CROP PROTECTION

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WEED SCIENCE

UNIT I: INTRODUCTION

Weed Science

– a body of knowledge that primarily focuses on the study of weeds and their control. It is also defined as an integrative, applied scientific discipline typical of most other pest management and production-oriented disciplines of modern agriculture.

– Study of vegetation management in agricultural production systems, natural areas, and managed properties in residential and urban areas

Main Goal:
formulation of the most effective, economical, and satisfactory methods of controlling weeds

DEFINITION

There are numerous definitions of a weed:
- a plant out of place and not intentionally sown
- a plant growing where it is not wanted
- a plant whose virtues have not yet been discovered
- a plant that is competitive, persistent, pernicious, and interfere negatively with human activity

Source: Dwight D. Ligenfelter, Extension Agronomist, Department of Agronomy, Penn State University

Before, weeds were not recognized as pests because of the following reasons:

- their damage is not as visible as those by insects and diseases
- seldom results in total crop failure
- crops and weeds are always associated together

Characteristics Of Weeds

Literature suggests that the most consistent trait of weed species is not related to their morphology or taxonomic relationships. It is, as Baker (1965) noted, their ability to grow well in habitats disturbed by human activity. Not all weeds possess every single characteristic that is considered undesirable, but in addition to growing in disturbed habitats, all have at least some of the following characteristics listed below:

1. Rapid seedling growth
2. Ability to reproduce when young.
3. Quick maturation/short life cycle
4. Capacity to tolerate and grow under a wide range of climatic and edaphic conditions (environmental plasticity).
5. Seeds exhibit dormancy or dispersal to escape the rigors of the environment and germinate when conditions are most favorable for survival.
6. Produces seed of the same size and shape as crop seed, making physical separation difficult and facilitates easy dispersal by man.
7. Can reproduce sexually and asexually
8. Specially adapted seed dispersal mechanism
9. Weeds have great competitive ability for nutrients, light, and water and can compete by special means (e.g., rosette formation, climbing, allelopathy)
10. High seed output
11. Most weeds have vegetative propagule and spread rapidly all over the field.
12. Easily disseminated over long distance.

Source: Baker, H.G. 1965. Characteristics and modes of origin of weeds. Pp. 147–172, in Genetics of Colonizing species. Proc. First Int. Union of Biol. Sci. Symp. on Gen. Biol. H.G. Baker and G.L. Stebbins, ed. Academic Press, New York.

Negative Impacts Of Weeds

a. Decrease in yield of crops
   - due to competition
b. Reduce quality of crops
   - weed rhizomes can puncture potato tubers
   - competition with crops can result to stunted growth, small fruits and reduced protein content of cereals
c. Alternate hosts of plant pathogens and insect pests
d. Interfere with animal feeding
   - spines of weeds may hurt foraging animals
e. Taint animal products
   - may affect flavor (e.g., undesirable flavor of milk after cow consumed *Lantana camara*)
f. Affect human and animal health
   - some weeds are poisonous
   - may cause allergies or skin irritations
   - *Pistia stratiotes* may serve as breeding grounds for mosquitoes
g. Plant parasites
h. Increases labor cost due to hand weeding
i. Affect aesthetics of landscapes
j. Competes with crops for pollinators
k. Prevents water flow
   - may block irrigation channels or ditches
l. Reduce wool quality
   - caused by seeds with hooks (e.g., *Cenchrus echinatus, Bidens Pilosa*)

Benefits From Weeds

a. Feed for animals
b. Food for humans
   i. *Amaranthus* spp.
   - may be eaten as salad greens
   ii. *Portulaca oleracea*
   - has high levels of fatty acids, vitamin E and Omega-3 fatty acid
   iii. *Echinochloa crusgalli*
   - may be eaten dry or may be ground into flour
   iv. *Digitaria ciliaris*
   - sees may be eaten whole
c. Medicinal uses
   i. *Euphorbia hirta* (Tawa-tawa)
   - increases platelet count in blood; used in dengue patients
   - latex applied to eyes when they turn reddish
   - extract used in bowel problems and cough
   - crushed plant applied to cuts
   ii. *Peperomia pellucida* (Pansit-pansitan)
   - chemotherapeutic
   - may cure gouts and wounds
d. Adds organic matter to soil
e. Prevent soil erosion
f. Habitat for natural enemies
g. Ornamentals/landscape materials
h. Biofilters
i. Source of genetic materials

