



**FACULTY OF AGRICULTURE SCIENCES AND
ALLIED INDUSTRIES**

(Breeding for Biotic and Abiotic stress Resistance)

For

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BREEDING FOR BIOTIC STRESS RESISTANCE

DISEASE RESISTANCE

Stress: Constraining influence, force, pressure or adverse conditions for crop growth caused by biological or environmental factors.

Biotic (living): Adverse effects due to pests and diseases

Abiotic (non living): Adverse effects on host due to environmental factors eg: Drought, water logging, heat, cold, salinity, alkalinity and air pollution etc.

Host : Plant effected by a disease or which can accommodate pathogen.

Pathogen : An organism that produces the disease

Disease : an abnormal conditions in the plant caused by an organism (pathogen)

Pathogenicity : The ability of a pathogen to infect a host strain

Virulence : Capacity of a pathogen to incite a disease

Avirulence : The inability of a pathogen to cause or incite a disease

Physiological race: Strains of a single pathogen species with identical or similar morphology but differ in pathogenic capabilities.

Pathotype: Strains of a pathogen classified on the basis of their virulence to known resistance genes present in the host.

Epidemic: Severe and sudden out break of disease beginning from a low level of infection.

Variability in fungal pathogens:

a) **Hybridization:** Recombination of genes of the two parental nuclei takes place in the zygote, and the haploid nuclei or gametes resulting after meiosis are different both from gametes that produced the zygote and from each other.

Thus every diploid pathogen individual is genetically different from any other pathogen even within the same species and variability of the new individual pathogens is continued indefinitely. e.g., *Phytophthora infestans*.

b) **Heterokaryosis:** Condition in which fungal hyphae that are genetically different come together in the same cell to form heterokaryons.

c) **Parasexualism :** Parasexuality – re-assortment of genetic material both in haploid and diploid condition, ready for natural and artificial selection.

Mixtures of races grown together on a susceptible host combine genetically to produce

new races e.g. *phytophthora infestans*

d) **Mutation:** The rate at which new variants of a pathogen are produced will depend on the mutation rate of the genes at a particular locus. The mutation rate varies from gene to

gene and from pathogen to pathogen. e.g. *Melampsora lini* – new race produced with UV rays (Flor 1956)

e) **Cytoplasmic adaptation:** There are several examples of cytoplasmic inheritance of

important characteristics such as growth rate and virulence (Jinks 1966). Virulence of *P.graminis f. sp. Avenae*, carrying gene E, is maternally inherited and may be controlled by single plasma gene (Johnson *et al* 1967).

MECHANISMS OF DISEASE RESISTANCE:

There are different ways of disease resistance *viz.*, disease escape, disease endurance or

tolerance disease resistance and immunity.

1. **Disease escape:** The ability of susceptible host plants to avoid attack of disease due to

environmental conditions factors, early varieties, change in the date of plating, change in

the site of planting; balanced application of NPK etc.

Eg. Early varieties of groundnut and potato may escape ‘Tikka’ and ‘Late blight’ diseases respectively since they mature before the disease epidemic occurs. Changing planting season in sugarcane from June to October has successfully escaped leaf-rust. Virus free seed potato is produced by sowing the crop in October in Jullundher and other places instead of November, the normal planting time.

2. **Disease endurance or tolerance:** The ability of the plants to tolerate the invasion of the pathogen without showing much damage. This endurance is brought about by the influence of external characters. Generally, tolerance is difficult to measure since it is confounded with partial resistance and disease escape. To estimate tolerance the loss in yield and some other trait of several host varieties having the same amount of disease eg., leaf area covered by disease etc., is compared.

Eg. In Barley the variety Proctor shows 13% yield loss as compared to 20% loss in the varieties Zephy and Sultan.

Wheat varieties when fertilized with potash and phosphorus are more tolerant to the rust and mildew infection.

The Rice crop fertilized with silicate is resistant to blast infection in Japan.

3. Disease Resistance: The ability of plants to withstand, oppose or overcome the attack of pathogens. Resistance is a relative term and it generally refers to any retardation in the

development of the attacking pathogen. In case of resistance, disease symptoms do not develop and the rate of reproduction is never zero i.e., $r > 0$ but it is sufficiently lower than

1 (the rate of reproduction on the susceptible variety) to be useful. The inhibition of growth of the pathogen is believed to be nutritional in nature and in some cases chemical growth inhibitors may be involved.

