

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 :

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

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 |

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

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

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.

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 |

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, hairness, leaf angle, taste etc

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

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 sps. And green bugs tolerance in cereals. Inheritance of tolerance is complex in many cases and is supposed to be governed by polygenes.

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 :

Morphological

Physiological (or)

Biochemical features of the host plant

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

Hairiness of leaves is associated with resistance to many insect pests leaf beetle in cereals, in cotton to Jassids, in turnip to turnip aphid.

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.

Thickness and Toughness of plant – Tissues prevent mechanical obstruction to feeding and oviposition and thereby lead to non-preference as well as antibiosis.

Eg.

Thick leaf lamina in cotton contributes to Jassid resistance

Solid stem in wheat confers resistance to wheat stem sawfly

Thick and tough rind of cotton bolls makes it difficult for the boll worm larvae 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.

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

Eg.

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

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

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

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.

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

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

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

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

Involve more than one feature of the host plant

Are much more durable than the cases of oligogenic resistance.

Difference between resistance & susceptible plants are not clear cut

Transfer of resistance is much more difficult

Examples for polygenic resistance

1) In wheat to cereal leaf beetle

In alfalfa to spotted aphid

In rice to stem borer

In maize to ear worm and leaf aphid

Evolution of resistance breaking biotypes is almost rare.

Cytoplasmic Resistance : governed by plasmagenes

Eg. 1. Resistance to European corn borer in maize

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

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.

Germplasm collection

: Eg.

In apples for rosy apple aphid, green apple, apple maker and apple saw-fly.
 In cotton, several strains resistant to Jassids.

Related wild species

: Eg.

Resistance to both the species of potato nematodes has been transferred fro
Solanum vernei to potato

Jassid resistances is known in wild relatives of cotton *G. tomentosum*;

G.anomalum and *G.armourianum*

An unrelated organism : It is done through recombinant DNA technology

The 'Cry' gene of *Bacillus thuringiensis* is the most successful example. Other genes of importance are the

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

Breeding Methods for Insect Resistance

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

Introduction :

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

Selection :

Eg.

Resistance to potato leaf hopper

Resistance to spotted alfalfa aphid

3. Hybridization : Pedigree oligogenic characters

Back cross Polygenic characters

Genetic Engineering : *B.thuringiensis* (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

Inter planting a row of known susceptible variety between two rows of testing material.

Screening in highly prone areas

in case Soil insect pests to be tested in sick plots only

Testing in a particular season when the infestation is very

high. Eg. Rice stem borer in off season.

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 :

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.

Reduction in quality or make unfit for consumption.

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

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.

It is a long term programme

Achievements

INDIA

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

Rice – variety vijaya – resistant to leaf

hopper Rice – TKM 6, Ratna – Stemborer

Rice – Vajram, chaitanya, Pratibha – BPH

BREEDING FOR ABIOTIC STRESS RESISTANCE

DROUGHT RESISTANCE

Drought: Scarcity of moisture (soil moisture) which restricts the expression of full genetic yield potential of a plant.

Drought resistance: The ability of crop plants to grow, develop and reproduce normally under moisture stress.

Mechanisms of drought resistance

There are 4 mechanisms of drought resistance.

Drought Escapes : It is due to ability of a genotype to mature early, before occurrence of drought. Drought escape is most common in plants grown in desert region.

Eg. Early maturing varieties of sorghum, maize, bajra, wheat, rice etc; give more yield than late maturing under drought.

Drought Avoidance (Dehydration avoidance) : It is due to the ability of plants to maintain favourable water balance even under stress. The plants which avoid drought retain high moisture content in their tissues and lose less water. This is possible either because of :

Increased water uptake (due to increase in root development) plants are called water spenders.(or)

Reduced water loss (due to reduction in growth of aerial parts are called water savers (i.e. to avoid transpiration)

Dehydration avoidance is interpreted as the ability of genotypes to maintain high leaf water potential when grown under soil moisture stress: Several traits contribute to dehydration avoidance Such as :

Leaf rolling, folding and reflectance narrow leaves, increased pubescence on aerial organs , presence of awns, osmotic adjustment of stomata, cuticular wax, increased water uptake ;

Reduced Transpiration : Increase in concentration of Abscisic Acid (ABA), closure of stomata, ABA plays role in reduction of leaf expansion, Promotion of root growth etc.

