Topic: Role of Cytogenetics in Crop Improvement

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Role of Cytogenetics in Crop Improvement

The study of inheritance in relation to the structure and function of chromosomes is known as Cytogenetics.

Here the genetic interpretation of cytological observation is dealt with.

Techniques used in Cytogenetics

1. Karyotyping
2. Analysis of banded chromosome
3. Cytogenetic banding technique
4. Molecular Cytogenetics such as fluorescent in situ hybridization (FISH) and comparative genomic hybridization.

FISH refers to using fluorescently labelled probe to hybridize to cytogenetic cell preparation.

In this era of comparative genomics, Cytogenetics is also offering insights into evolution. Using cross-species FISH, Scientists have identified groups of genes called synteny groups, that maintain the same linkage relationship with each other across species boundaries. Synteny data reveal numerous chromosomal rearrangements that have occurred during the course of evolution. Taken together with DNA sequence information, synteny data are proving useful for detecting genome duplications and for constructing phylogenetic trees.

How Cytogenetics emerged?

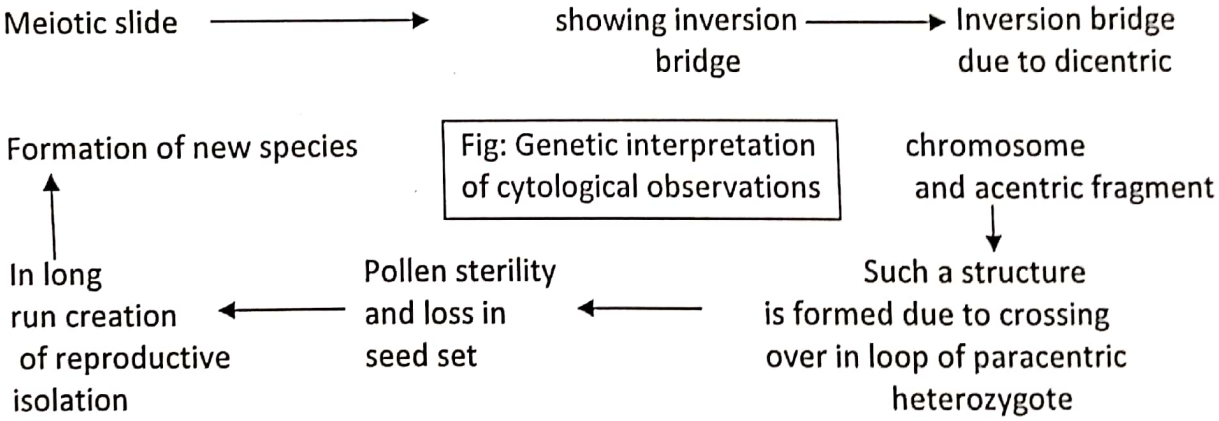

Fig: Genetic interpretation of cytological observations

Cytogenetics and crop improvement

Crop improvement is an art of improving economically important plants for growth, yield and function on scientific basis.

In crop improvement, the objectives may be-

1. Higher yield and good nutritional quality
2. Disease and drought resistance
3. Photo-and thermo insensitive variety
4. Dwarf variety
5. Toxin free food products

To fulfil these objectives, principles of Cytogenetics are much helpful. Without knowing the genetic make up of a plant, we can't improve it.

Polyploidy and Crop Improvement

Polyploidy provides genome buffering, increased allelic diversity and heterozygosity and permits novel phenotypic variation to be generated. Polyploid formation is often accompanied with loss of duplicated chromatin, changes in gene expression, novel epistatic interactions and endosperm effects. All of these factors need to be considered in a genome wide context for optimizing marker assisted selection and crop plant improvement.

In some situations, polyploidy crops are preferred because they are sterile.

e.g. Banana and seedless watermelon are sterile. They are autotriploids. Such crops are propagated using asexual techniques.

In Cassava, the triploids are developed by crossing 4x and 2x. They have been reported to be promising and it therefore seems possible to improve Cassava by developing new chromosomal lines in which the chromosome number does not go beyond an optimal level.

The triploid 76-9 had a yield similar to that of H-2304, the released cultivar, at CTCRI. Cassava is a root tuber and crop of Kerala.

Allopolyploidy has 3 major applications in crop improvement-

1. As bridging species in the transfer of characters from one species into another.
2. In the production of new crop species and
3. For widening the genetic base of existing allopolyploid crop species.

