Gene action and interaction

Deependra Dhakal

Academic year 2019-2020

Gokuleshwor Agriculture and Animal Science College
Tribhuwan University
ddhakal.rookie@gmail.com
`https://rookie.rbind.io`

Gene interaction

What and how ?

- In Mendelian phenotypic ratio, one gene is involved in expression of a single phenotype.
- Some phenotype develop through gene interaction between two or more genes. i.e. two or more genes may also be involved in determination of a single trait and the phenotypic ratio deviates from the expected Mendelian phenotypic ratio.
- There are a variety of phenotypic ratios which are the result of a variety of gene interaction. Steps in inferring gene interaction :

  1. Obtain many single-gene mutants and test for dominance
  2. Test the mutants for allelism
  3. Combine the mutants in pairs (the process is detailed in a Complementation test[1].->Refer to lecture notes on 'Nature of gene', Course: Genetics of population, 5^{th} semester, BScAg) to form double mutants to see if the genes interact.

- This double mutant may then be identified by looking for Mendelian ratios. For example, if a standard 9:3:3:1 Mendelian ratio is obtained, the phenotype present in only 1/16 of the progeny represents the double mutant (the “1” in 9:3:3:1).
- Gene interaction is inferred from the phenotype of the double mutant (doesn’t mean in two genes): if the genes interact, then the phenotype differs from the simple combination of both single-gene mutant phenotypes.
- In cases in which the two mutants interact, a modified 9:3:3:1 Mendelian ratio will often result (such as 9:3:4 or 9:7). We can then also infer that the wild-type genes interact normally as well.

Gene interaction types

Overview

- No interaction (9:3:3:1)
- Duplicate gene action (15:1)
- Complementary gene action (9:7)
- Supplementary gene action (9:3:4)
- Inhibitory gene action (13:3)
- Masking gene action (12:3:1)
- Polymeric gene action (9:6:1)
- Additive gene action (1:4:6:4:1)

Table 1: Each gene pair affecting a different character

Type of gene/s	Phenomena	Individuals	Phenotypes	Genotypes
Each gene pair affecting a different character	Complete dominance at both gene pairs	$\frac{9}{16}$	yellow round	1, 2, 3, 4, 5, 7, 9, 10, 13
	Example: Mendel's peas	$\frac{3}{16}$	yellow wrinkled	6, 8, 14
	Gene pair A: (seed color) yellow dominant over green	$\frac{3}{16}$	green round	11, 12, 15
	Gene pair B: (seed shape) round dominant over wrinkled	$\frac{1}{16}$	green wrinkled	16

Gamete	AB	Ab	aB	ab
AB	ABAB	ABAb	ABaB	ABab
Ab	AbAB	AbAb	AbaB	Abab
aB	aBAB	aBAb	aBaB	aBab
ab	abAB	abAb	abaB	abab

No interaction

- Two dominant genes controlling the development of a single trait.

Table 2: Each gene pair affecting the same character

Type of gene/s	Phenomena	Individuals	Phenotypes	Genotypes
Each gene pair affecting the same character	Complete dominance at both gene pairs; new phenotypes resulting from interaction between dominants, and also from interaction between both homozygous recessives	$\frac{9}{16}$	walnut	1, 2, 3, 4, 5, 7, 9, 10, 13
	Example: comb shape in poultry	$\frac{3}{16}$	rose	6, 8, 14
	Gene pair A: rose comb dominant over nonrose	$\frac{3}{16}$	pea	11, 12, 15
	Gene pair B: pea comb dominant over nonpea	$\frac{1}{16}$	single	16
	Interaction: Dominants for rose and pea produce walnut comb. Homozygous recessives for rose and pea produce single comb			

Gamete	AB	Ab	aB	ab
AB	ABAB	ABAb	ABaB	ABab
Ab	AbAB	AbAb	AbaB	Abab
aB	aBAB	aBAb	aBaB	aBab
ab	abAB	abAb	abaB	abab

Supplementary gene action

- The dominant allele of one gene produces a phenotypic effect.
- The dominant allele of the other gene does not produce any phenotypic effect on its own, but when present with dominant allele of the first gene, it modifies the phenotypic effect produced by the first gene.
- For e.g. development of grain (aleurone) color in maize producing 9:3:4 ratio in F_2.

