**Multiple factor inheritance**

The Inheritance of many different genes influencing the same phenotype in a cumulative fashion is called multiple factor inheritance.

**Features of polygenic traits**

The term polygene was introduced by Mather in 1941. This term has found wide usage in quantitative genetics replacing the older term multiple gene. Main features of polygenic characters are briefly presented below:

(i) Each polygenic character is controlled by several genes and has cumulative effect.

(ii) Polygenic characters exhibit continuous variation rather than a discontinuous variation. Hence, they cannot be classified into clear cut groups.

(iii) Effect of individual gene is not easily detectable in case of polygenic character and, therefore, such traits are also known as minor gene characters.

(iv) The statistical analysis of polygenic variation is based on means, variance and co-variances, whereas the discontinuous variation is analysed with the help of frequencies and ratios. Thus, polygenic characters are studies in quantitative genetics and oligogenic characters in Mendelian genetics.

(v) Polygenic traits are highly sensitive to environmental changes, whereas oligogenic characters are little influenced by environmental variation.

(vi) Classification of polygenic characters into different clear cut groups is not possible because of continuous variation from one extreme to the other. In case of qualitative characters, such grouping is possible because of discrete or discontinuous variation.

(vii) Generally, the expression of polygenic characters is governed by additive gene action, but now cases are known where polygenic characters are governed by dominance and epistatic gene action. In case of oligogenic characters, the gene action is primarily of non-additive type (dominance and epistasis).

(viii) In case of polygenic characters, bio-metric measurements like size, weight, duration, strength, etc, are possible, whereas in case of oligogenic characters only the counting of plants with regards to various kinds like colour and shape is possible. Thus, metric measurement is not possible in case of oligogenic characters.

(ix) Transgressive segregants are possible from the crosses between two parents for a polygenic character. Such segregants are not possible in case of qualitative or oligogenic traits. (x) The transmission of polygenic characters is generally low because of high amount of environmental variation. On the other hand, oligogenic characters exhibit high transmission because there is little difference between the genotype and phenotype of such character. Thus, polygenic Characters differ from oligogenic ones in several aspects. Yule (1906) gave the theoretical explanation for the multiple factor hypotheses. According to him quantitative characters are controlled by many genes with cumulative effect without dominance and would produces continuous variation. The experimental evidence for multiple factor hypothesis was provided by Nilsson & Ehle (1908) in studies on the inheritance of seed colour in wheat and oats.

They obtained 3:1, 15:1 and 63:1 ratios between coloured and white seeds from different crosses and revealed that seed colour in wheat and oats is produced by one, two or three genes. The seed colour genes interact in duplicate manner, so that white colour seed is produced only when all the genes are present in the recessive state. Further the coloured seeds showed a varied intensity for colouring pattern and they obtained in the ratio of 1 dark red : 4 medium dark red : 6 medium red : 4 light red : 1 white. This suggested that the seed odour in wheat is controlled by genes which show lack of dominance and have small and cumulative effects . In order to explain the 1:4:6:4:1 ratio in kernel colour in wheat, Nilson – Ehle made the following assumptions.

i. In crosses showing 15:1 ratio in the F2 seed colour is governed by two genes.

ii. One of the alleles of each colour gene produces seed colour and is called positive allele denoted by capital letter (eg.) R1,R2 etc. The other allele of each colour gene does not produce any colour and is known as negative allele denoted by corresponding small letter (eg.) r1, r2 etc.

iii. These genes do not show dominance and each of the gene (positive allele) has a small, equal effect on seed colour.

iv. The positive alleles of different coloured genes are additive in phenotypic effect.