Drought Tolerance (Dehydration tolerance) : Ability of plants to produce higher yield even under 'low water potential'. In cereals drought tolerance generally occurs during reproductive phase. Tolerant cultivars exhibit better germination, seedling growth and photosynthesis. Drought tolerance may be because of

- i. high proline accumulation
- ii. maintenance of membrane integrity

Drought Resistance : It is the sum total of avoidance and Tolerance. It refers to the genetic ability of plants to give good yield under moisture stress conditions.

Various morphological, physiological and biochemical features / parameters associated with drought resistance

Morphological

Earliness

Reduced tillering

Leaf characters : Leaf rolling , Leaf folding, Leaf shedding, Leaf reflectance

Reduced leaf area : Narrow leaf, Change in leaf angle

Hairiness (presence of hairs on leaf and other parts, lowers leaf temperature and reduce transpiration)

Colour of leaves

Wax content

Awns (eg. wheat and barley)

Root system (rooting depth and intensity)

Physiological

Photosynthesis (efficient system like C4) under stress, photosynthetic efficiency is reduced due to chloroplast damage.

Reduced Transpiration and reduced respiration losses

Stomatal behavior (closure of stomata, also change in size and number of stomata)

Osmotic adjustment

Leaf enlargement (increase in thickness)

Leaf cuticle wax (increases)

Biochemical

Accumulation of proline and betaine

Increase in Abscisic acid (barley) and Ethylene (maize & wheat)

Protein synthesis (increases under stress)

Nitrate – reductase activity

Sources of drought resistance

Cultivated varieties

Land (old or desi primitive varieties), Wild relatives (reported in several crops)

For example :

S.No.	Crop	Wild sps	Resistant to
i	Wheat	<i>Aegilops. variabilis</i>	drought
		<i>Aegilops speltoides</i>	"
		<i>Aegilops umbellulata</i>	"
		<i>Aegilops squarrosa</i>	"
ii	Sugarcane	<i>Sacharum. spontaneam</i>	Drought & salinity

4. Transgenes :

Eg. 'Rab' (Responsive to abscisic acid) in

rice **Screening / Evaluation**

Field Env. Highly desirable

Green house Env. More precisely controlled than field

B reeding Methods and Approaches

It is important that drought resistance be incorporate in material with high genetic potential for yield.

Yield and yield components are best evaluated under non stress / optimal environments, while

Drought resistance must be evaluated under water stress.

Breeding methods : Methods are same as for yield and other economic characters. Breeding for drought resistance refers to breeding for yield under moisture stress, i.e. developing varieties which can give high yields under stress. The common methods are

Introduction

Selection

Hybridization

Mutation

Biotechnology

Limitations :

Generally resistant varieties have low yield

Do not have much wider adaptability (as abiotic resistant is location specific)

Drought resistant genes may have linkage with undesirable genes.

Transfer of resistant genes from wild types may post problem.

Drought resistance is a consequence of a combination of characters and single character can be used for selection.

Measurement of many drought resistant traits is difficult and problematic, since virtually all the useful drought resistant traits are under polygenic control. (So pedigree method most common). But if resistant genes is from agronomically inferior race then 1-2 backcrossing with cultivated type in made. If resistance gene is from wild species-go for backcrossing breeding.

Generally selection is performed on individual plant progenies instead of individual plants (i.e. similar to line breeding)

Creation of controlled moisture stress Environments

Selection require considerable resources

WATER LOGGING

As per Levitt (1980 b) flooding (i.e. water logging) is the presence of water in soil excess of field capacity. It leads to deficiency of O₂ and build up of CO₂, Ethylene and other toxic gases and this leads to reduction in aerobic respiration.

Effects of water logging:

Once soil becomes water logged, air space in soil is displaced with water, the O₂ in the soil in dissolved in water. i.e. O₂ decreases; CO₂ ethylene and other toxic gases increases.

O₂ replacement in the soil is very inefficient. Diffusion of atmospheric O₂ into the water logged soils is very inefficient (because of the slow diffusion of atmospheric O₂ to water logged soil).

Root systems are suddenly plunged into an anaerobic condition. This switching from aerobic to anaerobic respiration disrupts root metabolism.

Carbohydrates level get depleted it is due to

Dissipation of metabolism

High water temperature

Low light

Characteristics of plants in response to water logging stress :

Reduced growth / elongation.

Chlorosis, senescence and abscission of lower leaves

Wilting & leaf curling

Hypertrophy (increase in size of organ due to increase in cell size)

Epinasty (downward growth of petioles)