VARIABILITY IN PLANT PATHOGENS

Aim: To acquaint the students with the concept of variability in plant pathogens

Variability means the quality of being subject to variation or quality of being uneven or lacking uniformity. In plant pathogens, the variation takes place due to genetic variability. Genetic variability is the measure of the tendency of individual genotype in a population to vary from other or having more than one genetic state or allele at each locus.

- Variation is usually associated with sexual reproduction by fungal oospores, zygospores,
- a **variant** can be defined as an individual among a certain population that have deviated from the normal individuals genetically and possesses certain different characters which are not generally associated with that particular population previously.

Mechanisms of variability in plant pathogens

- General mechanisms of variability are:
  -mutation, recombination, gene and genotype flow, genetic drift and selection, out-crossing etc.
- Specialized mechanisms of variabilityare:
  -heterokaryosis, parasexuality, saltation etc. in fungi
  -conjugation, transformation and transduction in bacteria
  - recombination in viruses

1. General mechanisms of variability in fungi

Mutation is more or less an abrupt change in genetic material of an organism or a virus, which is then transmitted in a hereditary fashion to the progeny.

- Mutations in nature are less frequent and are result of infrequent changes that take place during cell division and result in irregularities in replication or rearrangement of minute parts of genetic material of the cells.
- Mutation can be induced artificially with increased frequency by physical agents like ultra violet rays, X-rays, gamma-rays or by chemicals like alkaloids, phenols etc.
- Most mutations are recessive; therefore in diploid organisms mutation remains unexpressed until they are brought together in a homozygous condition.

- Although frequency of mutation is low, but given the great number of progeny produced by pathogen, it is possible that large number of mutants differ in virulence from their parents.
- Mutation has been reported in *Cladosporium fulvum* causing tomato leaf mould, *Phytophthora infestans, Puccinia graminis* and *Melampsora lini,* apart from the appearance of highly destructive race T of *Heliminthosporium maydis.*

Recombination occurs primarily during the sexual reproduction of plants, fungi, and nematodes whenever two haploid nuclei containing genetic material that may differ in many loci unite to form a diploid nucleus called a zygote.

- Recombination can be intraspecific, interspecific or even intergeneric; and the resulting hybrids may have different pathogenic abilities from the parental races.
- Often the hybrids are intermediate in pathogenicity between the two parental races, but some may be more pathogenic than others; and similar considerations apply to other inherited characteristics.
- Recombination of genes occurs in autoecious rusts, such as *Melampsora lini.* Similarly, evolution of new physiological races through meiotic recombination is common in many pathogenic fungi, rusts, smuts, powdery mildews apart from potato blight fungus.

Gene flow is a process by which certain alleles move from one population to another geographically separate population.

- **Population genetics, genetic drift and selection** also bring about variability in the plant pathogens.
- **Mating system** is considered in terms of the amount of inbreeding that occurs in a population of sexual organism. Many smut fungi are forced to inbreed because a dikaryon must form for a successful infection and likely encounters are between the basidiospores arising from same psuedobasidia of the strains in the soil.
- Outcrossing of individuals put together new combination of genes rapidly leading to many different genotype within population.

2. Specialized mechanism of variability in fungal pathogens

Heterokaryosis is occurrence of dissimilar or genetically different nuclei in a vegetative cell or spore or hypha as in basidiomycetes.

- It provides haploid organisms the ability or somatic flexibility with changing environment.
- It increases diversity as genetic recombination is brought about by interchanges of whole chromosome or through mitotic crossing-over.
- It plays an important role in homothallic and imperfect fungi.
- Heterokaryosis can arise by

  a) gene mutation

  b) fusion of vegetative mycelium

  c) at the time of spore formation in many fungi such as *Neurospora tetrasperma, Podospora* sp.
- Heterokaryosis is certainly a way in which avirulent strains may acquire virulence, for example in *Thanatephorus cucumeris.*

Parasexuality is a process in which genetic recombination occurs in the vegetative thallus in absence of sexual stage.

- Sequence of events in parasexuality is as follows:

  i) formation of dikaryotic mycelium

  ii) fusion between two nuclei

  iii) multiplication of diploid nuclei side by side the haploid nuclei

  iv) occasional mitotic crossing over during the multiplication of diploid nuclei

  v) sorting out of diploid nuclei

  vi) occasional haploidization of the diploid nuclei

  vii) sorting out of the new haploid strain.
- Parasexuality has produced new races of *Fusarium oxysporum* f. sp. *pisi, Ascochyta, Verticillium albo-atrum* etc.

Saltation is appearance of morphologically different sectors in fungal colonies.

