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FACULTY OF AGRICULTURAL SCIENCES

AND ALLIED INDUSTRIES

GENE INTERACTION OR EPISTASIS

When expression of one gene depends upon presence or absence of another gene in an individual, it is known as gene interaction.

Epistasis is the interaction between genes that influences a phenotype. Genes can either mask each other so that one is considered "dominant" or they can combine to produce a new trait. It is the conditional relationship between two genes that can determine a single phenotype of some traits. At each locus are two alleles that dictate phenotypes. They can affect one another in such a way that, regardless of the allele of one gene, it is recessive to one dominant allele of the other.

Six types of epistatic gene interactions are:

1. **Recessive Epistasis [9:3:4 Ratio]:**

When recessive alleles at one locus mask the expression of both (dominant and recessive) alleles at another locus, it is known as recessive epistasis. This type of gene interaction is also known as supplementary epistasis. A good example of such gene interaction is found for grain colour in maize.

There are three colours of grain in maize, viz., purple, red and white. The purple colour develops in the presence of two dominant genes (R and P), red colour in the presence of a dominant gene R, and white in homozygous recessive condition (rrpp).

A cross between purple (RRPP) and white (rrpp) grain colour strains of maize produced plants with purple colour in F_1. Inter-mating of these F_1 plants produced progeny with purple, red and white grains in F_2 in the ratio of 9 : 3 : 4.

Parents — Purple Grains PPRR × White Grains pprr

F_1 — PpRr Purple Grains

F_2

	PR	Pr	pR	pr
PR	PPRR [P]	PPRr [P]	PpRr [P]	PpRr [P]
Pr	PPRr [P]	PPrr [W]	PpRr [P]	Pprr [W]
pR	PpRR [P]	PpRr [P]	ppRR [R]	ppRr [R]
pr	PpRr [P]	Pprr [W]	ppRr [R]	pprr [W]

P = Purple, R = Red, and W = White grains

Fig: Recessive epistasis for grain colour in maize. The normal dihybrid segregation ratio of 9:3:3:1 is modified to 9:3:4 in F2

Here allele r is recessive to R, but epistatic to alleles P and p. In F_2, all plants with R-P-(9/16) will have purple grains and those with R-pp genotypes (3/16) have red grain colour. The epistatic allele r in homozygous condition will produce plants with white grains from rrP-(3/16) and rrpp (1/16) genotypes.

Thus the normal segregation ratio of 9 : 3 : 3 : 1 is modified to 9 : 3 : 4 in F_2generation. Such type of gene interaction is also found for coat colour in mice, bulb colour in onion and for certain characters in many other organisms.

2. **Dominant Epistasis [12 : 3 : 1 Ratio]:**

When a dominant allele at one locus can mask the expression of both alleles (dominant and recessive) at another locus, it is known as dominant epistasis. In other words, the expression of one dominant or recessive allele is masked by another dominant gene. This is also referred to as simple epistasis.

An example of dominant epistasis is found for fruit colour in summer squash. There are three types of fruit colours in this cucumber, viz., white, yellow and green. White colour is controlled by dominant gene W and yellow colour by dominant gene G. White is dominant over both yellow and green.

The green fruits are produced in recessive condition (wwgg). A cross between plants having white and yellow fruits produced F_1 with white fruits. Inter-mating of

F_1 plants produced plants with white, yellow and green coloured fruits in F_2 in 12 : 3 : 1 ratio. This can be explained as follows.

Parents: White Fruit WWgg × Yellow Fruit wwGG

F_1: WwGg White Fruit

F_2:

	WG	Wg	wG	wg
WG	WWGG [W]	WWGg [W]	WwGG [W]	WwGg [W]
Wg	WWGg [W]	WWgg [W]	WwGg [W]	Wwgg [W]
wG	WwGG [W]	WwGg [W]	wwGG [Y]	wwGg [Y]
wg	WwGg [W]	Wwgg [W]	wwGg [Y]	wwgg [G]

W = White Fruit, Y = Yellow fruit, G = Green Fruit

Fig: Dominant epistasis for fruit colour in Summer squash. The normal dihybrid ratio is modified to 12:3:1 ratio in F2 generation.