General Classification Of Weeds

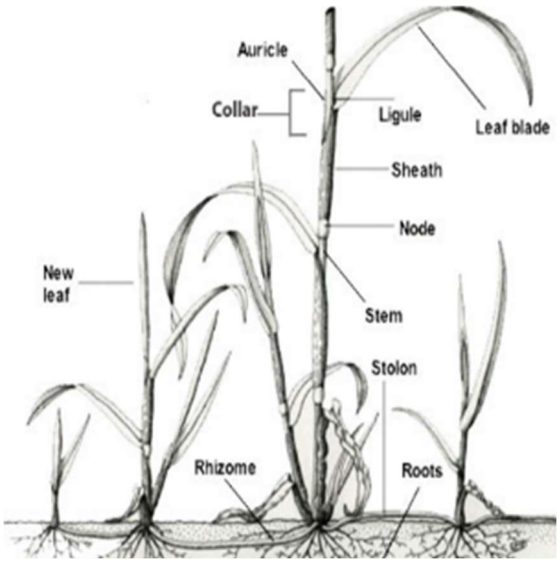
a. **Noxious Weeds** – plants having undesirable characteristics that can resist control practices.
b. **Common Weeds** – these can be found in every farm but are not injurious and can be readily controlled by good farming practices.

Specific Classifications Of Weeds

Based on Gross Morphology

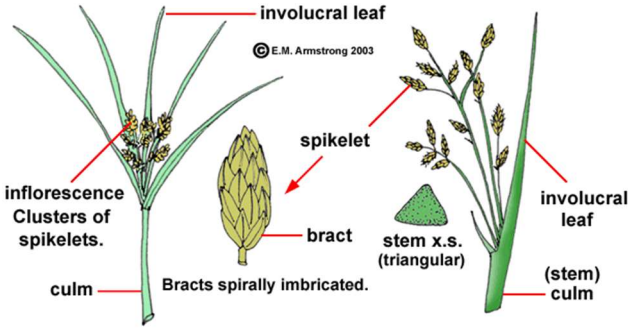
a. Grasses (Family Poaceae)

- range from small, twisted, erect, or creeping annuals and perennials
- Stems are called culms with well-defined nodes and internodes where leaves arise alternately in 2 rows
- Leaves usually thin and linear with parallel venation
- Leaf sheath clasps the stem
- Ligule and/or auricle is present



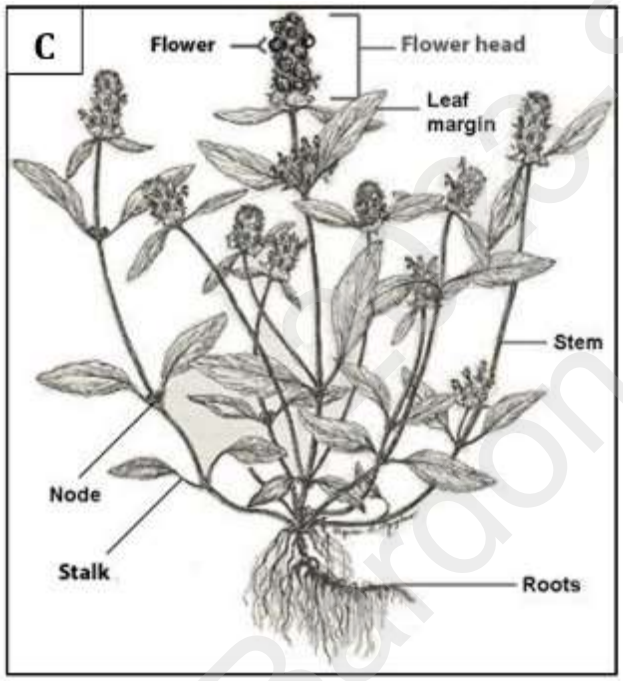
b. Sedges (Family Cyperaceae)

- Stems are triangular in cross-section, solid and do not have nodes.
- Absence of ligule
- Leaves are linear in a rosette formation



c. Broadleaves (Family Asteraceae)

- Leaves are shorter but wider with either parallel or netted venation
- Mostly dicots



