Inheritance of Quantitative Factors or Multiple-Factor or Multigenic Inheritance

In the previous sections, we have discussed genetic laws governing inheritance of qualitative characters. Such characters are not continuous in their expression, and are classifiable into different groups. For instance, in pea, on which Mendel performed his classic experiments, all the 7 characters were qualitative and displayed discontinuous variation. The flower position was either terminal or axillary; the seed either round or wrinkled, the pea plant was either tall or dwarf and so on and so forth. Such characters are called *qualitative, discontinuous, or Mendelian.*

On the other hand, we come across several other characters in plants and other living organisms, whose expression is continuous, i.e., they cannot be divided into distinct classes; there are no breaks in their expression and there is a continuous series of character expression from the one extreme to the other. Height, in several plants and other living beings behaves as a continuous character. Similarly, body weight, plant yield, mental faculties and several other characters are continuous characters. In these cases, one cannot distinguish and count different forms of a character merely by looking at them, as is possible in qualitative characters. But, measurements in the appropriate scale are made in order to study the mode of their expression and inheritance. Since the study of these characters involves their measurements, they are called *quantitative or metric* characters.

Genetic studies on quantitative or metric characters have demonstrated that the inheritance of these characters is not as simple as that of qualitative or Mendelian characters, but it is rather quite complex and is controlled by several genes which are usually equal in their effect. Because several genes determine expression of quantitative characters, their inheritance is termed *multiple-factor or multigenic inheritance* as contrasted with the simple inheritance of a qualitative character where only one, two, three or four genes may be involved.

Although inheritance of quantitative characters is multigenic, i.e. involving many genes more or less equal in effect, yet the same Mendelian laws are applicable in this type of inheritance as in simple inheritance. These genes segregate and assort independently subject to linkage. But because of the operation of many genes, the number of phenotypes is very large and since the genes have equal effect and the environmental effect is overwhelming they produce a continuous expression of character which is not classifiable into distinct groups.

The individual effect of such genes s relatively small and highly susceptible to environmental conditions. In animals, milk yield is a quantitative character. A cow, for instance, may have the potentiality (genotype) of yielding 40 lbs. of milk daily if fed on productive ration (environments). If the feed is reduced in quality or quantity, the milk yield will suffer a corresponding reduction. The reduction in ration has not actually affected the genotype of the animal but has changed the phenotype (milk yield). It is evident that a variation in the environments affects the expression of the quantitative characters, but similar changes are not so conspicuously expressed for qualitative characters. Another feature of the quantitatively controlled character is that the number of genes involved is usually large and there is a correspondingly large number of genotypes and phenotypes in the segregating generations.

Multiple factors or multiple genes or polygenes should not be confused with multiple alleles. Multiple alleles (skin colour in rabbits) are members of an allelic series and at a time only one pair of alleles is present in a diploid organism. Whereas several multiple genes, affecting a particular trait, are present together in a diploid organism and variation in the number of contributing genes (plus, major) brings about a change in the phenotype.

Pleiotropy

Sometimes a gene may have more than one effect, i.e. it influences more than one character simultaneously. It has long been noted that blue-eyed white cats are always deaf; blue eye gene also causes deafness. In wheat the presence of awn usually has a pleiotropic effect on grain yield. Awned wheats are better yielders than those without awns.

Kernel Colour in Wheat

*The first case of quantitative inheritance was studied by Nilsson-Ehle (1910—13) about kernel colour of wheat. He crossed varieties differing for red and white kernel colour, and observed that the F_1 grains were intermediate in colour between the two parents. The F_2 raised from the selfed seed of F_1 produced a continuous variation ranging from red to white, which was grouped arbitrarily into 5 classes. 1/16 of the total F_2 plants resembled red parent in grain colour and another 1/16 the white parent and, the rest 14/16 plants were midway between the two parents for colour expression. Of these 14/16 plants, 6/16 were like the F_1; 4/16 were lighter than the red parent and darker than F_1, and 4/16 were intermediate between F_1 and the white parent. This pattern of segregation showed that two gene pairs controlled the inheritance of kernel colour and that they were cumulative (additive) in their effect. In another study, the same author discovered that three gene pairs instead of two, controlled kernel colour difference.

Skin colour in man

*In man, skin colour is due to the presence of melanin, which is genetically controlled. It is believed that several genes may be involved. A negro has the maximum amount of melanin pigment while a white possesses none or a very small amount of it. In other words, negroes possess all the colour genes and the whites recessive alleles. From a marriage of a negro and a white all the children are mulattoes (intermediate in skin colour). When the mulattoes marry together, their children (F_2) show all grades of skin colour between black and white. The melanin production is, however, greatly influenced by exposure to sunlight. *The more the sunlight the more the melanin and vice versa.

Plant height in wheat

We shall now consider inheritance of another quantitative character plant height in wheat. It has been determined that plant height in wheat is controlled by several major and minor genes. Let us suppose that

5 gene pairs control inheritance of plant height, dominance exists at each locus and each dominant allele contributes two units to the expression of plant height. Consider this cross-between a tall and a dwarf parent. The dwarf parent measures 40 inches and the tall parent 60 inches in height.

Parents	AABBCCDDEE	x	aabbccddee
	60"		40"
F_1	AaBbCcDdEe (50 inches tall)		

To obtain frequency of various classes in the F_2, expansion of the binomial $(A+a)^{10}$ is helpful, where A is the dominant allele and a the recessive.

Frequency	Genotype	Phenotype
1	A^{10}	60" tall
10	A^9 a^1	58" tall
45	A^8 a^2	56" tall
120	A^7 a^3	54" tall
210	A^6 a^4	52" tall
252	A^5 a^5	50" tall
210	A^4 a^6	48" tall
120	A^3 a^7	46" tall
45	A^2 a^8	44" tall
10	A^1 a^9	42" tall
1	a^{10}	40" tall

It will be observed that in the F_2 of this cross, one plant out of 1024 plants one is 60" tall, 10 plants are 58" tall; 45 plants are 56" tall and so on down to one plant being 40" tall which does not have any dominant gene.

A large variety of characters behave quantitatively and the analysis of their inheritance may be attempted as shown above. Other methods are also available for this purpose.

PROBLEMS

1. What do you know about a qualitative ...