M.SC. IN ZOOLOGY
SEMESTER – IV
NAME OF TEACHER: DR. TAPAN KUMAR ROY
NAME OF TOPIC: ALLELOCHEMICALS IN INSECT – PLANT INTERACTION (ZCT- 434)

TOPIC GUIDELINES

UNIT-1: AN OVERVIEW ON PLANT DEFENCE AGAINST INSECT HERBIVORES

UNIT 2: ALLELOCHEMICALS IN DETAIL

UNIT-1
An overview on
PLANT DEFENSE AGAINST INSECT HERBIVORES

INTRODUCTION

- Plants and insects have been living together for more than 350 million years.
- Both have evolved strategies to avoid each other's defense systems.
- Plants respond to herbivory through various morphological, biochemicals, and molecular mechanisms to counter/offset the effects of herbivore attack.

TYPES OF WOUNDS THAT PRODUCED BY THE INSECT

Mining and Boring

- Insects live in between 2 epidermal layers of a leaf. Damage appears as tunnels,blotches or blisters.
- Independently evoloved in 4 orders; diptera , lepidoptera, coleoptera, and hymenoptera .
- Different species may excavate different layers of leaf parenchyma or reside in .particular leaf
- Fruit boring.
- Stem boring.
- Wood boring.
- Stalk boring.
- Plant boring.

Sap sucking

- Drains plants resources by tapping into xylem and phloem.
- Can retard growth and cause overall lower biomass.
- Often vectors.
- Serves to pierce tissues and suck liquid food.
- Food channels empties into cibarial cavity.
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Mealybugs →

Chewers

- No relative size restrictions.
- Heavy mechanical damage.
- Faced with indigestible compounds and toxins.

A scarab beetle (Coleoptera: Scarabaeidae)

Suckers

- Restricted to a relatively small size.
- Avoid mechanical damage(but still damaging).
- Avoid indigestible compounds and most toxins.
- Xylem less suitable.

(brown stinkbug feeding on tomato fruit →

Gall makers

- Galls consists of pathologically developed calls.tissues or organs of plants that have arisen by hypertrophy and /or hyperplasia as a result of sti,ulation from foreign organisms.

Orders that makes galls.

1. Hemiptera
2. Diptera
3. Hymenoptera

Nipplegalls are one of the most common gall-making insects on hackberry. →

<u>Plant Defenses</u>

- Defences can be constitutive or induced.
- <u>Constitutive</u>- defenses that are always present in the plant eg. Cuticle, wax, spines etc.
- <u>Induced</u>-defenses are produced to the site where a plant is injured. It induces several internal signals from the wounded tissue including calciun ion fluxes, phosphorylation cascades and jasmonate signaling.

- **Calcium ions (Ca^{2+}) in plant defense-**
- Plant defense upon herbivory undergo different signal transduction pathways. Ca^{2+} signaling is one of the early events in insect-plant interaction, where Ca^{2+} acts as a second messenger, which in turn mediates a number of plant signaling pathways.
- **Jasmonic acid in plant defense-**
- various phytohormones are involved in plant defense against herbivores, JA is the most important phytohormone linked to plant defense against herbivores and activates the expression of both direct and indirect defenses.
- JA is derived from linolenic acid through octadecanoid pathway and accumulates upon wounding and herbivory in plant tissues.
- play an important role in plant defense against a variety of biotic and abiotic stresses through signal transduction.

Plant Defenses

Defense responses

Direct Defense responses

1)bioactive specialized compounds.
2)Digestibility reduction
3)Reallocation of resources
4)Morphological features.

Indirect Defense responses

1)Volatiles
2)Food bodies
3)Nesting and refuge sites

Direct Defense responses

- The term "direct defense" is used when plants produce physical barriers against insect herbivores,or compounds that exert repellent, antinutritive or toxic effects on the herbivores themselves.

1. Bioactive specialized compounds.
2. Digestibility reduction.
3. Reallocation of resources.
4. Morphological features.

Bioactive specialized compounds.

- Chemical compounds produced by plants have traditionally been divided into primary and secondary metabolites.
- The primary metabolites are used for growth, development and reproduction. The secondary metabolites, nowadays known as bioactive specialized compounds, are on the other hand used to protect the plant against herbivory and microbial pathogen infection,
- Bioactive specialized compounds are targeted especially against biological systems unique to herbivores, such as the nervous, digestive and endocrine organs.