Based on Life Cycle

a. Annual Weeds

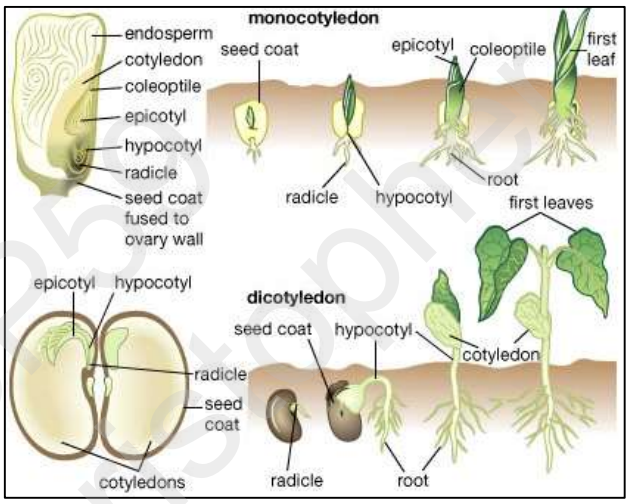
- weed species that complete their life cycle in one year or one cropping season
- reproduce primarily by seed only
- About 2/3 of the worst weeds in the world are annual weeds

b. Perennial Weeds

- weeds that live for two or more years
- can reproduce by seed or vegetative parts
- most difficult weeds to control

Based on number of cotyledons

a. Monocots – grasses, sedges, *Monochoria vaginalis*
b. Dicots – most broadleaves



Morphological difference between monocot and dicot weed species

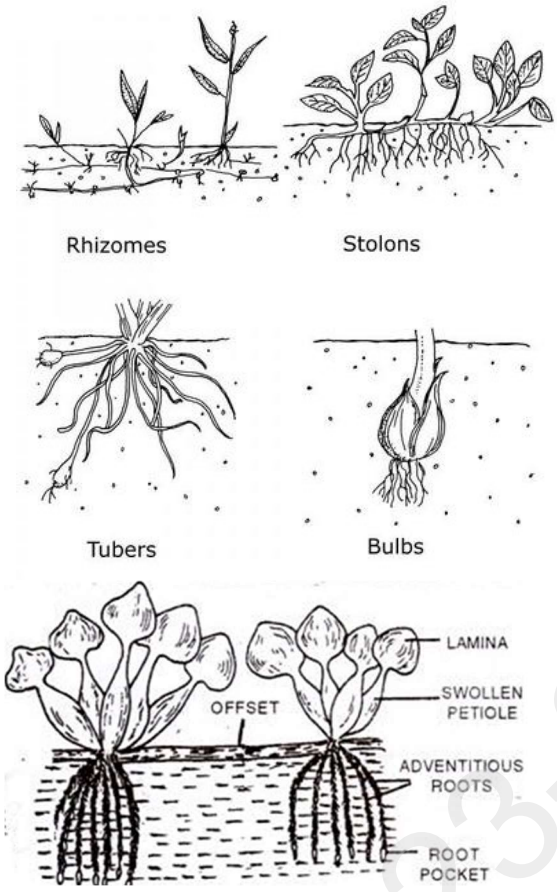
Based on Mode of Reproduction

a. **Sexual** – reproduce by means of seeds
b. **Asexual** – reproduce by means of vegetative propagules

Vegetative propagules:

i. **Rhizome** – modified horizontal underground stem with buds and scales (*Ex. Cogon grass*).
ii. **Tuber** – enlarged portions with extensive storage tissues produced in chains on a single rhizome (*Ex. Purple Nutsedge*).
iii. **Stolon/runners** – aboveground stem that creeps and having roots at the nodes (*Ex. Bermuda grass*).
iv. **Bulbs** – short, specialized storage organ underground surrounded by thick fleshy leaves

v. **Off-sets** – small plants that usually arises from the mother plant.



Based on Growth Habit

a. Erect
b. Prostrate
c. Creeping
d. Twining

Based on Habitat

a. **Lowland weeds** – weed species that grows favorably in moist area.
b. **Upland weeds** – weed species that grows favorably in dry area.

Based on Body texture

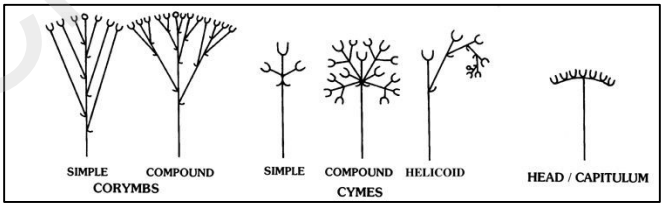
a. **Herbaceous** – weeds that do not develop woody stems
b. **Woody** - weeds that have stems that undergo secondary thickening, giving a hard fibrous structure

Examples of weed species that grows well in lowland
(A – Ex. Water hyacinth) and upland
(B – Three-lobed morning glory) areas.