Resistance is largely controlled by inherited characters i) may be controlled by single dominant gene in Ottawa 770 B, Newland flax variety, wheat all rusts NP 809

4. Immunity: When the host does not show the symptoms of disease it is known as immune reaction. Immunity may result from prevention of the pathogen to reach the appropriate parts of the host e.g. exclusion of spores of ovary infecting fungi by closed flowering habit of wheat and barley. It is more generally produced by hypersensitive reaction of the host usually immediately after the infection was occurred. In immune reaction the rate of reproduction is zero i.e. $r = 0$

5. Hypersensitivity: Immediately after the infection several host cells surrounding the point of infection are so sensitive that they will die. This leads to the death of the pathogen because the rust mycelium cannot grow through the dead cells. This super sensitivity (hypersensitivity) behaves as a resistant response for all practical purposes. Phytoalexins are specific polyphenolic or terpenoid chemicals and are produced by the host in response to the infection by a pathogen. More than 30 different phytoalexins have

been identified. Phytoalexins are either fungicidal or fungistatic. Eg. Rust fungi and virus attack.

Factors for disease resistance (Causes of Disease resistance)

The disease resistance may be caused due to 1. Morphological, structural and functional characteristics which prevents the entrance of the pathogen *i.e.* prevents the first stage of infection. 2. Biochemical or anatomical properties of tissue which prevent the establishment of parasitic relationship.

a. Morphological characters

Certain morphological features of the host may prevent infection. Eg. Resistance to Jassid attack in cotton has been shown to be correlated with the hairiness of varieties : hairy type resists the attack more, than glabrous types. Failure to germinate rust

spores on the leaves of the barley due to waxy coating. Young sugarbeet leaves practically immune to attack of the *Circospora* because the stomata size is very small.

b. Physiological characters Protoplasmic factors or chemical interactions :

By virtue of its chemical composition the protoplasm may exert an inhibitory influence on the pathogen bringing about the desired resistance in the plant.

Eg. : Resistance of grape to powdery mildew is highly correlated with the acidity of cell sap. Presence of toxic substance in the red pigment in the coloured onions. The outer scales resist the smudge fungus attack when the scales are removed they become susceptible.

c. Anatomical: More secondary thickening of the cell walls of resistant potato varieties which resists the mechanical puncture of the invading *Pythium* pathogen.

d. Nutritional factors : Reduction in growth and in spore production is generally supposed to be due to unfavourable physiological conditions within the host. Most likely a resistant host does not fulfill the nutritional requirements of the pathogen and thereby limits its growth and reproduction.

e. Environmental factors: In addition to the above the environmental factors have marked effect on the pathogen attack. Temperature, moisture, humidity and soil PH and fertility status of the soil effects the pathogen reaction greatly.

Genetic basis of disease resistance

The first study on genetics of disease resistance was done by Biffen in 1905. He reported

the inheritance of resistance to leaf rust of wheat variety Rivet in crosses with some susceptible varieties. In F₂ there were 3 susceptible : 1 resistant plants indicating that resistance was controlled by a single recessive gene. Most of the earlier studies were conducted without taking into consideration the physiological specialization (pathotype differentiation) of the pathogen which can materially influence the conclusions drawn. It is now recognized that disease resistance may be inherited in three different ways : Oligogenic, Polygenic and Cytoplasmic inheritance.

Oligogenic inheritance:

The disease resistance is governed by one or few major genes and resistance is generally dominant to the susceptible reaction. The action of major resistance genes may be altered by modifying genes in many cases. Eg. bunt resistance in Wheat. Oligogenes generally produce immune reaction. The chief characteristic of the oligogenic disease resistance is pathotypespecificity, i.e. resistant gene is effective against some pathogens, while it is ineffective against the others. In most cases, there are a number of major genes that determines resistance to a particular disease Eg. more than 20 different resistance genes are known for leaf rust of wheat, while those

for stem rust resistance exceed 30. The genetics of oligogenic resistance has advanced by two events *viz.*, 1. Discovery of a resistance gene to the prevalent pathotype and 2. Evolution of a pathotype virulent to the new resistance gene. Oligogenic resistance is synonymous to vertical resistance.

