# HOST PLANT RESISTANCE

- **Snelling (1941) defined plant resistance as those characters that enable a plant to avoid, tolerate or recover from attacks of insects under conditions that would cause greater injury to other plants of the same species.**
- **Painter (1951) described plant resistance as the relative amount of heritable qualities that influence the ultimate degree of damage done by the insect.**

- **In practical agriculture, resistance represents the ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population.**

- **Beck (1965) defined resistance as collective heritable characteristics by which a plant species, race, clone or individual may reduce the probability of successful utilization of that plant as a host by an insect species, race, biotype or individual.**
- **This definition restricts the spectrum of insect-plant interactions to the extent of successful use by the insect of a plant as host, but excludes the possible ability of plant to recover or repair the loss after injury occurs.**

# HOST PLANT RESISTANCE

**Host plant resistance refers to "the heritable qualities of a cultivar to counteract the activities of insects so as to cause minimum per cent reduction in yield as compared to other cultivars of the same species under similar conditions".**

**The emphasis here is not on the absolute yield pattern but on the proportional decrease in yield among the cultivars in the presence of insect vis-a-vis the yield obtained in its absence. It means that a cultivar may yield poor but carries the genes for resistance and, on the contrary, a cultivar may yield good without having any genes for resistance.**

**Moreover, it is not always true that resistance is manifested only in the form of greater yield because there can be stage or age specific characteristics imparting resistance.**

# Historical aspects

**Earliest documentation of an insect resistant variety was a wheat variety "Underhill" which was found to resist the attack of the Hessian fly, *Mayetiola destructor* (Say) in New York in 1782.**

- **Grape phylloxera (1860) leaf galls caused by *Viteus vitifoliae* (Hemiptera: Sternorrhyncha)**
  - **French wine production fell 70% between 1863-1875**

- **In 1890, European grape vines were successfully grafted on to resistant rootstock to save the French wine industry from *Viteus vitifoliae* (Fitch).**

# History

- **Apple variety "Winter Majetin" found to be resistant to the woolly aphid, *Eriosoma lanigerum* (Hausmann) in England.**

# Mechanism of resistance

- **Antixenosis**
- **Antibiosis**
- **Tolerance**

# Mechanisms of Resistance

3 categories –R. H. Painter

(1) Non-preference (Antixenosis) – Complex of plant characteristics which prevent insects from approaching, landing, settling, feeding or ovipositing; it affects the behavior of insects (altered number of insects landing or number laying eggs); has been termed non-acceptance

- Morphological nonpreference: leaf hairiness, stem hardness: cereal leaf beetle; wheat stem sawfly

# Allelochemical non preference

- **Volatiles (released into air and sensed by insect before they land) or sensed or tasted by insect after contact or during feeding: Examples: Raspberry aphid; Sugarbeet aphid; Rice brown planthopper**

**Raspberry aphid damage by Amphorophora ideai**

**11 Major genes for resistance**

**Resistance identified by aphids walking off leaves (antixenosis)**

**Rice brown planthopper resistance**

**Resistance based on the absence of asparagine production (antixenosis)**

**Wheat stem sawfly**

**Morphological non-preference**

**European corn borer damage**

**Resistance in leaves due to inhibition of larval growth by cyclic hydroxamic acid (DIMBOA) (antibiosis)**

**Greenbug resistance in barley**

**Damage caused by toxin secretion into leaves; resistance due to benzyl alcohol concentration (antibiosis)**

## Biochemical bases of resistance in plants to insects

A wide variety of traits expressed by plants are associated with the avoidance, resistance or tolerance of herbivory (Dhaliwal et al., 1999).

The field of insect-plant interactions has been dominated by studies on the effects of plant chemistry on the preference (choice made by individuals) and performance (growth, survival and reproduction) of insect herbivores (Speight et al., 1999).

- **These effects are the outcome of the absence of some nutritional factors, the presence of toxic metabolites or anti-enzymes, the presence of allomones or the absence of kairomones and the presence of synomones (Panda and Khush, 1995).**

# Nutrients

A nutrient is defined as a compound required for normal growth, development and maintenance of an organism's functions.