1. Alkaloids
2. Benzoxazinoides
3. Cyanogenic Glucosides
4. Glucosinolates
5. Nonprotein Amino Acids
6. Phenolics
7. Terpenoids

Examples of plant Bioactive Specialized Compounds with insecticidal activity

Plant Insecticidal Compounds	Activity	Plant localization	Insect
C Based compounds			
Terpenoids			
Monoterpene alcohol	repellent	flowers	*Lasius niger* (Hymenoptera)
Diterpenoids	repellent antifeeding	stems	*Ostrinia nubilalis* (Lepidoptera)
Cardenolides	toxicity	aerial and subterranean parts	*Danaus plexippus* (Lepidoptera)
Iridoid glycosides	toxicity	leaves nectar	*Junonia coenia* (Lepidoptera)
Phenolics of low molecular weight			
Phenolic glucosides	deterrent toxicity	aerial parts	Generalist and specialist invertebrates
Aromatic esters	repellent	nectar	*Solenopsis xyloni* (Hymenoptera)
Flavonoids	repellent	leaves	*Spodoptera exigua* (Lepidoptera)
Isoflavones	feeding deterrent	roots	*Costelytra zealandica* *Heteronychus arator* (Coleoptera)
Furanocoumarins and coumarins	toxicity	leaves	*Trichoplusia ni* (Lepidoptera)

Ibanez et al., 2012

Plant Insecticidal Compounds	Activity	Plant localization	Insect
Phenolics of high molecular weight			
Tannins	toxicity (oxidation)	leaves	*Orgyia leucostigma* (Lepidoptera)
N Based compounds			
Cyanogenic glucosides	toxicity	leaves	*Spodoptera frugiperda* (Lepidoptera)
Glucosinolates	toxicity	leaves	*Pieris brassicae* (Lepidoptera)
Alkaloïds	repellent	nectar	Bee pollinators
Pyrrolizidine alkaloids	toxicity	leaves	Non adapted Arctiidae (Lepidoptera)
Azoglucosides	toxicity (mutagen)	leaves, seeds, cones	*Rhopalotria sp.* (Coleoptera)
Non protein amino-acid	toxicity	leaves	Invertebrates
Protease inhibitors	toxicity	leaves	*Spodoptera littoralis* (Lepidoptera)

Digestibility Reduction

- Plants produce a number of defense proteins that reduce insect herbivores ability to digest the plant.
- The five major classes of defense proteins are:

1. α-Amylase Inhibitors.
2. Chitinases.
3. Lectins.
4. Polyphenol Oxidases.
5. Proteinase Inhibitors.

α-Amylase Inhibitors.

- The lectin-like α-amylase inhibitors (α-AI) are found in cereal seeds, such as wheat, barley, maize.
- The activities of these inhibitors are directed against α-amylases from animals (including insects) and microorganisms
- Used for starch breakdown.
- Wheat α-AIs can inhibit mealworm, flour beetles, wheat weevils, among other stored-grains insect pests.

Chitinases.

- Chitin is present in the exoskeleton and peritropic membrane of insects.
- Role in defense against herbivore by disrupting the gut preitropic memberane.

Lectins.

- Lectins are sugar-binding proteins found especially in storage organs and protective structures of some plants.
- When lectins come into contact with the glycoproteins lining the intestinal area of insect herbivores, they are assumed to inhibit the absorption of nutrients.

Polyphenol Oxidases

- Polyphenol oxidase (PPO) enzymes are anti nutritive enzyme.
- enzymes cause the typical browning of plant extracts, mainly fruits, and damaged tissues , This is caused by the spontaneous polymerization and cross-linking of o-*quinones.*
- PPOs appear frequently upon wounding, and are therefore suggested to play a defensive role.
- reducing the nutritive value of proteins.
- PPOs can also be combined with specific phenolic substrates in glandular trichomes to produce a kind of “super glue” to trap smaller insects.

Proteinase Inhibitors

- Four different classes of endopeptidases or proteinases, found in the midgut region of the insect digestive tract, are used by insect herbivores to cleave internal peptide bonds in plant proteins.
- The most common are the serine proteases, which are found in Coleoptera, Lepidoptera and Orthoptera.

Reallocation of resources

- To protect valuable resources, they might be reallocated by the plant upon attack.
- For instance,*Centaurea maculosa (spotted knapweed) allocates more nitrogen to the shoots upon attack by Agapeta zoegana (sulphur knapweed moth) [292]. In this way, the plant can sustain the high* photosynthetic activity needed for compensatory growth.
- Reallocation can also be directed from shoot to root.

