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FACULTY OF AGRICULTURAL SCIENCES AND ALLIED INDUSTRIES

LINKAGE AND CROSSING OVER

Bateson and Punnett discovered in 1906 that the principle of independent assortment of members of different pairs of alleles at the timeof formation of gametes is not universsal but has same exception. Thomas Hunt Mongan (1910) found similar situations in Droshphila to give a satisfactory explanation for such deviation.

Linkage in maize

'C' for coloured aleurone is dominant over 'C' colourless

Sh for Full endosperm is dominant over 'sh' shrunken.

Parents (Short 'S' , 's' Col full x Colourless, Shrunken

CCSS ↓ ccss

Ce Ss Colour full

↓

F2	Colour full	7300
	Colourfull shrunken	200
	Colour full	200
	Colouless shrunken	2300

F2 did not show 9: 3: 3 : 1 ratio. There were greater number of colour full, colour shrunken (parental types) than colourfull shrunkern , colour full, If two character considered separately,t hey segregate 3 : 1

i.e .	Colour	7500	Full - 7500
	Colouless	2500	Shrunken- 2500

The large deviation of the observed F2 population form the excepted segregation is therefore not because the members of each pair of alleles do not segregate from each other but because of the separation in one pair of alleles is not independent of the separation in the other pair of alleles.

Test cross

Colour full x Colourless shrunken

	CCSS			eess	
F1		CeSs	x	eess	
F2	F2	Colour full	4800	No expected	
		Col. Shrunken	200	ratio 1:1:1:1	
		Col. Less full	200		
		Col less shrunken	4800		

The data show that, the two pairs of genes have nto assorted independently.

Segression of two pairs of genes on two pairs of chromosomes

Let us suppose that, gene 'C' is located on chromosome number 9 and 'S' on chromosome number 10 of maize. The segregation of chromosome bearing C and c is entirely independent of segregation of chromosome bearing S and s. So four type of gametes Cs, Cs, eS, eS are formed in F1 and F2 normal dihybrid ratio 9:3:3:1 and test cross 1:1:1:1

Segregation fo two pairs of genes on one pair of chromosomes

Let us suppose that, two genes C and S are located on chromosome No. 9 during meiosis only 2 gametes will be formed Cs and cs gametes.

So, Genes C and S situated on same chromosomes are said to be linked. Linkage is the association of character in inheritance due to fact that genes determining them are physically located on the same chromosomes.

Detectionof Linkage

Compare the number of individuals observed in each class with those expected on the basis of independent assortment and then to test the deviation between these two values by chi-square test.

Linkage Group

The number of linkage groups will be equal to the haploid number of chromosomes which the species possess. Thus maize has 10 pairs chromosomes has 10 linkage groups.

Symbol of linked genes

While representing linked gene, the two homologous chromosomes are indicated by two horizontal links.

e.g. $\frac{CS}{cs}$ $\frac{CS}{cs}$ CS/cs

Coupling

In the condition is linked inheritance in which an individual heterozygous for two pairs of genes receives the two dominant member from one parent and the two recessive members from the other parent.

eg. CS / CS x cs / cs

↓ It is also said to be in C is position.

CS / cs

Repulsion CS / Cs x cS / cS

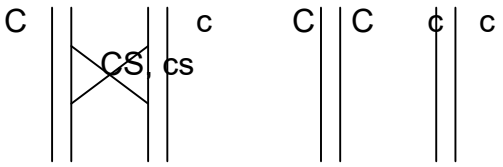
↓

Cs / cS 'Trans' position

Repulsion is the condition is linked inheritance, in which an individual heterozygous for two pairs of linked genes receives the dominant member of one pair and the recessive member of the other pair from one parent and the reverse from the other parent.

Crossing over

Leading to recombination of linked genes is due to the exchange of corresponding segments between the chromatids of homologous chromosomes and was first observed by Belgian cytologist Janssens in 1909.



Parental type

Recombination types Cs, cS

Linkage studies revealed the following

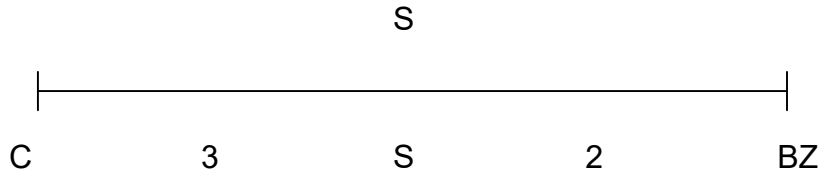
1. Genes that assort at random are non linked genes. Genes that do not segregate at random are linked genes.
2. Linked genes are arranged in a lines fashion on the chromosome. Each linked gene has a definite and constant order in its arrangement.
3. The distance between the linked genes determines the degree of strength of linkage. Closely located genes show stronger linkage that the widely located genes.
4. Linked genes do not always stay together, but are often exchanged reciprocally by cross over.

LINKAGE MAP (Cross over map / chromosome map or genetic map)

Morgan postulated that genes are arranged in linear order along with length of chromosome, each gene having a fixed place on the chromosome and its allele, a corresponding position on the homologous chromosome. Under standardized environmental conditions, thre frequency of crossing over of a pair linked genes has been found to be cosntant and Morgan put forward the hypothesis that it depends upon the distance between two genes on the chromosome. The greater the distance between the two genes, the greater in the chance that a Chiasma will occur between their loci, and the higher in the percentage of crossing over between them. If therefore , the percentage of crossing over between various genes are determined experimentally, the gene can be mapped in their order on the chromosome.

In mapping genes, a unit of distance must be used and this unit is called a map unit, which is the space within which one percent of crossing over takes palce. If percent of cross over between two linked genes is 1% it means that the map distance between these two linked genes is one unit of map distance or one map unit or one centimaorgan.

If the genes are in the order C, S, BZ,



The genes C and BZ show 5% crossing over . (If the gene are in the order C, BZ and Z, the genes C and BZ should show 1% corssing over. Experimental data revealed that the percentage of crossing over between C and BZ in 5. There three genes C, S and BZ on the ninth chromosome of maize and plotted as above.

Importance of linkage in breeding

When there is a close linkage between desirable and undesirable characters these genes are inherited in blocks and not individually and recombination is practically nil. In such cases linkage has to be broken by ' irradiation'.