Here W is dominant to w and epistatic to alleles G and g. Hence it will mask the expression of G/g alleles. Hence in F_2, plants with W-G-(9/16) and W-gg (3/16) genotypes will produce white fruits; plants with wwG-(3/16) will produce yellow fruits and those with wwgg (1/16) genotype will produce green fruits.

Thus the normal dihybrid ratio 9 : 3 : 3 : 1 is modified to 12:3: 1 ratio in F_2 generation. Similar type of gene interaction has been reported for skin colour in mice and seed coat colour in barley.

3. **Dominant [Inhibitory] Epistasis [13 : 3 Ratio]:**

In this type of epistasis, a dominant allele at one locus can mask the expression of both (dominant and recessive) alleles at second locus. This is also known as inhibitory gene interaction. An example of this type of gene interaction is found for anthocyanin pigmentation in rice.

The green colour of plants is governed by the gene I which is dominant over purple colour. The purple colour is controlled by a dominant gene P. When a cross was made between green (IIpp) and purple (iiPP) colour plants, the F_1 was green. Inter-mating of F_1 plants produced green and purple plants in 13 : 3 ratio in F_2 . This can be explained as follows.

Parents Green Plant Ilpp × Purple Plant iiPP

F_1 IiPp Green Plant

F_2

	IP	Ip	iP	ip
IP	IIPP [G]	IIPp [G]	IiPP [G]	IiPp [G]
Ip	IIPp [G]	IIpp [G]	IiPp [G]	Iipp [G]
iP	IiPP [G]	IiPp [G]	iiPP [P]	iiPp [P]
ip	IiPp [G]	Iipp [G]	iiPp [P]	iipp [G]

G = Green Plant, P = Purple Plant

Fig: Inhibitory epistasis for anthocyanin pigmentation in rice. The normal dihybrid ration is modified to 13:3 ratio in F2 generation.

Here the allele I isepistatic to alleles P and p. Hence in F_2, plants with I-P-(9/16), I-pp (3/16) and iipp (1/16) genotypes will be green because I will mask the effect of P or p. Plants with iiP-(3/16) will be purple, because I is absent.

In this way the normal dihybrid segregation ratio 9 : 3 : 3 : 1 is modified to 13 : 3 ratio. Similar gene interaction is found for grain colour in maize, plumage colour in poultry and certain characters in other crop species.

4. Duplicate Recessive Epistasis [9 : 7 Ratio]:

When recessive alleles at either of the two loci can mask the expression of dominant alleles at the two loci, it is called duplicate recessive epistasis. This is also known as complementary epistasis. The best example of duplicate recessive epistasis if found for flower colour in sweet pea.

The purple colour of flower in sweet pea is governed by two dominant genes say A and B. When these genes are in separate individuals (AAbb or aaBB) or recessive (aabb) they produce white flower.

A cross between purple flower (AABB) and white flower (aabb) strains produced purple colour in F_1. Inter-mating of F_1 plants produced purple and white flower plants in 9 : 7 ratio in F_2 generation. This can be explained as follows.

Here recessive allele a isepistatic to B/b alleles and mask the expression of these alleles. Another recessive allele b is epistatic to A/a alleles and mask their expression.

Hence in F_2, plants with A-B-(9/16) genotypes will have purple flowers, and plants with aaB-(3/16), A-bb-(3/16) and aabb (1/16) genotypes produce white flowers. Thus only two phenotypic classes, viz., purple and white are produced and the normal dihybrid segregation ratio 9 : 3 : 3 : 1 is changed to 9 : 7 ratio in F_2 generation.

Parents Purple Flower AABB × White Flower aabb

↓

F_1 AaBb Purple Flower

F_2

	AB	Ab	aB	ab
AB	AABB [P]	AABb [P]	AaBb [P]	AaBb [P]
Ab	AABb [P]	AAbb [W]	AaBb [P]	Aabb [W]
aB	AaBb [P]	AaBb [P]	aaBB [W]	aaBb [W]
ab	AaBb [P]	Aabb [W]	aaBb [W]	aabb [W]

P = Purple Flower, W = White Flower

Fig: Duplicate recessive epistasis for flower colour in sweet pea. The normal dihybrid segregation ratio modified to 9:7 in F2.