Based on Inflorescence

Common inflorescence in weeds:

a. **Spike** - the flower is attached directly to the stem and pedicles (stalks) are absent
b. **Raceme** - pedicels attach the flowers to the stem
c. **Panicle** – compound/branched racemes
d. **Corymb** - pedicles are different lengths with the pedicels at the base are longer than those near the top, giving a flat to rounded top
e. **Umbel** - a flat topped or convex inflorescence with the pedicels arising from a common point, like an umbrella



Different types of inflorescence exhibited by several weed species.
Photo Courtesy: Swink, F. and G. Wilhelm., 1994

Based on Photosynthetic Activity

a. **C3 Weeds**
- 3-carbon compound is the final product of photosynthetic pathway
- most of these weeds are dominant in rice fields that are under submerged conditions

b. **C4 Weeds**
- more efficient photosynthetic pathway in which a 4-carbon compound is the first stable product

UNIT II: WEED REPRODUCTION & DISPERSAL

SEXUAL REPRODUCTION
- reproduce through <u>seeds</u>

- Flowering stage starts as early as 4 to 5 weeks after planting
- Seeds are produced in 3 to 4 weeks after flowering

Weed Seeds

a. Seed number

- The number of weed seeds in arable soil is large
- In lowland rice fields in the Philippines, 804 million seeds from 12 different species (sedges dominated) were found over 1 hectare 6 inches deep (Vega and Sierra, 1970).

Weed Species	No. of seeds/plant
Commelina benghalensis	1,610
Ageratum conizoides	36, 865
Cyperus difformis	21,096
Cyperus iria	4,775
Cyperus rotundus	2,975
Dactyloctenium aegyptium	65,800
Digitaria sanguinalis	1,705
Echinochloa colona	8,148
Echinochloa crusgalli	2,173
Echinochloa glaberescens	2,235
Eleusine indica	50,352
Rottboellia cochinchinensis	2,208

b. Seed size

- Most weeds produce small seeds
- Small seeds are easily dispersed by wind and water

c. Seed dispersal

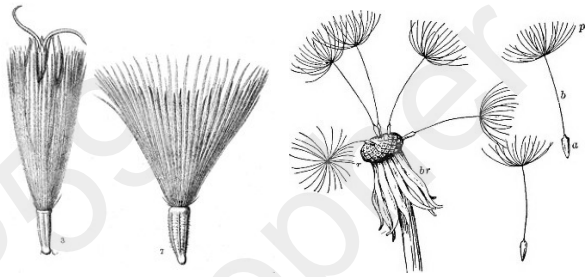
- Seeds possess special structures for dissemination
- Structure of the seed, habitat of weeds, and the activities of man are key factors for efficient dispersal
-

Means of weed seed dispersal

1. Wind

- for seeds that are small and light that have flattened structures, wing-like outgrowth or feathery appendages (pappus)

- **Pappus** – (*pl. pappi*) a parachute like modification of persistent calyx into hairs, Ex: Little iron weed (*Vernonia cinerea*), Dandelion (*Taraxacum officinale*)



Pappi of A. *Vernonia cinerea* and B. *Taraxacum officinale*

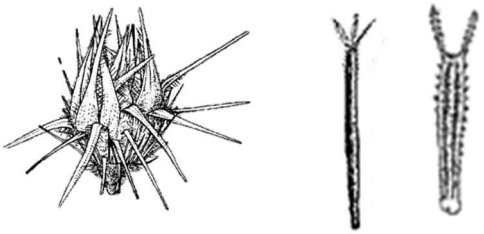
2. Water

- common in lowland weeds whose seeds have oily film, light pericarp, or inflated structure; can float in water
- many seeds are dispersed by water where irrigation is common

3. Human-aided

- failure to screen irrigation water
- failure to clean farm machineries
- trade and importation of farm products
- transported in animal feeds
- sold as ornamentals
- mistaken identification
- spread seeds with burs by mechanical means (e.g., seeds cling to clothing)

- **Burs** - consist of one to several spikelet surrounded by spiny, scabrous bristles. Ex: *Cenchrus echinatus, Bidens pilosa*