Being a nutrient is not an intrinsic characteristic of a molecule but rather depends on the biochemistry of the ingesting organisms, the concentration of the compound, etc. (Reese, 1979).

# Nutrients

Most insects have qualitatively similar nutritional requirements since the basic chemical composition of their tissues and their metabolic processes are generally similar.

Some of the nutrients which must be obtained form the diet are called essential nutrients. Others may be synthesized by the insect from dietary components.

# Nutritional Requirements of Insects

**Amino acids:** Production of proteins which are used as structural components, enzymes and receptor molecules as well as for transport and storage. Some amino acids are also involved in morphogenesis.

**Tyrosine:** Cuticular sclerotization

**Tryptophan:** Synthesis of visual screening pigments
**Arginine:** Phosphagen in the insect muscular system
**Glutamate & gamma-amino butyric acid:** neurotransmitters.

# Nutritional Requirements of Insects

**Amino acids are usually ingested as proteins and their utility depends on the insect's digestive ability. Proteins contain some twenty different amino acids, of which only ten are essential. The essential amino acids for insects are the same as those needed by higher animals and humans. These are: arginine, histidine, isoleucine, leucine, lysine, methionine, phyenyl alanine, threonine, tryptophan and valine. In addition to these, proline is also commonly required by many insects.**

# Nutritional Requirements of Insects

**Carbohydrates** are used as fuels by majority of insects. **Chitin**, the most important structural component of insect cuticle, is also a polysaccharide. The insect haemolymph contains substantial amounts of **trehalose**, a disaccharide of glucose. **Carbohydrates may be converted to fats and may contribute to the production of amino acids**.

# Carbohydrates

- They are, therefore, important components of the diets of most insects. But they are not necessarily essential because they can be synthesized from fats or amino acids. Nevertheless, most insects require some carbohydrate in the diet, and grow better as the proportion is increased. Usually, insects are able to digest and utilize polysaccharides (starch), disaccharides (sucrose, maltose) and hexose mono-saccharides (glucose, fructose).

# Nutritional Requirements of Insects

Most insects are unable to utilize cellulose and other plant polymers while pentose sugars (ribose, xylose, rhamnose and arabinose) are poorly utilized. Some of these sugars especially sucrose, fructose and glucose also act as phagostimulants for insects.

Among lipids, fatty acids, phospholipids and sterols are components of cell membranes. Sterols are also required for biosynthesis of ecdysone or moulting hormone while fatty acids serve as store houses for energy and as components of the insect cuticle.

## Nutritional Requirements of Insects

Unlike vertebrates, insects are unable to synthesize sterols and all insects need a dietary source of sterols to meet their requirements.

Phytophagous insects are able to utilize plant sterols like compesterol, sitosterol, stigmasterol and ergosterol and convert it into cholesterol.

All insects require water-soluble B complex vitamins: thiamine, riboflavin, nicotinic acid, pyridoxine, pantothenic acid, folic acid and biotin. These vitamins mostly act as coenzymes in various biochemical reactions.

# Nutritional Requirements of Insects

Most phytophagous insects require a dietary source of ascorbic acid (Vitamin C).

Among the fat-soluble vitamins, β-carotene (provitamin A) is essential as component of visual pigments, and for normal pigmentation.

Vitamin E (α-tocopherol) is necessary for normal reproduction.

Minute quantities of sodium, potassium, calcium, magnesium, chloride and phosphate are essential for the functioning of cells. Traces of iron, zinc and manganese are also required.

## Nutritional Quality of Host Plants

If a plant is to serve as a host, it must be able to provide holistic nutrients that can support the growth, development and reproduction of insects (Beck, 1972).

The host plant should not only meet the insect's nutritional requirements but also be suitable for being assimilated and converted into energy and structural compounds for normal activity and development. Plant species vary in their adequacy as hosts for even the most polyphagous insects, such as cutworms and grasshoppers (Slansky and Rodriguez, 1987).

# Nutritional Quality of Host Plants

- The key role of host plant variation- morphology, nutrients, water content, and allelochemicals in the regulation of herbivore populations is now well recognized (Bernays, 1985; Panda and Khush, 1995).
- Application of high levels of inorganic nitrogen significantly increased the incidence of most insect pests including stem borers, plant-hoppers and hispa on the rice crop.