Gene for gene hypothesis:

The concept of gene for hypothesis was first developed by Flor in 1956 based on his studies of host pathogen interaction in flax rust caused by *Malampsora lini*. The gene for gene hypothesis states that for each gene controlling resistance in the host, there is a corresponding gene controlling pathogenicity in the pathogen. The resistance of host is governed by dominant genes and virulence of pathogen by recessive genes. The genotype of host and pathogen determine the disease reaction. When genes in host and pathogen match for all the loci, then only the host will show susceptible reaction. If some gene loci remain unmatched, the host will show resistant reaction. Now gene-for -gene relationship has been reported in several other crops like potato, *Sorghum*, wheat etc. The gene for gene hypothesis is known as “Flor Hypothesis”.

Note: Dominant genes in the host are responsible for resistance and recessive genes in the pathogen for virulence.

Vertifolia Effect : Vander plank introduced the term vertifolia effect and refers to epidemic development in a variety carrying vertical resistance genes (oligogenes) leading to heavy economic losses. Total failure of vertical resistance leading to a disease epidemic is known as vertioalia effect. This failure occurs because of two reasons :

1. The level of horizontal resistance in varieties carrying oligogenes is usually low and
2. The pathogen is able to evolve new virulent pathotypes.

Polygenic inheritance

In this type the disease resistance is governed by many genes with small effects and a continuous variation for disease reaction is produced. The genes show additive and non additive effects and the environmental effect is also observed. The polygenic resistance does not show pathotype-specificity as against the oligogenic resistance. It is almost same as horizontal resistance. In some cases the polygenic inheritance may have a oligogenic component, the oligogenes acting in an additive manner eg. bacterial blight resistance in cotton.

Cytoplasmic inheritance :

Resistance in some cases is determined by cytoplasmic genes or plasma gene(s). Eg. The T-male sterilizy cytoplasm (cms-T) in maize is extreamly susceptible to

Helminthosporium leafblight, while the non-T cytoplasms are resistant to this disease.

Vertical and Horizontal Resistance (Vander plank)

Feature Vertical resistance Horizontal resistance

1. Pathotype – specificity Specific Non specific
2. Nature of gene action Oligogenic Polygenic; rarely oligogenic
3. Response to pathogen Usually, hypersensitive Resistant response
4. Phenotypic expression Qualitative Quantitative
5. Stage of expression Seedling to maturity Expression increases as plant matures
6. Selection and evaluation Relatively easy Difficult
7. Host pathogen interaction Present Absent
8. Commonly used, synonyms Major: gene, race –specific seedling, monogenic, pathotype specific resistance Polygenic, race nonspecific, pathotype-nonspecific, mature plant, adult plant, field uniform resistance
9. Efficiency Highly efficient against specific races Variable, but operates against all races

Sources of Disease Resistance

Resistance to diseases may be obtained from four different sources :

1. A known variety
2. Germplasm collection
3. Related species
4. Through mutations

1. **A known variety:** Disease reactions of most of the cultivated varieties are documented

and a breeder may find the resistance he needs in a cultivated variety. Resistant plants were also later found from commercial varieties as in the case of cabbage yellows in cabbage curlytop resistance etc. These provide the basis for new resistance varieties.

2. **Germplasm collection :** When resistance to a new disease or a new pathotype of a disease is not known in a cultivated variety germplasm collection should be screened. Several instances disease resistance were found from the germplasm collections. Eg. resistance to neckblotch in barley resistance to wilt in watermelon.

3. **Related species :** Often the resistance to a disease may be found in related species and

transferred through interspecific hybridization. Eg. Resistance to stem, leaf & stripe rusts of wheat.

4. **Mutation :** Resistance to diseases may be obtained through mutation arising spontaneously or induced through mutagenic treatments.

Eg.

1. Resistance to Victoria blight in oats was induced by irradiation with x-rays or thermal neutrons / also produced spontaneously
2. Resistance to stripe rust in wheat
3. Resistance to brown rust in oats
4. Resistance to mildew in barley
5. Resistance to rust in linseed
6. Resistance to tikka leaf spot and stem root in groundnut

Vertical and Horizontal Resistance (Van der plank)

Vertical Resistance is generally determined by major genes and is characterized by pathotype specificity. Clearly immune or susceptible response in the case of vertical resistance depends on the presence of virulent pathotype. When virulent pathotype becomes frequent, epidemics are common in the cases of vertical resistance. Thus an avirulent pathotype will produce an immune response i.e. $r=0$ or close to 0 but the virulent pathotype will lead to susceptible reaction i.e. $r=1$. It is also known as race specific, pathotype specific or simply specific resistance.

Horizontal Resistance

Race non-specific, pathotype -nonspecific and partial, general or field resistance. Horizontal resistance is generally controlled by polygenes i.e. many genes with small effects and

it is pathotype nonspecific. In this case, the reproduction rate is not zero but it is less than one. Poly genes, govern horizontal resistance.