Burs on seeds of A. *Cenchrus echinatus* and B. *Bidens pilosa.*

4. Animal-aided
- seeds stick/entangle to animal bodies or by fecal matter.
- Rats, birds and ants carry weed seeds
- seeds with hard seed coats that pass through the digestive system of birds and cattle are still viable

5. Machinery
- machineries can easily carry weed seeds, rhizomes, and stolons
- harvesting equipment often spreads weed seeds
- cultivation equipment, tractors, and tractor tires frequently carry soil that may include weed seeds

Soil as a Weed Seedbank

Seedbank
- refers to the portion of the earth where weed seeds are deposited

Weed seed reserve
- volume of weed seeds in the soil or a certain soil volume capable of infesting the succeeding crop
- maintenance of the weed seed reserve will be determined by the dormancy and longevity properties of the seeds

Seed Longevity
- the ability of weed seeds to germinate even after a prolonged dormancy

Dormancy of Weed Seeds
- a condition of suspended growth
- the temporary inability of a viable seed or any vegetative propagules to germinate under favorable conditions
- also called the resting stage of a seed

Dormancy of Weed Seeds

Types of Dormancy

1. Innate/Primary dormancy
- present immediately
- such dormancy prevents the seed from germinating viviparously and also usually for some time after the ripe seed is shed or harvested

Causes of Primary Dormancy:

- ***Immature embryo*** – once seed was released from the mother plant, a rudimentary embryo needs time to mature
- ***Impermeable seed coat*** – inhibits entry of water and important gasses for germination
- ***Environmental stimuli*** – ex. Quality of light, presence of phytochrome systems
- ***Endogenous chemical inhibitors*** – may require washing for these chemicals to be removed from the seed

2. Enforced/Secondary dormancy
- due to the environment or existence of an unfavorable environment
- when viable seeds do not germinate due to a limitation in the environment but will germinate when the limitation is removed

Causes of secondary dormancy

- ***Light*** – absence of light, *e.g., Photoblastic seeds (require light for germination)*
- ***Water*** – lack of moisture would prevent the rupture of the seed coat
- ***Temperature*** – extreme temperature may allow germination but might affect the growth of the embryo into seedlings

Benefits of Seed Dormancy

1. Distribution of germination over time
   - seeds are dispersed from the mother plant with different degrees of dormancy
2. Reduced competition
3. Increased likelihood that some individuals will survive
4. Ability to overcome an impending adverse environmental condition
5. Minimizes damage to seeds or preservation of quality of harvest

Ways to break dormancy

- **Stratification** – exposure to low temperature
- **Mechanical scarification** – damaging or removing seed coat
- **Chemical scarification** – treatment with acid
- Treatment with gibberellic acid or cytokinin
- Treatment with specific light wavelength
- (sulfuric, nitric)
- Soaking in water
- Treatment with potassium nitrate/potassium nitrite

Breaking of dormancy in nature

- rupture of seed coat by fire
- decay of seed coat by saprophytic fungi
- exposure to light
- passage of seeds through the digestive tract of animals
- mechanical damage of seed coat by animals
- low or chilling temperature (stratification)
- alternating or fluctuating temperatures
- leaching out of inhibitors by rain

Seed Germination

- the resumption of growth of the embryo of the seed or of the young plantlet in the tuber, bulb or rhizome
- important for the survival of weeds

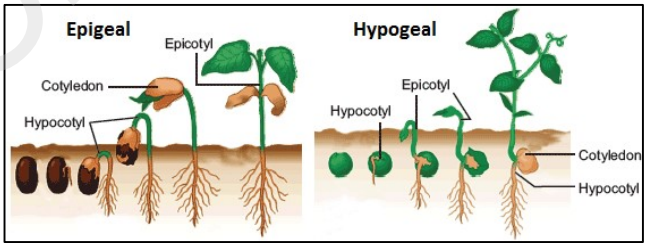
General illustration of seed germination.

Steps in Seed Germination

1. **Imbibition**
   – absorption of water
   – marks the initiation and progress of starch hydrolysis
2. **Rapid metabolic activity**
   – respiration, translocation of metabolites
   – cell division and cell elongation occur in a fast rate supported by a rapid synthesis of materials in the seed
3. **Root Emergence**
   – the radicle emerges from the seeds and grow into the soil.
4. **Shoot Emergence**
   – considered the first sign of weed growth
5. **Independent growth**
   – capable of manufacturing its own food

Two types of seed germination

A. **Epigeal germination**
   – cotyledons are carried above the ground like in the case of some leguminous species and
B. **Hypogeal germination**
   – cotyledons remain below or at the surface of the ground as in grasses and sedges.