# Nutritional Quality of Host Plants

- In cotton also, N application results in greater attack of bollworms and whitefly.
- In sugarcane, N application builds up internodes and stalk borer and pyrilla populations.
- Application of potash (K) and sometimes phosphorus also either singly or in combination with nitrogen results in lower incidence of many insect pests including leafhoppers and plant hoppers on rice, aphid on chillies, jassid on cowpea, etc. (Dhaliwal and Arora, 2001)

# Allelochemicals

Allelochemicals are **non-nutritional chemicals** produced by an organism of one species that affect the growth, health, behaviour or population biology of individuals of another species (Whittaker, 1970).

The allelochemicals have been broadly classified into two categories: **Allomones** tending to confer and adaptive advatage to the producting organism, i.e. the host plant, and **kairomones** – tending to confer and adaptive advantage to the receiving organism i.e. the phytophagous insect (Whittaker and Feeny, 1971).

# Allelochemicals

The involvement of allelochemicals in various types of insect-plant relationships can determine the status of a plant either as a host (presence of kairomone) and non-host (absence of kairomone) or as resistant (presence of allomone) and susceptible (absence of allomone).

Allomones are considered a major factor responsible for insect resistance in plants and these have been exploited to increase levels of resistance in several agricultural crops.

# Terpenoids

Terpenoids are the largest and most diverse class of organic compounds found in plants. They exhibit enormous chemical variety and complexity but all are formed by fusion of five-carbon isopentane units (Ruzicka, 1953) and most of them are lipophilic substances.

Monoterpenoids have been demonstrated to act as toxins, feeding deterrents, and oviposition deterrents to a large variety of insects.

# Terpenoids

The best known insect toxin among monoterpenoids is the botanical insecticide pyrethrum found in the flowers and leaves of certain Chrysanthemum species. The active ingredient in pyrethrum is mixture of monoterpene esters collectively known as pyrethroids (Casida, 1973).

Pyrethroids are neurotoxins causing hyperexcitation, uncoordinated movements and paralysis of insects.

# Terpenoids

Cotton and related malvaceous plants possess spherical pigment glands in leaves, flowers and most other parts of the plants. In addition to anthocyanin pigments, these pigment glands contain high concentrations of variety of mono and sesquiterpenoids especially gossypol. Gossypol is a phenolic, sesquiterpene diamer with two aldehyde residues.

# Terpenoids

**Gossypol** is toxic to a variety of herbivorous insects, causing significant decrease in the survival, growth and development of a number of important lepidopterous and coleopterous pests. The toxicity of gossypol to herbivores is supposed to result from **its binding to proteins in the gastrointestinal tract**, causing a reduction in the rate of protein digestion. The proteins in the gastrointestinal tract may be the ingested dietary proteins or the digestive enzymes produced by the insect (Meisner et al., 1977).

# Alkaloids

The alkaloids are a heterogeneous class of natural products that occur in all classes of living organisms but are most common in plants. Alkaloids generally include basic substances that contain one or more nitrogen atoms.

# Alkaloids

Numerous alkaloids have been reported to be toxic or deterrent to insects. Because of their nitrogenous nature, many alkaloids interfere with the key components of acetylcholine transmission in the nervous system.

Nicotine and nornicotine derived form tobacco plant were popular as botanical insecticides before the advent of synthetic organic insecticides.

# Glucosinolates

Glucosinolates form a small group of about 100 sulphur or nitrogen containing distinctive secondary compounds, which act as precursors of **mustard oils**. Glucosinolates occur commonly in the order Capparales, including the commercially important family **Cruciferae**.

# Glucosinolates

Glucosinolates appear to contribute to effective chemical defenses against a majority of non-adapted phytophagous insects.

On the other hand, a small minority of adapted (curcifer-feeding) insects are able to utilize glucosinolates in host seeking and host recognition behaviour.

# Insect Hormone Mimics and Antagonists

The endocrine system is critical for the development, growth, survival and multiplication of insects. Although many insect hormones are known, two powerful hormones, the juvenile hormone (JH) and the ecdysone or moulting hormoe (MH) are recognized to play a major role in these processes.