Methods of Breeding for Disease Resistance

The methods of breeding for disease resistance are essentially same as those used for other agronomic traits. They are :

1. Introduction
2. Selection
3. Hybridization
4. Budding & Grafting
5. Mutation Breeding
6. Biotechnological methods.

1. **Introduction** : Resistant varieties may be introduced for cultivation in a new area.

Eg.

□□ Early varieties of groundnut introduced from USA have been resistant to leaf spot

(Tikka)

□□ Kalyanasona and Sonalika wheat varieties originated from segregating material introduced from CIMMYT, Mexico, were rust resistant.

□□ African bajra introductions have been used in developing downy mildew resistant cms lines.

2. **Selection** : Selection of resistant plants from commercial varieties is easiest method.

Eg.

□□ Kufri Red potato is selection from Darjeeling Red round

□□ Pusa Sawani behind (yellow mosaic) selection from a collection obtained from Bihar

□□ MCU I was selection from CO4 for black arm resistance in cotton

3. **Hybridization** : Transferring disease resistance from one variety or species to the other.

a. Pedigree method is quite suitable for horizontal resistance. Artificial disease epiphytotics are produced to help in selection for disease resistance.

Eg. In wheat Kalyana Sona, Sonalaka, Malvika 12, Malvika 37, Malavika 206, Malavika 234, Laxmi in Cotton (Gadag 1 x CO2) for leaf blight resistance

b. Backcross method is used to transfer resistance genes from an undesirable agronomic variety to a susceptible, widely adoptable and is agronomically highly desirable variety. If the resistant parent is a wholly unadapted variety, backcross method is a logical choice.

If resistant variety also possess some good qualities then chose pedigree method of handling segregating material.

4. **Budding & Grafting** : The disease resistance in vegetatively propagated material is transferred by adopting either by budding or grafting. By grafting or budding the resistant material, the resistance can be transferred.

5. **Mutation Breeding** : When adequate resistance is not available in the germplasm ; Mutation breeding is resorted to induce resistance. This is also used to break the linkages

between desirable resistant genes and other desirable genes.

Precautions

1. The donor parent must possess the required amount of resistance

2. It must be simply inherited without any linkage

3. The recovery in the recipient parent should be more

4. Proper condition for full expression of the resistant genes has to be provided

Advantages with breeding for disease resistance

1. Helps in reducing the losses caused by pathogens

2. Reduces the high cost of disease control by chemical treatment

3. Helps to avoid the use of poisonous fungicides

4. Only method available to some specific diseases like viruses, wilt etc.

Limitations

1. Linkage of resistant genes with genes of inferior quality
2. Occurrence of physiological races of varying capacities
3. Self sterility in host plants

Utilization and achievements

1. Rice ADT 10 x Co4 (resistant to blast)
2. Potato *Solanum tuberosum* x *Solanum demissum* (susceptible to late blight) (wild resistant to late blight) F1 backcrossed with *Sol. Tuberosum* Resistant variety

Varieties resistant to different diseases

Rice : Blast Co25, Co26,

Wheat : all three rusts : NP 809

Yellow rust : NP 785, NM86

Black rust : NP 789

Brown rust : NP 783, NP 784

Sugarcane : Red rot Co 419, Co 421, Co 527

Cotton : Wilt Vijay, Kalyan, Suyog

Groundnut : Tikka leafspot Ah 45

Chilli : Mosaic resistant Pusa red, Pusa orange

INSECT RESISTANCE

Global average loss due to insect pests is 14%. Estimated losses in individual crops vary

from 5% in wheat to 26.7% in rice and still more in crops like cotton & sugarcane.

Insect Resistance :

1. The ability of a plant to withstand, oppose or overcome the attack of an insect is known as insect resistance.

2. It is the property of a variety or a host crop due to which it is attacked by an insect pest to a significantly lower degree than are other varieties of the same host.

Biotypes : Strains of a species of an insect pest, differing in their ability to attack different varieties of the same host species (syn: Physiological races)

Host Habitation :

1. Polyphagy 3. Seasonal Oligophagy

2. Oligophagy 4. Monophagy

1. Polyphagy : Insects feed on a wide range of hosts avoiding few plant species. Eg. Scales & moths.

2. Oligophagy : Live on one taxonomic unit only. Eg. Hessianfly on wheat

3. Seasonal oligophagy : Insects may live on many species in one part of the year and on

few in another part of the year. Eg : Aphids.