Morphological Features

- To be able to feed, insect herbivores from all feeding guilds will come in contact with the plant surface. Plants have therefore developed a number of physical features such as wax films and crystals,trichomes, leaf and root toughness and quantity, laticifers and resin flow.

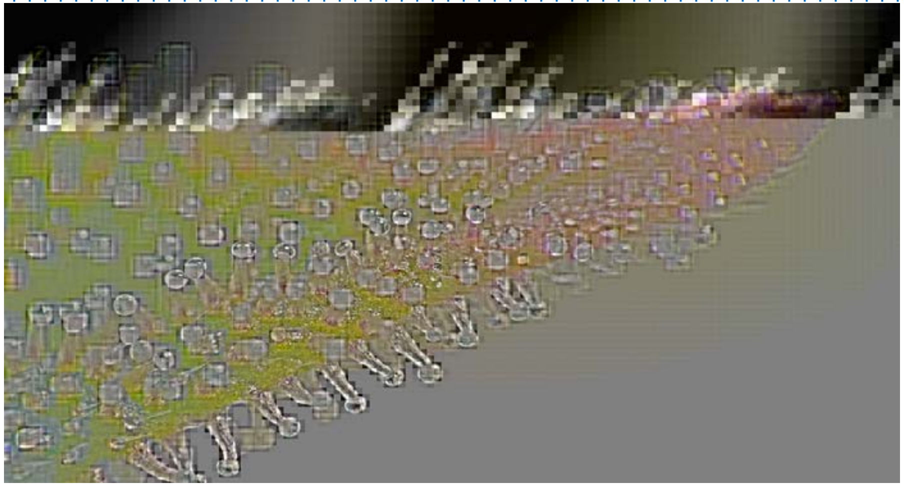
1. Waxes and Crystals.
2. Trichomes.
3. Leaf and Root Toughness.
4. Laticifers and Oleoresins.

1. Waxes and Crystals.

- Epicuticular waxes form films and crystals that cover the cuticle of most vascular plants.
- Aside from their role in desiccation tolerance and protection against pathogens.
- they also increase the slipperiness, which hinder non-specialized insects from populating the leaf surfaces.

2. Trichomes.

- Plant surfaces may further be covered by thorns and spines, for protection against insects. trichomes (hairs) are defense against herbivorous insects.
- Glandular trichomes contain glands that produce volatile or non-volatile bioactive natural products or proteins that repel, deter or poison insects.
- Non-glandular trichomes, on the other hand, prevent small insects from making contact with the surface.



Trichomes.

3.Leaf and Root Toughness

- Leaf toughness interferes with the penetration of plant tissues by mouthparts of piercing-sucking insects and increase mandibular wear in biting-chewing herbivores.
- Roots eaten by insect herbivores exhibit extensive regrowth, both in density, as seen in *T. repens* eaten by *Sitona lepidus (clover root weevil).*
- and in quantity, as observed in *Medicago sativa* (alfalfa) attacked by clover weevil (*Sitona hispidulus).*

4. Laticifers and Oleoresins

- Several plants contain networks of channels in vascular tissues called laticifers and resin ducts. Latex and resins are stored under internal pressure, and when the channels are broken, they are secreted and might entrap or intoxicate the herbivore.
- Latex laticifers are found in more than 10% of the angiosperms, and is especially common in the tropics . Of the more than 50 latex producing plant families, *Asclepias (milkweeds) is the one most studied.*
- For instance, the latex of *Cryptostegia grandiflora (rubber wine) may be transported 70 cm upwards to the wounding site, where* it, upon exposure to air, will coagulate and thereby trap small insect larvae.

Indirect Defense Response

- The term "indirect defense" is used when plants attract, nourish or house other organisms to reduce enemy pressure . This is done by producing volatiles, food bodies and nesting or refuge sites.
- Volatiles.-- More than 1000 volatile organic compounds (VOCs), primarily consisting of 6-carbon aldehydes, alcohols, esters and various terpenoids are released from plant flowers, vegetative parts or roots . VOCs are used to attract pollinators and predators or repel herbivores.

Indirect Defense Response

- Food Bodies.--Food bodies (FBs) are cellular structures containing mainly carbohydrates, proteins and lipids They serve as food for ants and are thereby used to attract predators. Because of the high lipid and protein content of FBs, they are considered to be an expensive form of defense.
- Nesting and Refuge Sites.--Plants can offer predators like ants, mites and bugs small chambers in the juncture of the midrib and the vein used as nesting or refuge sites