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A Review

Genetic Detection of Chromosomal Interchanges and its Consequence on Plant Breeding: a Review

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Abstract

Chromosomal interchanges are of primary interest because of the opportunities they offer for the study of chromosome behavior and crossing over. The great volume of work which has already been done on crossing over and on translocations but still lack of understanding among the graduates students. Hence, continue discussions and question still to be made on this terminology. This paper gives the opportunity for students to understand chromosome mechanism in which crossing over and cytological changes are often occurs. In very beginning (middle of 20^{th} century), several study on the behavior of chromosomes such as crossing over, interchange and trisomics. But in order to link them with plant systems and breeding implications, it is necessary to review in brief since the interchange in plants are revealed so far only a small proportions but large proportion being ignored by current phase of crop improvement scientists. Since interchange is being a good cytogenetic markers are useful in genetic and basic investigation studies in cytology. Hence this has some practical applications on ploidy breeding programme which is re-patterning or alteration of basic chromosome number of a species and also an important evolutionary mechanism of species and they are poorly understood (Jauhar, 1971). However, a comprehensive explanation of translocation role in evolutionary aspects of a species is lengthy profession so that, my paper will explains the basics and applied aspects of interchange in plants in briefly.

Key words: Chromosomal, translocations, plant breeding, genetic, cytology

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Introduction

Interchanges are those structural changes in chromosome where terminal segments of non-homologous chromosomes have exchanged positions. These changes are also called reciprocal translations. Interchanges in plants are usually associated with semi sterility of gametes. Although in exceptional cases interchanges with high fertility may be observed such semi sterility is absorbed only in those plants which have translocation in only one set of chromosome, the other set being normal. These plants are called interchange heterozygote. On the contrary, there can be plants, which have same interchange in both sets of chromosome this is called interchange homozygote and would exhibit complete fertility. Study of interchange is important for plant breeders, genetisties and evolutionists. While interchange can be used in plant breeding exercise, they also bring about changes in linkage relationship and leads to changes in chromosome structure and behavior. They also bring about variability, which is very important for evolutionary processes and the creation of new variation by the interchange may thus useful in plant breeding (Hagberg and Hagberg, 1969). In the beginning there several studies done with respect to interchange in drosophila, however occurrence of translocation in crop plants have been studied with less number of species such as maize and its application in crop improvement has yet to be shown widely. With all this aforementioned points I have took and was presented this paper as student assignment to Tamil Nadu Agricultural University, Coimbatore, India. This paper will briefly enlighten that, basic and applied aspects and specifically the cytological and genetic methods for detection of interchanges and identification of chromosomes involved in interchange.

Who discover the interchange and terms related to interchange?

The exchange of chromosomal segments between non-homologous chromosomes of sister chromatids are called as translocation or interchange. Interchanges are also known as segmental chromosome interchange, reciprocal translocation or simply translocation. Translocation first observed by Gates (1908) in *O.ruvrinervis* and McClintock (1930) was the first provide chytologically evidence of interchange between two non-homologous chromosomes in maize.

Difference between translocation and crossing over

Many students often puzzle with terminology such as translocation and crossing over in their memory and mis-defined these two terms in their exams. The following table will distinguish the differences of this terminology

Translocations	Crossing over
Involves non homologous chromosome of sister chromatids	Non sister chromatids of homologous chromosomes
Translocation homozygote change the linkage map	Does not change the linkage map
Breakage an d reunion will occurs	Chiasma formation will occur
Leads to Pollen and ovule sterility	No such sterility

Different type of interchanges

1. Simple interchanges

- A piece of chromosome segment transfer and attached to end of non homologous chromosome
- Simple breakage will occur in one chromosome
- This type is very rare due to telomere none fusability.

2. Shift interchange

- Transfer of intercalary segment from one chromosome to intercalary position of non-homologoues chromosomes.
- Two breaks occur in loser chromosome whereas one break occurs in gainer chromosomes. It is also called insertional / intercalary translocation.

3. Reciprocal translocation

- Mutual exchange of chromosome segments between non-homologous chromosome

- Single break occurs in each of the chromosome
- It has the evolutionary significant
- Normally in translocation studies two types of terminology were frequently used and they are described as follows:

1. Translocation homozygote

Both chromosomes of two pairs are involved (cause fertility) – as a results the gene content of these chromosomes is identical in nature.

2. Translocation heterozygote

Translocation will occur only one set of chromosome and other set is normal (cause semi sterility) – as a results the gene content of these chromosomes is not identical.

Origin of interchange

Interchanges may originate in nature and it can be induced by artificially through various methods by breakage and reunion among non-homologous chromosomes. The natural occurrence of interchanges might be due to one of the following reasons.

- Natural radiations
- Separation of interlocked bivalents at meiosis
- Spontaneous association of heterochromatic regions crossing over between duplicated segment in non homologous chromosome
- Mis-division of univalent and reunion (Robertsonian) centricfusion

Effects of interchange on plant population or species

Strelity:

- Translocation leads to duplication and deficiency of genes in a chromosome
- Gametes become inviable (sterility of pollen, ovule, zygote)
- Ring of four chromosome will cause 50% sterility and ring of six chromosome leads to 75% sterility were found.
- Due to imbalanced zygote in the individual the crop yield has been reduced

Crossing over

- Crossing over surprised in translocated chromosome due to competition in pairing.

