Breeding for Disease Resistance

Resistance refers to the ability of the host to interfere with the normal growth and for development of the pathogen. The plant affected by the disease is known as host while the organism that produces the disease is known as pathogen. Therefore, disease is an abnormal condition in the plant produced by an organism/pathogen.

Thus, the abnormalities produced by the non-biological environment or by the genetic factors present in the host are not diseases.

➢ Economic significance of diseases :

The diseases reduce the total biomass (dry matter) production by the crop (host) in one or more of the following ways:

(i) Killing of plants
(ii) Killing of branches
(iii) General stunting
(iv) Damage of leaf tissues
(v) Damage to the reproductive organs including fruits and seeds

These disturbances in plant growth and development ultimately led to the consequent decrease in yield. The loss due to disease may range from a few 20 or 30 percent or in cases of severe infection, the total crop may be lost. A striking effect of diseases is the disappearance from cultivation of otherwise excellent but susceptible varieties, eg. Wheat variety 'Kalyan sona' dominated the Indian agriculture for more than a decade but had to be abandoned as it became susceptible to leaf rust. Similarly, another wheat variety 'Janak' was eliminated from cultivation due to its susceptibility to karnal bunt disease.

➢ Historical background for breeding for disease resistance:

- Theophrastus in the 3rd century B.C. noted that cultivated varieties differed in the ability to resist/avoid diseases.
- In 1894, Erikson showed that pathogens although morphologically similar, differed from each other in their ability to attack different related host species
- In 1911, Barrus showed that different isolates of a microorganism differed in their ability to attack different varieties of the same hostspecies. This finding made the basis for physiological races and pathotypes

It was subsequently established that the ability of a pathogen to infect a host strain i.e. PATHOGENECITY is genetically determined. Thus, both the ability of the host to resist invasion by the pathogen as well as the ability of the pathogen to invade the host are genetically controlled.

- In 1955, Flor postulated the hypothesis of gene-for-gene relationship between host and pathogen which holds true in most of the cases and is widely accepted.

It was subsequently established that the disease resistance of the host is not the function of the host genotype alone but is also determined by the genotype of the pathogen as well.

The host strains differ in resistance while those of the pathogen differ in pathogenicity, both variations have genetic basis. The pathogen has remarkable capacity to generate new variations in pathogenicity by a variety of reproduction methods and mutation. Thus, the task of the breeder is not only to develop varieties resistant to the prevalent pathotypes of the pathogen but also to be ready to face the challenge that is to be posed by new pathogen genotypes in future.

➢ PHYSIOLOGICAL RACES AND PATHOTYPES vs. DIFFERENTIAL HOSTS:

Physiological races are strains of a single pathogen species differing in their ability to attack different varieties of same host species. The varieties of a host species used to identify physiological races of a pathogen are known as ‘differential hosts’ or ‘host testers’. The differential hosts are chosen on the basis of differences in their resistance to the pathogen. Ideally, each of the differential hosts should possess a single resistance gene which is different from those present in the others.

➢ CATEGORIZATION OF RESISTANCE TO DISEASES:

The host varieties are classified as susceptible or resistant according to their response to the pathogen. The various reactions of the host may be grouped into the following types:

(a) Susceptible Reaction: In case of susceptible reaction, the disease development is profuse and is not checked by the genotype.

(b) Resistance Reaction: Resistance denotes less disease development than the susceptible variety and is a relative attributes. Infection and establishment to take place but the growth of the pathogen in the host tissue is restricted. This results in smaller spots or pustules than in susceptible variety.

(c) *Tolerance reaction:* Tolerance implies that the host is attacked by the pathogen but there is no less in biomass production or yield. It is desirable not to use the word 'tolerance' unless it has been clearly shown to be the case.

➢ VERTICAL AND HORIZONTAL RESISTANCE:

- **Vertical Resistance:** It is also known as race-specific, pathotype specific or simply specific resistance. Vertical resistance is determined by the major genes and is characterized by pathotype specificity. Pathotype specificity denotes that the host carrying a gene for vertical resistance is attacked by only that pathotype which is virulent towards that resistant gene. To all other pathotypes, the host will be resistant.
- **Horizontal Resistance:** It has many synonyms eg., race- nonspecific, partial, general and field resistance. Horizontal resistance is generally controlled by polygenes i.e., many genes with small individual effects and it is pathotype non specific. Thus, it is also known as general resistance. Horizontal resistance doesnot prevent the development of symptoms of the disease, but it slows down the rate of spread of disease in the population.

➢ SYSTEMIC ACQUIRED RESISTANCE:

At the dawn of 20^{th} century, it was recognized that plants previously infected by a pathogen become resistant to further infections. This involves viral cross-protection, bacterial and fungal antagonism and induced systemic resistance.

Induced systemic resistance processes in plants may be of several types, the most extensively studied of which is *Systemic Acquired Resistance (SAR).* It is a long lasting systemic resistance that is often effective against viral, bacterial and fungal pathogens and is induced by such pathogens that cause a necrotic reaction, which may range from a hypersensitive response to necrotic disease lesions.

SAR is accompanied by elevated levels of salicylic acid which is in some cases may be essential for the development of SAR. Salicylic acid may function as the phloem translocated signal that mediates SAR. Development of SAR is associated with the introduction of SAR genes which appear to be different in monocotyledonous and dicotyledonous plants. In tobacco, SAR genes comprise a set of non-allelic genes that can be broadly classified on the basis of proteins they encode such as the pathogenesis related (PR) genes.