Table 3: Each gene pair affecting the same character

Type of gene/s	Phenomena	Individuals	Phenotypes	Genotypes
Each gene pair affecting the same character	Complete dominance at both gene pairs, but one gene, when homozygous recessive, is epistatic to the other	$\frac{9}{16}$	agouti	1, 2, 3, 4, 5, 7, 9, 10, 13
	Example: mouse coat color	$\frac{3}{16}$	black	6, 8, 14
	Gene pair A: color dominant over albino	$\frac{4}{16}$	albino	11, 12, 15, 16
	Gene pair B: agouti color dominant over black			
	Interaction: homozygous albino is epistatic to agouti and black			

Gamete	AB	Ab	aB	ab
AB	ABAB	ABAb	ABaB	ABab
Ab	AbAB	AbAb	AbaB	Abab
aB	aBAB	aBAb	aBaB	aBab
ab	abAB	abAb	abaB	abab

Complementary gene action

- Production of one phenotype requires the presence of dominant alleles of both genes controlling the character.
- When any one of the two or both the genes are present in homozygous recessive state, the contrasting phenotype is produced.

Table 4: Each gene pair affecting the same character

Type of gene/s	Phenomena	Individuals	Phenotypes	Genotypes
Each gene pair affecting the same character	Complete dominance at both gene pairs, but either recessive homozygote is epistatic to the effects of the other gene	$\frac{9}{16}$	purple	1, 2, 3, 4, 5, 7, 9, 10, 13
	Example: sweet pea flower color	$\frac{7}{16}$	white	6, 8, 11, 12, 14, 15, 16
	Gene pair A: purple dominant over white Gene pair B: color dominant to colorless (white) Interaction: homozygous recessives at either gene A or B produce white			

Gamete	AB	Ab	aB	ab
AB	ABAB	ABAb	ABaB	ABab
Ab	AbAB	AbAb	AbaB	Abab
aB	aBAB	aBAb	aBaB	aBab
ab	abAB	abAb	abaB	abab

Masking gene action

- Dominant alleles of the two genes affecting a character produce distinct phenotypes when they are alone. But when dominant alleles of both the genes are present together, the expression of dominant allele of one gene masks the expression of the other. When both the genes are present in recessive state, a different phenotype is produced.

Table 5: Each gene pair affecting the same character

Type of gene/s	Phenomena	Individuals	Phenotypes	Genotypes
Each gene pair affecting the same character	Complete dominance at both gene pairs, but one gene, when dominant, epistatic to the other	$\frac{12}{16}$	white	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14
	Example: fruit color in summer squash	$\frac{3}{16}$	yellow	11, 12, 15
	Gene pair A: white dominant to color	$\frac{1}{16}$	green	16
	Gene pair B: yellow dominant to green Interaction: Dominant white hides the effect of yellow or green			

Gamete	AB	Ab	aB	ab
AB	ABAB	ABAb	ABaB	ABab
Ab	AbAB	AbAb	AbaB	Abab
aB	aBAB	aBAb	aBaB	aBab
ab	abAB	abAb	abaB	abab

Inhibitory gene action

- One dominant gene produces the concerned phenotype or the character, while its recessive allele produces the contrasting phenotype.
- The second gene has no effect of its own on the character in question, but it stops the expression of the dominant allele of the first gene.
- As a result, when two dominant genes are present togethe, they produce the same phenotype as that produced by the recessive homozygote of the first gene.
- The recessive allele of the second gene does not affect the development of the character in any way.
- For e.g. genes controlling seed color in maize.