# Insect Hormone Mimics and Antagonists

The analogues of these hormones are called juvenoids and ecdysteroids respectively. It is presumed that plants may have developed juvenoids and ecdysteroids as subtle defenses against insect pests.

More than 100 biologically active phytoecdysteroids have bee isolated form plants especially ferns and yews.

# Coumarins

Natural Products possessing a 5,6-benz-2pyrone skeleton are called coumarins.

Coumarins exert a tremendous range of effects on the herbivorous insects. Coumarins can deter feeding as well as interfere with development of insects. The simple coumarin bergamottin is ovicidal to *Leptinotarsa decemlineata* (Say) and mammein toxic to mustard beetles.

# Coumarins

**Furanocoumarins** are deterrents and toxicants to a variety of insects. Coumarins also appear to act as kairomones for certain insects that are specialized for feeding on coumarin-containing plants (Berenbaum).

# Lectins

Lectins or pyhtohaemagglutinins are proteins of non-immunoglobulin nature.

Lectins are thought to be involved in the defense of plant against insects and phytopathogens. The lectin from *Phaseolus vulgaris* was found to have a lethal effect on the bruchid grubs (Liener, 1991).

# Lectins

**The soybean lectin has been shown to inhibit larval growth of a leaf-defoliating insect, *Manduca sexta* (Johannsen) (Shukle and Murdock, 1983).**

# Tannins and Lignins

Tannins are known to inhibit enzymes, coagulate proteins and bind to other materials as different as membranes and metal ions. The most commonly observed effects of tannins on insects are reduced food consumption, decreased weight gain and decreased efficiency of food utilization (Hangerman and Butler, 1991).

# Tannins and Lignins

**Lignin** is found in all vascular plants and **helps maintain the rigidity of the vascular system**. Lignin contributes to leaf toughness, which may help to defend leaves form insect herbivores.

# Biophysical bases of resistance

During the process of evolution plants have developed several defense mechanisms against harmful insects.

Each plant species has a unique defense mechanism involving various morphological and biochemical traits which have deep effect on the reproduction and survival of herbivores on a plant species.

## Morphological characteristics of a plant conferring resistance to insect pests:

- Trichomes on plant surface
- Surface waxes
- Hardness of plant tissues
- Thickening of cell walls and cuticle
- Anatomical modifications
- Silica content
- Colour
- Shape and size

## Trichomes

The epidermis of plants bears **hair-like outgrowths** celled trichomes or hairs (Esau, 1965). These are found on leaves, shoots and roots of plants. Trichomes occur in several forms, shapes and sizes (Uphof, 1962; Hummel and Staesche, 1962; Schnepf, 1969; Jhonson, 1975; Jeffree, 1986).

The trichomes are either **glandular or non-glandular**. The non-glandular trichomes are known to affect locomotion, attachment, shelter, feeding and survival of insects.

# Biophysical bases of resistance

**Glandular trichomes, which are very common in dicotyledonous angiosperms, secrete chemicals which are toxic to the insect.**

**The exudates inhibit movement on the plant surfaces and act as repellents and adversely affect survival.**

**Trichomes may favour incidence of insect pests by providing suitable place for egg laying and by interfering with the activities of natural enemies.**

## Insect Mobility

Trichomes restrict insect mobility on plant surface by entrapping, immobilizing and impaling them thus imparting mechanical resistance.

Hooked trichomes of bean *Phaseolus vulgaris* L. were found to impale the aphid, *Aphis craccivora* Koch (Johnson, 1953) and Potato leafhopper, *Empoasca fabae* (Harris) (Poos and Smith, 1931; Pillemer and Tingey, 1978) leading to wounding and death.