- It occurs frequently in fungal colonies of some isolates of *Fusarium* and *Helminthosporium*.
- Saltation may be influenced by compaction and thickness of culture media.

3. Sexual-like processes in bacteria

New biotypes of bacteria seem to arise with varying frequency by means of at least three sexual-like processes.

i) In **conjugation,** two compatible bacteria come in contact with each another and a small portion of the chromosome or plasmid from one bacterium is transferred to the other through a conjugation bridge or pilus.

ii) In **transformation**, bacterial cells are transformed genetically by absorbing and incorporating in their own cells genetic material secreted by or released during rupture of other bacteria.

iii) In **transduction**, a bacterial virus (phage) transfers genetic material from the bacterium in which the phage was produced to the bacterium it infects next.

- When the gene transfer is limited to members of the same species or even genus, it is called **vertical gene transfer**. Sometimes, gram-negative bacteria can transmit genetic material readily across species; as *Agrobacterium* transmits genes across kingdom barriers to plants, such events are called **horizontal gene transfer**.

4. Genetic recombination in viruses

- When two strains of the same virus are inoculated into the same host plant, one or more new virus strains are recovered with properties (virulence, symptomatology, and so on) different from those of either of the original strains introduced into the host.

- The new strains probably are recombinants, although their appearance through mutation, not hybridization, can not always be ruled out.

- In multipartite viruses consisting of two, three, or more nucleic acid components, new virus strains may also arise in host plants or vectors from recombination of the appropriate components of two or more strains of such viruses.

5. Loss of pathogen virulence in culture

- The virulence of pathogenic microorganisms toward one or all of their hosts often decreases when the pathogens are kept in culture for relatively long periods of time or when they are passed one or more times through different hosts.
- If the culturing of the pathogen is prolonged sufficiently, the pathogen may lose virulence completely. Such partial or complete loss of virulence in pathogens is sometimes called **attenuation**, and it has been shown to occur in bacteria, fungi and viruses.
- Loss of virulence in culture, or in other hosts, seems to be the result of selection of individuals of less virulent or avirulent pathogen strains that happen to be capable of growing and multiplying in culture, or in the other host, much more rapidly than virulent ones.
- After several transfers in culture or the other hosts, such attenuated individuals largely, or totally, overtake and replace the virulent ones in the total population so that the pathogen is less virulent or totally avirulent.
- On reinoculation of the proper host, isolates in which the virulent individuals have been totally replaced by avirulent ones continue to be avirulent, and therefore loss of pathogenicity is irreversible.
- However, on reinoculation of the proper host with isolates in which at least some virulent individuals survived through the transfers in culture or the other host, the few surviving virulent individuals infect the host and multiply, often in proportion to their virulence.

- The virulent individuals increase in number with each subsequent inoculation; while at the same time, non-virulent individuals are reduced or eliminated with each reinoculation.

Stages of variation in pathogens

- **Species:** The entire population of a particular organism on the earth, e.g. a fungal pathogen, has certain morphological and other phenotypic characteristics in common and makes up the species of pathogen, such as *Puccinia graminis*, the cause of stem rust of cereals.
- **Varieties or special forms:** Some individuals of this species, however, attack only wheat, barley, or oats, and these individuals make up groups that are called varieties or special forms (*forma specialis*) such as *P. graminis* f. sp. *tritici* or *P. graminis tritici, P. graminis hordei,* and *P. graminis avenae*.
- **Race:** Even within each variety or special form, some individuals attack some of the varieties of the host plant but not the others, some attack another set of host plant varieties, and so on with each group of such individuals making up a race. Thus, there are more than 200 races of *P. graminis tritici* (race 1, race 15, race 59 and so on).
- **Variant:** Occasionally, one of the off-spring of a race can suddenly attack a new variety or can cause severe symptoms on a variety that it could barely infect before. This individual is called a variant.
- **Biotype:** The identical individuals produced asexually by the variant make up a biotype. Each race consists of one or several biotypes (race 15A, 15B and so on).

Appearance of new pathogen biotypes

- The appearance of new pathogen biotypes may be very dramatic when the change involves the host range of the pathogen.
- If the variant has lost the ability to infect a plant variety that is widely cultivated, this pathogen simply loses its ability to procure a livelihood for itself and will die without even making its existence known to us.
- If, however, the change in the variant pathogen enables it to infect a plant variety cultivated because of its resistance to the parental race or strain, the variant individual, being the only one that can survive on this plant variety, grows and multiplies on the new variety without any competition and soon produces large populations that spread and destroy the resistance variety.
- This is the way the resistance of plant variety is said to be broken down although it was the change in the pathogen, not the host plant that brought it about.