5. Duplicate Dominant Epistasis [15 : 1 Ratio]:

When a dominant allele at either of two loci can mask the expression of recessive alleles at the two loci, it is known as duplicate dominant epistasis. This is also called duplicate gene action. A good example of duplicate dominant epistasis is awn character in rice. Development of awn in rice is controlled by two dominant duplicate genes (A and B).

Presence of any of these two alleles can produce awn. The awnless condition develops only when both these genes are in homozygous recessive state (aabb). A cross between awned and awnless strains produced awned plants in F_1. Inter-mating of F_1 plants produced awned and awnless plants in 15 : 1 ratio in F_2 generation. This can be explained as follows.

Parents: Awned Rice AABB × Awnless Rice aabb

F_1: AaBb Awned Rice

F_2:

	AB	Ab	aB	ab
AB	AABB [A]	AABb [A]	AaBB [A]	AaBb [A]
Ab	AABb [A]	AAbb [A]	AaBb [A]	Aabb [A]
aB	AaBB [A]	AaBb [A]	aaBB [A]	aaBb [A]
ab	AaBb [A]	Aabb [A]	aaBb [A]	aabb [a]

A = Awned Rice, a = Awnless Rice

Fig: Duplicate dominant epistasis for awn character in rice. The normal dihybrid segregation ratio is modified to 15:1 in F2.

The allele A is epistatic to B/b alleles and all plants having allele A will develop awn. Another dominant allele B is epistatic to alleles A/a. Individuals with this allele also will develop awn character. Hence in F_2, plants with A-B-(9/16), A-bb-(3/16) and aaB-(3/16) genotypes will develop awn.

The awnless condition will develop only in double recessive (aabb) genotype (1/16). In this way only two classes of plants are developed and the normal dihybrid segregation ratio 9 : 3 : 3 : 1 is modified to 15 : 1 ratio in F_2. Similar gene action is found for nodulation in peanut and non-floating character in rice.

6. Polymeric Gene Interaction [9:6:1 Ratio]:

Two dominant alleles have similar effect when they are separate, but produce enhanced effect when they come together. Such gene interaction is known as polymeric gene interaction. The joint effect of two alleles appears to be additive or cumulative, but each of the two genes show complete dominance, hence they cannot be considered as additive genes. In case of additive effect, genes show lack of dominance.

A well-known example of polymeric gene interaction is fruit shape in summer squash. There are three types of fruit shape in this plant, viz., disc, spherical and long. The disc shape is controlled by two dominant genes (A and B), the spherical shape is produced by either dominant allele (A or B) and long shaped fruits develop in double recessive (aabb) plants.

A cross between disc shape (AABB) and long shape (aabb) strains produced disc shape fruits in F_1. Inter-mating of F_1 plants produced plants with disc, spherical and long shape fruits in 9 : 6 : 1 ratio in F_2. This can be explained as follow.

Parents — Disc Shape Fruit AABB × Long Shape Fruit aabb

↓

F_1 — AaBb Disc Shape Fruit

F_2

	AABB	Ab	aB	ab
AB	AABB [D]	AABb [D]	AaBB [D]	AaBb [D]
Ab	AABb [D]	AAbb [S]	AaBb [D]	Aabb [S]
aB	AaBb [D]	AaBb [D]	aaBB [S]	aaBb [S]
ab	AaBb [D]	Aabb [S]	aaBb [S]	aabb [L]

D = Disc shape fruit, S = Spherical fruit, L = Long fruit

Fig: Polymeric gene interaction for fruit shape in summer squash. The normal dihybrid ratio modified to 9:6:1 in F2.

Here plants with A—B—(9/16) genotypes produce disc shape fruits, those with A-bb-(3/16) and aaB-(3/16) genotypes produce spherical fruits, and plants with aabb (1/16) genotype produce long fruits. Thus in F_2, normal dihybrid segregation ratio 9:3:3: 1 is modified to 9 : 6 : 1 ratio. Similar gene action is also found in barley for awn length.