- **The small, hooked epidermal hairs of French beans. *P. vulgaris* have detrimental effect on colonies of *A. craccivora* resulting in impaling, bleeding, starvation, decreased longevity and fecundity, high larval mortality, increased time of larval development and decreased size.**

**Cotton cultivars with trichomes on upper and lower leaf surfaces and petioles provide a mechanism of resistance to movement of newly hatched larvae of tobacco budworm, *Helicoverpa virescens* (Fabricius) (Ramalho *et al*., 1984).**

**Hairiness in cotton also confers resistance to *Pectinophora gossypiella*.**

**Adults of whitefly, *Bemisia tabaci* (Gennadius) were found trapped by the glandular hairs on tomato leaves (Kriha, 1984). The insects after landing on plant surface come in contact with the glandular exudates usually of Type IV trichomes and become immobile due the hardening of these exudates.**

## Trichomes: Insect Feeding, Development and Survival

In soybean, beanfly infestation in early plant growing stages was influenced by trichome density on the under surface of leaves, leaf area, leaf moisture content and stem diameter.

Hooked trichomes of bean, *Phaseolus vulgaris* L. limited damage to beans by reducing population density of the potato leafhopper, *E. fabae*.

# Biophysical bases of resistance

## Oviposition

Trichomes inhibit oviposition of various insect pest species on different crop plants. Negative correlations between trichomes and oviposition have been reported in many insect species.

In wheat, females of Hessian fly, *Mayetiola destructor* (Say) laid fewer eggs on the pubescent-leaved "Vel" wheat than on the glabrous-leaved "Arthur".

Cereal leaf beetle, *O. melanopus* was found to oviposit less on pubescent wheat.

# Biophysical bases of resistance

In okra, *A. biguttula* population decreased with an increase in hair density on lamina and such varieties were less preferred for oviposition.

In contrast to the above observations, trichomes also enhance oviposition by some insect species resulting in the build-up of pest population. Positive correlation have been observed between oviposition and pubescence. Navasero and Ramaswamy (1991) reported that *H. virescens* preferred to lay eggs on the abaxial leaf surfaces where greater densities of trichomes occur.

# Biophysical bases of resistance

## Allelochemical Trichomes and Insect Survival

In addition to entrapping, the glandular trichome exudates contain several chemicals which are toxic to the insects. Trichome exudates from the leaves of Nicotiana and Petunia species are highly toxic to the larvae of the tobacco hornworm, *Manduca sexta* (Johannsen) Thurston et al., 1966 b). Removal of these trichnome exudates greatly reduced the toxicity of the leaves to tobacco hornworm larvae.

# Biophysical bases of resistance

## Anatomical Adaptations of Organs

Variations in plant structures also contribute towards insect resistance. Rice varieties with tight leaf sheath wrapping were found less susceptible to Asiatic rice borer, *C. suppressalis*.

In sugarcane, low number of stomata per unit area has been associated with the resistance character of varieties to sugarcane scale, *Melanaspis glomerata*.

# Biophysical bases of resistance

**Rajarajeswari and Subbarao (1997) found that number of gossypol glands on leaf and ovary surface of cotton, *Gossypium hirsutum* L. had significantly negative relation with bollworm, *H armigera* incidence.**

**Cotton, *G. arboreum* genotypes with high gossypol-gland density on ovary surface showed low incidence of bollworms, viz. *H. armigera*, *E. vittella, P. gossypiella* on the basis of locules and higher seed cotton yield/plant.**

# Biophysical bases of resistance

## Silica Content

**Silica Contents absorbed by the plants get deposited in the tissues of several plant species especially those belonging to Gramineae.**

**Several studies have shown that silica deposits in certain plant tissues contribute to resistance of these plants to insect attack.**

**In sorghum, cultivars with high silica content in 4$^{th}$ and 6$^{th}$ leaf stage had low incidence of shoot fly, *A. soccata*.**

# Biophysical bases of resistance

- **In rice, a highly significant negative correlation was recorded between silica content of the stem in various cultivars and the susceptibility to the Asiatic rice borer, *C. suppressalis*. High silica contents apper to interfere with feeding and boring of the larvae and could cause defacing of their mandibles.**

## Solidness and Other Stem Character

Toughness and thickness of plant stems has been found to alter the insect plant interactions. Rice varieties having small stem with a ridged surface were found less susceptible to Asiatic rice borer, *C. supressalis* (Patanakamjorn and Pathak, 1967).

Resistant rice varieties were characterized with little interspaces while the susceptible varieties had more interspaces between leaf-sheaths enabling the entry of the gall midge, *Orseolia oryzae*.