Karyotype

- Translocation may change the chromosome number and structure of an individual
- It also alters the size and position of centromere of a chromosome

Phenotype

- Translocation leads to changes the phenotypes of organisms. since it alters the structure and number of chromosomes
- Eg. Human down syndrome (Mangolism)

Breeding behaviors of interchange

Since interchange is being a good cytogenetic markers are useful in genetic and basic investigation studies in cytology (Burnham, 1932). Hence this has some practical applications on ploidy breeding programme which is re-patterning or alteration of basic chromosome number of a species and also an important evolutionary mechanism of species (Jauhar, 1971). But the role of interchange in evolutionary of karyotype is poorly understood in many crops (Jauhar, 1971). Progeny obtained on selfing an interchange heterozygote, mainly consists of the fallowing, *a) normal b) interchange heterozygote, c) interchange* homozygote. Functional gametes obtained from alternate disjunction of two types – those with interchange chromosomes and other with normal chromosomes. These two types of gametes function with equal efficiency on male and female sides and thus leads to production of three types (a,b,c) in 1:2:1 ratio. Rarely an interchange ring , due to no co orientation of centromere may undergo 3:1 disjunction , so that in a diploid the gametes with X+1 and X-1 chromosomes can be produced. Although deficient gametes don't function, gametes with X+1 chromosome can function and can leads to the production of variety of trisomics.

Chromosome orientation

In co-orientation configuration, the chromosomes are distributed in equal numbers to the opposite poles. There are three types of co-orientation

Alternate (zigzag): Two normal chromosomes (AB) moves to one site and two translocated chromosome (A'B') moves to another pole.

Adjacent I (open): One normal chromosome with one translocated chromosome of non homologous chromosomes (AB') moves to one pole and other normal chromosome with another translocated chromosome of non homologous chromosomes (A'B) moves to another pole.

Adjacent II (open): One normal chromosome with one translocated chromosome of homologous chromosome (AA') moves to one pole and other homologous chromosome (BB') moves another pole.

Detection of Chromosome Interchanges

Here, we can detect only whether the interchange are presence or not. But can not identify the types of interchange occurred and which chromosome is involved in translocation event. An interchange produced by artificially or naturally can be identify/ detected by the cytological methods, genetical methods and cytogenetically. They are described briefly hereunder

Cytological method

- Pachytene configuration: Cross-shaped configuration (figure) at pachytene stage of meiosis. E.g. Drosophila-salivary gland chromosome
- Metaphase I configuration: a quadrivalent or higher chromosome association at diakinesis or metaphase I.

Genetical method

- Altered linkage relationship between genetic marker
- Due to linkage of semi sterility with factors in two linkage group.

Pollen sterility

- Interchange usually associated with pollen abortion and reduced seed set.
- There is possible of missing interchange heterozygote with low fertility, only plant with 50% or higher sterility used to study then only interchange confirmed by cytological or genetical methods.

Identification of Chromosome Involved In Interchanges

Once detected the presence of interchange in plants, there are several methods available for identifying the chromosome which are involved in this interchange.

1. Interchange linkage analysis:

(only based on association of contrasting traits with partial sterility)

Translocated chromosome are designated as *T*, and normal one symbolized *N*. an individual heterozygous for a translocation *(T/N)* and for a gene pair (*Aa*) produces four kinds of gametes *AT, AN, aT* and *aN*. In an F2 generation, plants that are *T/T* or *N/N* genotypes are fertile (F), while plants with *T/N* are partial sterile (PS). Thus, four classes in progenies are expected in F2:

- A PS (T/N)= Normal,PS,Translocation heterozygote
- A F (T/T or N/N)= normal, fertile, translocation homozygote or normal homozygote
- a PS (T/N)= mutant, PS, translocation heterozygote
- a F (T/T or N/N)= mutant, fertile, translocation homozygote or normal homozygote

2. Linkage effect on interchange stock

Linkage alters the interchange stocks (Interchange homozygote) in an interchange stock, while linked marker may become independent and the Independent markers become linked markers. For instance in maize (Figure 1), in an interchange of T 5-9 (translocation between chromosome 5 and 9), two linked genes, viz., wx (waxy) and v1 (virescent) are normally located on chromosome 9, assorted independently, and two independent genes, namely pr gene located on the chromosome 5 and wx gene located on the chromosome 9 become linked together. This suggested that this interchange involved chromosome 5 and 9, and that breakage took place between wx and v1 genes in chromosome 9 and involved pr gene on

chromosome 5. This is how the linkage will affect the interchange stocks.