(A) epigeal and (B) hypogeal germination

Factors affecting weed seed germination

- **Environmental factors**
  ✓ ***moisture*** - first crucial step in the germination is imbibition of water
  ✓ ***light*** - abundance of red light in the environment will lead to germination
  ✓ ***temperature*** - governed by the cardinal temperatures wherein there occurs a minimum, maximum, and optimum temperature for germination
  ✓ ***oxygen level*** - low oxygen levels inhibit germination

- **Cultural factors**
  ✓ ***cultivation/tillage*** - may contribute to inhibition of germination; may bring buried seeds to the surface
  ✓ ***flooding*** - reduces oxygen levels in soil; will lead to inhibition of germination, ex: lowland rice production
  ✓ ***mulching*** - inhibit germination since mulch materials cover the soil, therefore reducing light penetration

Weed Seedling Growth and Development

- most important stage in establishment of weeds and weed control
- the stage where damage against crop is at low level
- most sensitive stage to environmental influences and herbicide action
- leaves at seedling stage are tender and succulent, lack cutin & waxes allowing easy penetration of herbicides
- roots have thin epidermal walls making herbicide absorption more efficient
- highly demand for nutrients and water

Factors affecting weed seedling growth and development

1. Soil factors
✓ ***Nutrient level***
- seedling stage is characterized by a high demand for resources to sustain a rapid phase of growth
- weeds have shorter vegetative growth than crops, thus, rapid absorption of resources at the earliest vegetative phase of growth

✓ ***Salinity/acidity***

2. Availability of light
- affects both crop and weeds due to its influence on photosynthesis

3. Competitive power of weeds

Flowering and Seed Production

- large volume of seed production is due to early and prolonged reproductive development
- many weeds start flowering shortly after germination & continue flowering and producing seeds throughout the vegetative stage

Factors influencing flowering and seed production

a. Daylength
- not very pronounced in the Tropics than in the Sub-Tropical countries

b. Light intensity
- affects vegetative development

c. Nutritional status
- indirect effect on flowering and seed production through its effect on vegetative development
- may flower early under nutrient deficiency; will shift from vegetative to reproductive

d. Temperature
- most pronounced effects on species and ecotypes in the sub-temperate parts of the world

ASEXUAL REPRODUCTION

- reproduces through vegetative propagules
- if a weed reproduces asexually efficiently, sexual reproduction is of secondary importance

- Some weeds have more than one type of vegetative propagule
  ✓ *Cyperus rotundus* has tubers and bulbs
  ✓ *Paspalum distichum* has stolons and rhizomes

- Vegetative reproduction creates some of the most difficult weed management problems

- **Tubers of *Cyperus rotundus***
  - produced 3 weeks after shoot emergence
  - Estimated tuber production:
    ✓ 1500 tubers/m^2
    ✓ 3 to 7 million tubers/ha/season

Factors influencing asexual reproduction

1. Light
- affect photosynthesis, hence, vegetative and reproductive development

2. Tillage
- can favor or inhibit production of vegetative propagules

3. Soil texture
- affects the rate. depth and development of rhizomes and tubers but not the total number of propagules
- tubers are found in the upper soil if soil is heavy

4. Soil type
- is related to nutrient content. Weeds can grow on poor soils.

Factors affecting sprouting of vegetative propagules

- **Cultivation**
- can break tuber chains
- cut rhizomes and stolons into fragments
- desiccation of vegetative propagules by up turning the soil
- **Water management**
- changing from flooded to upland condition will interrupt normal sprouting and growth of propagules
- thorough land preparation can damage vegetative propagules; when combined with flooding may result in the decay of plant parts

UNIT III: CROP-WEED COMPETITION

Weed Competition

It is the demand of 2 or more organisms for a common resource that is in short supply in the environment where they exist.