SAR genes play an active role in the disease resistance process because their expression in transgenic plants can impart significant disease resistance. SAR genes expressed in different species differ to a considerable extent.

➢ GENETICS OF DISEASE RESISTANCE:

Biffen (1905) reported the inheritance of resistant to leaf rust of wheat variety 'Rivet' in crosses with some susceptible varieties. In F_2 , there were 3 susceptible:1 resistant plants indicating that the resistance was controlled by a single recessive gene. Subsequently, several other studies showed that resistance to various diseases are monogenically controlled but cases of duplicate, complementary and other interactions have also been reported taking into consideration the physiological differentiation o the pathogen. The disease resistance may show following three modes of inheritance: (i) oligogenic; (ii) polygenic and (iii) cytoplasmic.

(i) **Oligogenic inheritance:** In such cases, disease resistance is governed by one or few major genes and resistance is generally dominant to the susceptible reaction. In many cases, the action of major resistant genes may be altered by modifying the genes eg. Bunt resistance in wheat. But, in some other cases, modifying genes are not known eg. Resistance to X and Y viruses in potato.

Oligogenes generally produce immune reaction. The chief characteristic for oligogenic disease resistance is its pathotype specificity i.e., the resistance gene is effective against some pathotypes, while it is ineffective against the others. Oligogenic resistance is synonymous to vertical resistance. The inheritance of oligogenic disease resistance may be explained with the help of bean (Phaseolus vulgaris) anthracnose resistance. There are two physiological races, alpha and beta, of the pathogen; race alpha is virulent towards the bean variety Robust but not towards White marrow, while beta is virulent towards white marrow but not towards Robust.

When a cross between white marrow and Robust was tested against the alpha pathotype, the F_1 was resistant and in F_2 a 3:1 segregation was observed for resistance and susceptibility. Similar results were obtained when the same cross was tested against the beta pathotype. This resistance of each of the two bean variety is governed by a single gene, which appear to be different.

Gene for gene relationship:

The gene for gene relationship between a host and its pathogen was postulated by Flor in 1951 based on his work on linseed rust. Gene for gene relationship has been studied exclusively and is widely accepted. It has been found that for every resistant gene present in the host, the pathogen has a gene for virulence. Susceptible reaction would result only when the patho gene is able to match all the resistant genes present in the host with appropriate virulence genes. If one or more genes is not matched by the pathogen with appropriable virulence genes, resistance reaction is the result. In most of the patho genes, virulence is recessive to avirulence (resistance).

(ii) Polygenic Inheritance: In this case, disease resistance is governed by many genes with small effects, and a continuous variation for disease reaction is produced, ranging from low resistance (extreme susceptibility) to good resistance (low susceptibility). In case of polygenic resistance, disease resistance is not classifiable into clear cut resistant and susceptible class as is the case with oligogenes. The polygenes, show both additive and non-additive effects and there is a large environmental effect as is the case with most of the quantitative traits. Polygenic inheritance is quantitatively inherited and visually has a large SCA component.

The mechanism of resistance is not clearly known but resistance to infection is observed as in slow growth of pathogen and slow spore production. Presently, polygenic resistance doesnot show pathotype specificity as against the oligogenic resistance. Polygenic resistance is almost the same as horizontal resistance.

(iii)Cytoplasmic Inheritance: In some cases, resistance is determined by cytoplasmic gene(s) or plasmagene(s). For example, maize strain having 'T' male sterile cytoplasm (cms-T) are extremely susceptible to *Helimenthosporium* leaf blight, while those having the normal or non-T cytoplasm are resistant to this disease. Cases of cytoplasmic inheritance of disease resistance are rare.

METHODS OF BREEDING FOR DISEASE RESISTANCE

(i) Selection: Selection of resistant plants from a commercial variety is the cheapest and quickest method of developing a resistant variety.

(ii) Introduction: Resistant variety(ies) may be introduced for cultivation in a new area. This offers a relatively simple and quick means of obtaining resistant varieties.

(iii)Mutation: Selection of spontaneous and induced mutant plants with resistant to diseases through the use of mutagenesis.

(iv)Hybridization: It is the most common method of breeding for disease resistance. Hybridization serves two chief purposes:

- (a) Transfer of disease resistance from an agronomically undesirable variety to a susceptible but otherwise a desirable variety (by backcross method).
- (b) Combining disease resistance and some desirable characters of one variety with superior characteristics of another variety (by pedigree method).

Backcross method: This is useful for transferring genes for resistance from a variety that is undesirable in agronomic characteristics to a susceptible variety which is widely adapted and is agronomically highly desirable. The resistant parent variety is the donor of the resistance gene and thus is known as the donor parent or non-recurrent parent. The susceptible variety to which the resistance gene is transferred is used as a parent in the recessive backcrosses, hence it is known as the recurrent parent. The backcross program would differ depending upon the allelic relationship of the resistance genes i.e., whether it is resistance or dominant to the allele for susceptibility. Generally, backcrosses are made for the recovery of recurrent parent phenotype along with transfer of disease resistance.

Pedigree method: It is quite suited for breeding for horizontal or polygenic resistance. In breeding for disease resistance, artificial disease epidemics are generally produced to help in selection for disease resistance.