Table 6: Each gene pair affecting the same character

Type of gene/s	Phenomena	Individuals	Phenotypes	Genotypes
Each gene pair affecting the same character	Complete dominance at both gene pairs, but one gene, when dominant, epistatic to the second, and the second gene, when homozygous recessive, epistatic to the first	$\frac{13}{16}$	white	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16
	Example: feather color in fowl Gene pair A: color inhibition is dominant to color appearance Gene pair B: color is dominant to white Interaction: dominant color inhibition prevents color even when color is present: color gene, when homozygous recessive, prevents color even when dominant inhibitor is absent	$\frac{3}{16}$	color	11, 12, 15

Gamete	AB	Ab	aB	ab
AB	ABAB	ABAb	ABaB	ABab
Ab	AbAB	AbAb	AbaB	Abab
aB	aBAB	aBAb	aBaB	aBab
ab	abAB	abAb	abaB	abab

Polymeric gene action

- Two completely dominant genes controlling a character produce the same phenotype when their dominant alleles are alone. But when dominant alleles of both genes are present together, their phenotypic effect is enhanced as if the effect of the two genes are present together, their phenotypic effect is enhanced as if the effect of the two genes were cumulative or additive.

Table 7: Each gene pair affecting the same character

Type of gene/s	Phenomena	Individuals	Phenotypes	Genotypes
Each gene pair affecting the same character	Complete dominance at both gene pairs; interaction between both dominants to give new phenotypes	$\frac{9}{16}$	disc	1, 2, 3, 4, 5, 7, 9, 10, 13
	Example: fruit shape in summer squash	$\frac{6}{16}$	sphere	6, 8, 11, 12, 14, 15
	Gene pair A: sphere shape dominant over long shape Gene pair B: sphere shape dominant over long shape Interaction: dominants at A and B, when present together, form disc-shaped fruit	$\frac{1}{16}$	long	16

Gamete	AB	Ab	aB	ab
AB	ABAB	ABAb	ABaB	ABab
Ab	AbAB	AbAb	AbaB	Abab
aB	aBAB	aBAb	aBaB	aBab
ab	abAB	abAb	abaB	abab

Additive gene action

- Each positive allele of the two genes governing a trait produces equal and identical effect on the character.
- This gene action is the basis for **multiple factor hypothesis** and the gene action sometimes aka polygenic action.

Table 8: Each gene pair affecting the same character

Type of gene/s	Phenomena	Individuals	Phenotypes	Genotypes
Each gene pair affecting the same character	Partial dominance at both gene pairs; additive effects for each partially dominant gene	$\frac{1}{16}$	purple shade 10	1
	Example: flower color in beans (Mendel)	$\frac{2}{16}$	purple shade 8	2, 5
	Gene pair A: purple flower color partially dominant to white; additive effect on color for each A gene (i.e., value of 3)	$\frac{2}{16}$	purple shade 7	3, 9
	Gene pair B: purple flower color partially dominant to white; additive effect on color for each A gene (i.e., value of 2)	$\frac{1}{16}$	purple shade 6	6
		$\frac{4}{16}$	purple shade 5	4, 7, 10, 13
		$\frac{1}{16}$	purple shade 4	11
		$\frac{2}{16}$	purple shade 3	8, 14
		$\frac{2}{16}$	purple shade 2	12, 15
		$\frac{1}{16}$	purple shade 0 (white)	16

Gamete	AB	Ab	aB	ab
AB	ABAB	ABAb	ABaB	ABab
Ab	AbAB	AbAb	AbaB	Abab
aB	aBAB	aBAb	aBaB	aBab
ab	abAB	abAb	abaB	abab

Bibliography

See also

- For enzymatic explaination of genetic ratios refer to the lecture “Nature of gene” (Course: Genetics of population, 5^{th} semester, BScAg)

References