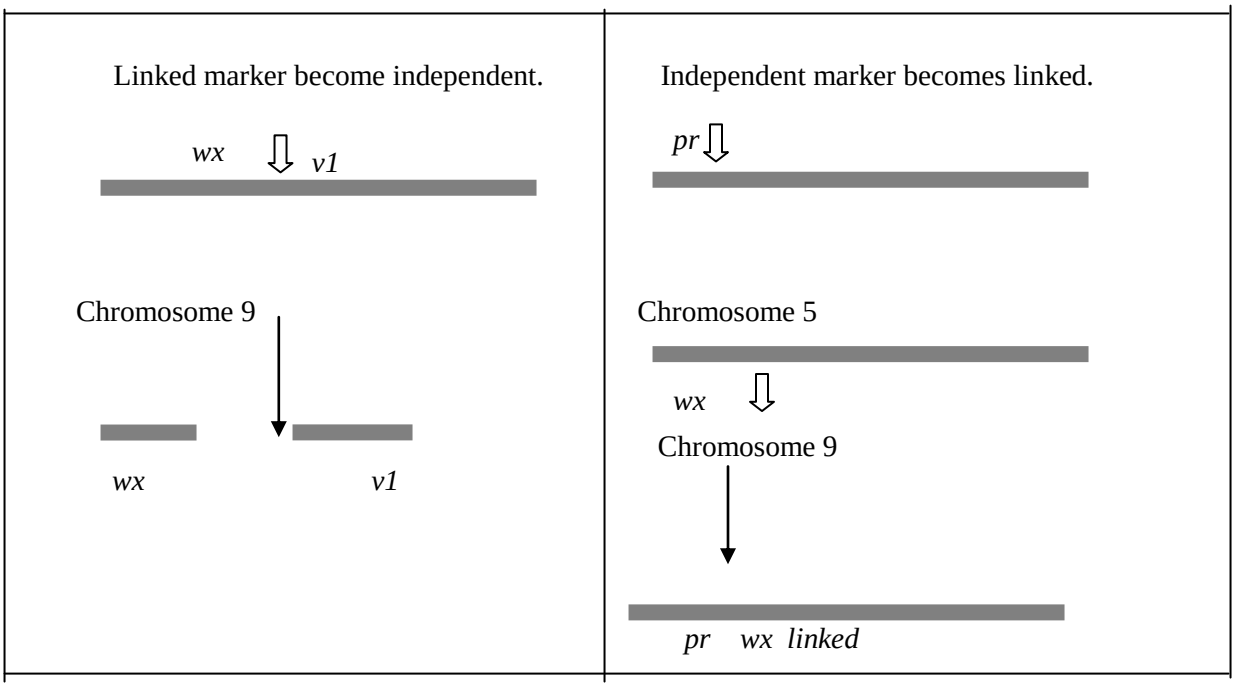

Fig. 1: Linkage effect on the interchange chromosomes

3. Pachytene analysis

If morphology of pachytene chromosome is known in normal plants as in case of maize and tomato, pachytene morphology in cross-shaped figure can be used to identify chromosomes involved in an interchange. This method used in to identify large number of interchange in maize.

4. Karyotype analysis

By comparing, the karyotype of normal plants with that an interchange stock; the chromosome involved in interchange can be easily identified. However, it is not always possible to identify all chromosomes in a haploid complement. In addition, possible exchange of equal segment of chromosome takes place. In such a case use banding technique (Giesma).

5. Use of trisomics

If trisomic set is available, it can used for identification of chromosome involved in interchange. Interchange stock (in question) crossed with all trisomic set and F1 with 2x+1 chromosome may be analysed for meiotic configurations. Pentavalent observed chromosomes are involved in the translocation events.

6. Inter cross method

If no prior information on the cytology or genetics of a material is available and other methods cannot be profitably, utilized, easiest course will be to intercross the available translocation stocks (all diallel / possible combinations), or inter cross unidentified stock with known translocation stocks and to study the chromosome pairing in meiosis of F1 hybrids. Absence of quadrivalent or presence of a single quadrivalent will mean that the two interchanges involve same chromosomes. Presence of two quadrivalent is usually meant that the two interchanges involve entirely different chromosomes. Similarly, a hexavalent would mean that one interchanged chromosome is common in two interchanges used in an intercross.

7. Use of monosomics

Chromosome involved in the interchange identify by observing trivalents structure instead of

quadrivalents. It may some time wrong identification of monosomics due to univalent shift. To avoid this, use double monotelosomics.

Uses of chromosome interchange

- Prediction of genetic consequences by cytological observations
- Information on chromosome behaviors (E.g. crossing over, unequal behavior of inheritance, segregation pattern)
- Locating the new genes on targeting chromosomes (by B-A chromosome interchange)
- Useful in linkage test analysis
- Source of monosomic (Cotton) and trisomics studies (Maize, Barley)

Conclusion

Off course this paper written in view of the student understanding purpose but the main idea is to focus that basic research will always not be ignored in rapid growing science world. Though recent era of scientific research dig into the deep system of biology of a species is good to know the hidden science but the basic studies such as chromosomal interchange will also to be given equal important in ongoing researches for better understanding of the evolving scientific findings. Although artificial method available to induce interchange, and they can also known to occurs spontaneously in certain species. Adaptable variations induced by interchange mechanism may possible to get and those will helps the breeder to evolve a variety with desirable gene combinations.

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