4. Monophagy : Avoid all hosts except one particular species or variety Eg. Boll weevil on cotton.

Mechanism of Insect Resistance :

Insect resistance is grouped into four categories :

1. Non preference

2. Antibiosis

3. Tolerance

4. Avoidance

1. **Non preference** : Host Varieties exhibiting this type of resistance are unattractive or unsuitable for colonization, oviposition or both by an insect pest. This type of resistance is also termed as non-acceptance and anti-xenosis. Non preference involves various morphological and biochemical features of host plants such as – color, hairiness, leaf angle, taste etc.

2. **Antibiosis** : Antibiosis refers to an adverse effect of feeding on a resistant host plant on the development and/or reproduction of the insect pest. In severe cases, it may even lead to the death of the insect pest. Antibiosis may involve morphological, physiological or biochemical features of the host plant; some cases of insect resistance involve a combination of features. Eg. Resistance to BPT is due to antibiosis & non preference.

3. **Tolerance** : An insect tolerant variety is attacked by the insect pest to the same degree as a susceptible variety. But at the same level of infestation, a tolerant variety produces a higher yield than a susceptible variety. Ability of the host plant to withstand the insect population to a certain extent which might have damaged a more susceptible host. Tolerance is mainly a host character and it may be because of greater recovery from pest damage. Eg. Rice varieties tolerant to stem borer/gall midge produce additional tillers to compensate yield losses (as in stem borer in sorghum) or due to the ability of host to suffer less damage by the pest eg. aphid tolerance in Sugarbeet & Brassica spp. And green bugs tolerance in cereals. Inheritance of tolerance is complex in many cases and is supposed to be governed by polygenes.

4. **Avoidance** : Pest avoidance is the same as disease escape , and as such it is not a case of true resistance. Mostly insect avoidance results from the host plants being at a much less susceptible developmental stage when the pest population is at its peak. Eg. 1. Early maturing cotton varieties escape pinkboll worm infestation, which occurs late in the season.

Nature of Insect Resistance / Factors for insect -resistance

Insect resistance may involve :

1. Morphological
2. Physiological (or)
3. Biochemical features of the host plant

1. **Morphological features** : Morphological factors like, hairiness, colour, thickness and toughness of tissues etc. are known to confer insect resistance.

a) Hairiness of leaves is associated with resistance to many insect pests leaf beetle in

cereals, in cotton to Jassids, in turnip to turnip aphid.

b) Colour of plant : Color may contribute to non preference in some cases. For example : Red cabbage, Red leaved brussel's sprouts are less favored than green varieties by butterflies and certain Lepidoptera for oviposition. Boll worms prefer green cotton plants to red ones.

c) Thickness and Toughness of plant – Tissues prevent mechanical obstruction to feeding

and oviposition and thereby lead to non-preference as well as antibiosis.

Eg.

1. Thick leaf lamina in cotton contributes to Jassid resistance

2. Solid stem in wheat confers resistance to wheat stem sawfly

3. Thick and tough rind of cotton bolls makes it difficult for the boll worm larva to bore holes and enter the bolls.

Other characters : also contribute to insect resistance.

Eg. 1. *Gossypium arboreum* varieties with narrow lobed and leathery leaves are more resistant to Jassids than are those with broad lobed and succulent leaves.

2. Cotton varieties with longer pedicels are more resistant to boll worms.

2. Physiological Factors : Osmotic concentration of cell sap, various exudates etc; may be associated with insect resistance.

Eg.

1) Leaf hairs of some *solanum* spp. secrete gummy exudates. Aphids and Colorado beetles get trapped in these exudates.

2) Exudates from secondary trichomes of *Medicago disciformis* leaves have antibiotic effects on alfalfa weevil.

3) Cotton- High osmotic concentration of cell sap is associated with Jassid resistance.

3. Biochemical Factors: Several biochemical factors are associated with insect resistance in many crops. It is believed that biochemical factors are more important than morphological and physiological factors in conferring non-preference and antibiosis.

Eg.

1) High concentrations of gossypol is associated with resistance in several insect pests in cotton.

