ploidy.
d. Bridge crosses : Some times, two species say ‘A’ and ‘C’ do not cross directly. In such case a third species say ‘B’ which can cross with both ‘A’ and ‘C’ is chosen as a bridge species. First ‘B’ is crosses with ‘C’ and then the amphidiploid is crossed with ‘A’. Bridge crosses have been used in Tobacco and wheat.
e. Use of pollen mixtures : Cross incompatibility results due to unfavorable interaction between the protein of pistil and pollen which inhibits normal germination and growth of pollen tube. This problem can be overcome by using the mixture of pollen from compatible (self) and incompatible parents.
f. Manipulation of pistil : In some cases, pollen tube is short and style is very long, due to species difference. Thus pollen tube cannot reach ovule to effect fertilization. In such situation either reciprocal cross should be made or the style should be cut to normal size before pollination.
g. Use of growth regulation : Some times, the pollen tube growth is so slow that the eggcell dies or the flower aborts before the male gametes reach the ovary. In such cases, growth regulators should be used to accelerate the pollen tube growth or to prolong the viability of the pistil. Eg. NAA, GA3, 24-D and IAA
h. Large number of crosses : The success of seed set is generally very low in wide crosses. Hence, large no. of crosses should be made to obtain crossed seeds.
i. Protoplast fusion : The wide crosses can be obtained through protoplast fusion, when it is not possible to produce such crosses through sexual fusion.
j. Embryo culture : This technique is being used widely to obtain viable interspecific or intergeneric hybrids. This is used when hybrid zygote is unable to develop.
k. Grafting : Grafting of interspecific hybrid on to the cultivated species helps in making the cross successful.

Applications of wide hybridization in crop improvement

1.Alien addition lines: Carries one chromosome pair from a different species in addition to somatic chromosome complement. For Eg. Disease resistance in Wheat, oats, tobacco

2. Alien substitution lines : It has one chromosome pair from different species in place of the chromosome pair of the recipient parent.

3. Introgression of genes : Transfer of small chromosome segments with desirable genes. Eg. A. Disease resistance : In Cotton transfer of black arm disease resistance from *G. arboreium to G. barbadense*

B. Wider adaptation : Cold tolerance has been transferred from wild relatives to Wheat, onion, potato, tomato and grape.

C. Quality : Oil quality in oil palm was improved by genes from wild relatives.

D. Changing the mode of reproduction :

E. Self-incompatibility : S.I. genes from *B. campestris* to self compatible *B. napus* for hybrid seed production. F. Yield : G. Other characters :

4. Development of New crop species : Eg. Triticale

5. Utilization as New hybrid varieties:

Eg. F1 hybrids in cotton Varalaxmi cotton (*G.hirsutum x G. barbadense*)

Sugarcane : All the present day commercial varieties are complex interspecific hybrids involving *S. officinarum* & *S. spontaneum*

Limitations of distant hybridization

a. Incompatible Crosses
b. F_1 Sterility
c. Problems in Creating New species
d. Lack of Homoeology between Chromosomes of the Parental Species
e. Undesirable Linkages
f. Problems in the Transfer of Recessive Oligogenes and Quantitative Taits
g. Lack of Flowering in F1
h. Problems in using Improved varieties in Distant Hybridization
i. Dormancy

Achievements

What, Tobacco, Cotton

Parbhani Kranthi : Derived from A. esculentus C.V. Pusa Sawani x A. Manihot – Resistant to yellow mosaic vein virus, yield – Kharif : 110-120 q/ha, Summer : 85-90 q/ha

Pusa Kranthi : Kharif 105-110 q/ha, Summer 75-80 q/ha

Conclusion

In conclusion, distant hybridization holds significant promise as the next horizon for plant breeding. This approach, which involves crossing distantly related species, has the capacity to unlock valuable genetic diversity and introduce novel traits that can improve crop resilience, yield, and nutritional content. As global challenges such as climate change and population growth intensify, the capacity to utilize the genetic potential offered by wide hybridization becomes increasingly essential. While there are barrier and intricacies associated with this technique, ongoing research and technological advancements are laying the way for its successful implementation. Adopting wide hybridization as a tool for crop improvement highlights a proactive and forward-thinking strategy in ensuring food security and sustainability in the face of evolving agricultural landscapes.

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