Production **of Raphanobrassica-**

Raphanus sativus (Having quick growth and disease resistance 2n=18 AA) x *Brassica oleracea* (Having hardiness) 2n=18 BB

F_1 AB (Sterile)

AABB
(2n=4X=36)
Raphanobrassica

Fig: Origin of **Raphanobrassica**

Production of **Triticale**

It is a man made cereal. It combines the yield potential and grain quality of wheat with the disease and environment tolerance of rye.

Triticum durum 2n=4x=28 AABB x Secale cereale 2n=14 DD

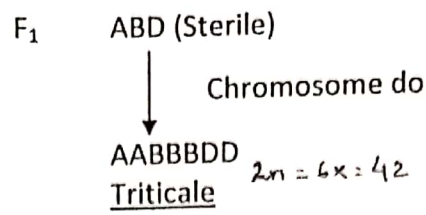

Fig- Production of Triticale

Both Triticale and Raphanobrassica have low fertility, cytogenetic and genetic instability.

Role of aneuploidy in Crop improvement

e.g.

Wheat- Knowledge of Cytogenetics has enabled us to evaluate the various wheat traits imposed by different obromosome by the method of chromosome localization. The key lying behind the chromosome localization is to specifically identify the particular traits carried by particular chromosomes, effect of chromosome transfer on the plant, monosomic and/or substitution lines production, find the linkage groups, phenotypic effects of multiple copies chromosome and many other genetic evaluations so that genotype may be utilized in much more useful manner for humanity.

Grass pea (Lathyrus sativus)-Grasspea has 2n=14. It is an important food crop. But it has neurotoxin (B oxalyl amine alanine). Monosomics, tertiary trisomics, double trisomics and reciprocal substitution lines have been produced in order to incorporate low neurotoxins, high yield and genetic basis.

Chromosomal aberrations in crop improvement

Structural variations in chromosome are-

1. Deficiencies/ Deletions
2. Duplications
3. Inversion
4. Translocations

A large number of cytogenetic stocks involving chromosomal interchanges (translocations) inversions, deletions and duplications have been produced in maize, barley and rice.

In barley alone cytologically defined stocks include over 1000 reciprocal translocations, inversions ,deletions and duplications.

These stocks have been used for duplication of defined segments of chromosome 6 and 7 in barley, which seem to be promising for enhanced yield.

Translocations are being used for producing duplications in the short arm of chromosome 5 and 6 which carry genes for mildew resistance and alpha-amylase activity respectively.

Mutation and Crop Improvement

The development of dwarf wheat and rice varieties that led to the green revolution are classic examples of mutation breeding achieved through successful exploitation of mutant genes - Norin in case of wheat and dee-gee- woo-gen in rice which affect a large constellation of characters responsible for their superior agronomic responses.

The impact of induced mutation on crop improvement is reflected in the 3248 mutant varieties officially registered by FAO.

The most up-to-date list of 345 mutant varieties belonging to 57 crop species released in India is available.

Chickpea mutant varities- Pusa 408, 413, 417 and 547

Groundnut mutant varieties- TAG-24 and TG-26

Urdbean variety-TAU-1 released by BARC

Back cross and crop improvement- it is widely used to incorporate one or a few genes into an elite or adapted variety.

Genetically modified plants –

GM plants have altered DNA using genetic engineering techniques. It is done to introduce a new character to the plants which they do not have already.

The most widely accepted and highly used GM crop is GM soybean which contains resistant gene to herbicides glyphosate.

This resistant gene has been extracted from bacteria resistant to herbicides. 77% people all over the world use this GM soybean.

BT cotton is the 2nd highest exploited crop all over the world. It has been grown by 49% of cotton growers in the world. BT cotton imposes resistance to pests by producing Cry toxin. This Cry toxin producing gene has been obtained from a soil bacterium *Bacillus thuringiensis.*

Bt maize is also an important and extensively accepted GM crop. It has same CRY I – gene as in Bt cotton. It has also been made resistance to herbicide glyphosate by inserting a resistance gene from bacteria. Some genes from South African white corn have also been inserted in GM maize in order to obtain bright orange kernel with high degree of vitamin C and carotene.

Flavr Savr tomato is another example. Technology used to produce this tomato is the insertion of antisense gene, responsible for production of an enzyme polygalacturonase (PG) This antisense gene restricts the production of PG enzyme which initiates ripening/ softening in fruit after harvest.

Protype GM rice contained 2 transgenes from Daffodil and one from a soil bacterium.

Latest golden rice contains genes from maize and a soil bacterium. This rice shows enhanced content of beta carotene which is a source of vitamin A.

The knowledge of Cytogenetics has played a vital role in crop improvement and we except much more prospects from this field.