# Biophysical bases of resistance

**In wheat, solid-stemmed cultivars were resistant to wheat stem sawfly, *Cephus cinctus*.**

**In sugarcane, rind hardness is an important factor in reducing sugarcane borer, D. saccharalis damage.**

**In sorghum, genotypes having thin and longer stem with fewer but longer internodes, short peduncle and yellowish green leaves with high trichome density were resistant to stem bore, *C. partellus*.**

## Thickening of cell walls and Rapid proliferation of Plant Tissues

**Hardness of various plant tissues has been reported to be correlated with the resistance to insect pests. Toughness and thickness of various plant parts adversely affect penetration and feeding by insects. Seed damage due to alfalfa seed chalcid, *Bruchophagus roddi* (Gussakovsky) was less in annual *Medicago* species which has highly lignified pod-walls.**

# Biophysical bases of resistance

**Rice varieties with thicker hypodermal layers were found less susceptible to Asiatic rice borer, *C. suppressalis* (Patanakamjorn and Pathak, 1967); yellow stem borer, *S. incertulas*.**

**In chickpea, resistance to bruchild, *C. maculatus* (Fabricius) is associated with roughness and toughness of the seed coat.**

# Biophysical bases of resistance

## Surface Waxes

Surface waxes over the epicuticle protect the plant surface against desiccation, insect feeding and diseases. Epicuticular waxes affect the feeding behavior of insects, particularly the setting of probing insects, acting as phagostimulants or feeding deterrents. There have been a number of reports about insect response to chemicals on the leaf surface as obtained from experiments using surface extracts of leaves or pure chemicals that are known to occur on leaf surfaces.

# Biophysical bases of resistance

- Waxes are esters formed by a linkage of a long chain fatty acid and an aliphatic alcohol.
- Due to the presence of these waxes on plant surface, the sense organs on the insect tarsi and mouth parts receive negative chemical and tactile stimuli from the plant surface resulting in resistance of the plant to insect pest attack.

# Biophysical bases of resistance

**Leaf epicuticular wax is an important antixenotic factor that affects the rate and pattern of feeding of flea beetle, *Phyllotreta cruciferae* Goeze in Brassicaceae (Bodnaryk, 1992 a).**

**Neonate larvae of *Plutella xylostella* (Linnaeus) had non-preference for leaf wax charcteristic in glossy-leaved resistant *Brassica oleracea* L.**

# Biophysical bases of resistance

- **In rice, increased activity of the brown planthopper, *Nilaparvata lugens* (Stal) on rice variety IR 46 over that observed on yarietes IR 22 and IR 62 was shown to be due to the chemical composition of the surface wax. Bioassays showed that the effect is caused by the hydrocarbon and carbonyl containing fractions of the wax of IR 46.**

# Biophysical bases of resistance

## Colour

Colour-related insect resistance in plants does not exist but genetic manipulation of plant colour usually has an effect on some fundamental physical plant processes (Norris and Kogan, 1980). Red-foliaged Brassica species/ cultivars are much less attacked by *P. rapae*, *P. brassicae*.

Brassica genotype with purple foliage and apetalous flowers were resistant to development of *L. erysimi.*

# Biophysical bases of resistance

## Plant Cuticle

Plant cuticle consists of wax, pectin and cellulose. It plays important role in feeding and oviposition behavior of insect pests. Young cuticle is usually preferred over mature cuticl e by insect pests for feeding and oviposition. Larvae of H. zea preferred to feed on older leaves of soybean plants over younger one throughout the season.

# Biophysical bases of resistance

## Shape and Size

Plant shape and size is also known to bring some behavioral changes in insects but no resistance mechanism has been reported (Norris and Kogan, 1980). Plants with erect growth habit were more acceptable to females of *H. virescens* for oviposition than plants with procumbent growth habit (Navasero and Ramaswamy. 1991).

# Biophysical bases of resistance

**In tomato, vine size was negatively correlated with fruit damage by fruitworm, *H. zea* (Fery and Cuthbert, 1973).**

**The resistant soybean cultivars to *Ophiomyia phaseoli* have significanty smaller cotyledons and unifoliate leaves and these are the parts where the insect lays eggs.**