Inheritance of kernel colour in wheat

| | | | |
|---|---|---|---|
| | Dark red | x | White |
| Parents | R1R1R2R2 | | r1r1r2r2 |
| Gametes | (R1R2) | | (r1r2) |

F1 R1 r1R2 r2

Medium Red

F2 generation

| | R1R2 | R1r2 | r1R2 | r1r2 |
|---|---|---|---|---|
| R1R2 | R1R1R2R2 DR | R1R1R2r2 MDR | R1r1R2 R2 MDR | R1r1R2r2 MR |
| R1r2 | R1R1R2r2 MDR | R1R1r2r2 MR | R1r1R2r2 MR | R1r1r2r2 LR |
| r1R2 | R1r1R2R2 MDR | R1r1R2r2 MR | r1r1R2R2 MR | r1r1R2r2 LR |
| r1r2 | R1r1R2r2 MR | R1r1r2r2 LR | r1r1R2r2 LR | r1r1r2r2 white |

**Genotype and phenotype frequencies produced by two genes with cumulative effect on seed colour in wheat**

| **Genotype** | **Frequency** | **No. of positive allele** | **Phenotype** | **Frequency** |
|---|---|---|---|---|
| R1R1R2R2 | **1** | **4** | Dark Red | **1** |
| R1r1R2R2 | 2 | 3 | Dark Medium Red | 4 |
| R1R1R2r2 | 2 | **3** | | |
| R1r1R2r2 | **4** | 2 | Medium Red | **6** |
| R1R1r2r2 | **1** | **2** | | |
| r1r1R2R2 | **1** | **2** | | |
| R1r1r2r2 | **2** | **1** | Light Red | **4** |
| r1r1R2r2 | **2** | **1** | | |
| r1r1r2r2 | **1** | **0** | White | **1** |

***Cumulative Factors or polygenic traits***

The greater the genes, larger will be its effect; these factors are quantitative in nature and bring out different degrees of phenotypic expressions according to the number of doses of the determiner. The effect increases with each increase in the number of genes and so is called as cumulative. Such genes are known as multiple genes or polygenes, a name coined as the mode of inheritance of such genes is called polygenic inheritance or multiple factor inheritance. It is also known as quantitative or blending inheritance. Such type of inheritance has been observed with wheat (kernel colour), human (skin colour), cattle (coat colour), chicken (size), cows (milk production) etc.

Davenport showed this type of interaction of genes in human beings, saying that the colour of skin is dependent on the presence of a pigment melanin in the skin. It is commonly seen that the offsprings of black and white parents are usually more or less with intermediate complexion. This is due to the cumulative action of several pairs of genes which do not show dominance.

Explanation

In case of the pure-blooded Negro, two pairs of genes are present for black pigmentation. Let us assume ‘A’ & ‘B’ are the genes for the skin colour and ‘a’ and ‘b’ for the lack of pigment. A pure blooded Negro has four dominant genes (AABB) and a pure white has ‘aabb’ for the skin colour. On crossing the Negro with white, $F_1$offsprings are ‘AaBb’ and skin colour mulatto, which is intermediate between the two parents. On selfing $F_1$, offspring in $F_2$ show a variety of skin colours depending on the number of genes for pigmentation. The results of $F_2$ generation are as follows:

1 = Negro = AABB
4 = Dark brown = AaBB, AABb
6 = mulatto = AaBb, AAbb, aaBB
4 = light brown = Aabb, aaBb
1 = white = aabb.

The above cross shows that it is possible for the parents heterozygous for skin colour to produce children with darker as well as lighter colours than themselves.

P- Generation black Negro X white
Genotype AA BB aa bb
Gametes AB ab
Progeny Bb Aa mulatto
Mulatto women Bb Aa X Bb Aa Mulatto man
Gametes produced are BA, Ba, bA. Ba

| Gametes | BA | Ba | bA | ba |
|---|---|---|---|---|
| BA | BBAA Negro | BBAa Dark brown | BbAA Dark brown | BbAa Mulatto |
| Ba | BBAa Dark brown | BBaa Mulatto | BbAa Mulatto | Bbaa light brown |
| bA | BbAA Dark brown | BbAa Mulatto | bbAA Mulatto | bbAa light brown |
| ba | BbAa Mulatto | Bbaa light brown | bbAa light brown | bbaa white |