2) In rice – high silica content in shoots gives resistance to shoot borer

Genetics of Insect Resistance

Insect resistance is governed by -

1. Oligogenes

2. Polygenes

3. Cytoplasmic genes

1. **Oligogenic Resistance** : Insect resistance is governed by one or few major genes or oligogenes, each gene having a large and identifiable individual effect on resistance. Oligogenic resistance may be conditioned by the dominant or the recessive allele of the concerned gene. The differences between resistant and susceptible plants are generally large and clear-cut. In several cases, resistance is governed by a single gene (monogenic resistance)

Eg. In wheat to green bugs In cotton to Jassids In apple to woolly aphis In rice to plant & leaf hopper.

2. **Polygenic Resistance** : It is governed by several genes, each gene producing a small and usually cumulative effect. Such cases of resistance.

- 1) Involve more than one feature of the host plant
- 2) Are much more durable than the cases of oligogenic resistance.
- 3) Difference between resistance & susceptible plants are not clear cut
- 4) Transfer of resistance is much more difficult

Examples for polygenic resistance

- 1) In wheat to cereal leaf beetle
- 2) In alfalfa to spotted aphid
- 3) In rice to stem borer
- 4) In maize to ear worm and leaf aphid Evolution of resistance breaking biotypes is almost rare.

3. **Cytoplasmic Resistance** : governed by plasmagenes

Eg. 1. Resistance to European corn borer in maize

2. Resistance to root aphid in lettuce

Sources of Insect Resistance

1. A cultivated variety
2. Germplasm collections.
3. A related wild species
4. An unrelated organisms

1. Cultivated variety : Resistance to many insect pests may be found among the cultivated

varieties of the concerned crop. Varieties SRT 1, Khand waz ; DNJ 286 and B 1007 of *G. hirsutum* are good sources of resistance to Jassids.

2. Germplasm collection :

Eg.

1) In apples for rosy apple aphid, green apple, apple maker and apple saw-fly.

2) In cotton, several strains resistant to Jassids.

3. Related wild species :

Eg.

- 1) Resistance to both the species of potato nematodes has been transferred from *Solanum vernei* to potato
- 2) Jassid resistances is known in wild relatives of cotton *G. tomentosum*; *G. anomalum* and *G. armourianum*
4. An unrelated organism : It is done through recombinant DNA technology
- a) The 'Cry' gene of *Bacillus thuringiensis* is the most successful example.

Other genes of importance are the

- b) Protease inhibitor encoding genes found in many plants eg. the cowpea pea, trypsin inhibitor (cp TI) gene.

Breeding Methods for Insect Resistance

1. Introduction
2. Selection
3. Hybridization
4. Genetic Engineering

1. Introduction :

Eg. *Phylloxera vertifoliae* resistance grape root-stocks from U.S.A. into France.

2. Selection :

Eg.

- 1) Resistance to potato leaf hopper
- 2) Resistance to spotted alfalfa aphid
3. Hybridization : Pedigree oligogenic characters Back cross Polygenic characters
4. Genetic Engineering : *B.theningiensis* (cry gene) resistance in maize, soybean, cotton etc.

Screening Techniques for determining resistance

The most crucial and, perhaps , the most difficult task in breeding for insect resistance is the identification of insect resistant plant during segregation generations. There are two types of screenings.

1. Field Screening
2. Glass house screening

Field Screening :

The techniques designed to promote uniform infestation by an insect pest in the field are 1. Inter planting a row of known susceptible variety between two rows of testing material.

2. Screening in highly prone areas
3. in case Soil insect pests to be tested in sick plots only
4. Testing in a particular season when the infestation is very high. Eg. Rice stem borer in off season.

5. Transferring manually equal number of eggs or larvae to each test plant.

Glass house screening

Result from glass house tests are much more reliable than those from field tests since both the environment and the initial level of infestations are more or less uniform for all the plants being tested.

Problems in Breeding for Insect Resistance :

1. Breeding for resistance to an insect pest may lead to the susceptibility to another pest.

Eg. Glabrous strains of cotton are resistant to bollworms but susceptible to Jassids.

2. Reduction in quality or make unfit for consumption.

3. Linkage between desirable & undesirable genes. Inter specific varieties are generally low yielding and their produce is often of inferior quality.

4. Screening for resistance is the most critical and difficult step in a breeding programme it necessitates a close co-ordination among scientists belonging to different disciplines.

5. It is a long term programme.

Achievements

INDIA

1. India – cotton varieties – G 27, MCU 7, LRK 516 – resistant to boll worms.

2. Rice – variety vijaya – resistant to leaf hopper

Rice – TKM 6, Ratna – Stem borer

Rice – Vajram, chaitanya, Pratibha – BPH