Crop–Weed Interaction

a. Competition
- active acquisition of limited resources by an organism that result in a reduced supply and consequently reduced growth of other organisms.

b. Interference
- total adverse effect that plants exert on each other when growing in a common ecosystem
- combination of competition and other forms of interaction
- sum total of how weeds affect crops

Competition happens when:

1. When two or more plants demand for the same resources from the environment in excess of the immediate supply
2. Resources being shared are supplied in limited amounts
   Resources competed for:
   ✓ *Water*
   ✓ *Nutrients*
   ✓ *Space*
   ✓ *Light*
3. shading limits the amount of light available to crops
4. Weeds influence crop growth, resulting in decreased yield (especially if the weed is very competitive)

Types of Competition

a. Interspecific competition
- between plants of different species
- weeds vs crops, weed sp. 1 vs weed sp. 2

b. Intraspecific competition
- between plants of the same species
- individual plants of weed sp.1 or individual plants of crop 1

What makes weeds more competitive?

- rapid root growth and development
- rapid leaf production
- multiple shoot development
- extensive root system
- rapid reproduction
- dormancy of seeds and propagules
- higher water use efficiency
- Efficient fertilizer absorbers

Factors affecting degree of competition

a. Weed species
- similar morphology (rice vs grass weeds, vegetables vs broadleaves)

b. Density
- competition increases with number and size of weeds per unit area

c. Crop variety
- some varieties (some local varieties) are better competitors than others

d. Seeding methods
- crops given a head-start compete better (transplanted rice vs direct-seeded rice, closer vs wider spacing)

e. Time of weed competition

✓ time of crop and weed emergence (transplanting vs direct seeding)

✓ the critical period of competition is the time in which the crop is very sensitive to weed competition

✓ weeds should be removed before or during the critical period of competition.

Critical Period of competition for some economic crops

Crop	Maturity (days)	Critical Period of Competition (days)
Corn	120	49
Upland rice	120	40
Lowland rice	120	30-40
Onion	95	56
Peanut	105	42
Mungbean	60-65	21-35
Soybean	125	42

To reduce competition

- Provide enough of the resources being competed for
- Remove one of the competing individuals in this case, weeds: direct and indirect control methods
- Apply strategies that will weaken weeds or make weeds grow slower, but make crops grow faster: weed management strategies.

Other interference mechanism of weeds

Allelopathy

- refers to the beneficial or harmful effects of one plant on another plant from the release of biochemicals, known as allelochemicals, from plant parts by the following means: leaching, root exudation, volatilization, and residue decomposition (Fraenkel 1959; Stamp 2003).
- a form of plant interference that occurs when one plant interferes with the growth of another plant via a chemical inhibitor produced by the plant and secreted into the surrounding environment
- Etymology: from the Greek-derived words *allelo* & *pathy* which means "mutual harm" or "suffering") and was first used in 1937 by Austrian scientist Hans Molisch in the book *Der Einfluss einer Pflanze auf die andere*

Effects of allelopathy

- Inhibits germination and growth
- Destroys root cells and becomes less competitive

Chemical nature of allelochemicals

a. simple water - soluble organic acids, straight-chain alcohols, aliphatic aldehydes and ketones
b. simple unsaturated lactones
c. long-chain fatty acids and polyacetylenes
d. naphthoquinones, anthroquinones and complex quinines
e. simple phenols, benzoic acids and derivatives
f. cinnamic acid and derivatives
g. flavonoids
h. tannins
i. terpenoids and steroids
j. amino acids and polypeptides
k. alkaloids and cyanohydrins
l. sulphides and glucosides
m. purines and nucleotides

Allelopathic crops

Allelopathic plants	Affected Plants
Imperata cylindrica	Corn
Cyperus rotundus	Cucumber
Salvia leucophylla	Cabbage
Rottboella cochinchinensis	Cucumber and *Ipomoea triloba*
Barley	*Stellaria media*
Cucumber	*Panicum millaceum*

In the study conducted by Amba and Ahluwalia (2016) on the allelochemicals in rice, observations and significant findings were:

1. Allelochemicals are present commonly in almost all plants and any parts of the plants.
2. Plants respond to different stimuli through synthesis and release of the allelochemicals.
3. It can lengthen survival in a hostile environment and serve as defensive weapons to prevent damage and decay of reproductive organs.
4. It can be found in the rhizosphere and have been demonstrated to show allelopathic interactions between organisms through root-to-root contact.

Indicators of Competition

a. Critical Threshold Level (CTL)

- the economic threshold for weed control, or the so called "break-even point", is defined as level of weed infestation at which the cost of controlling the weeds is equal to the increase in crop value obtained as a result of controlling the weeds.

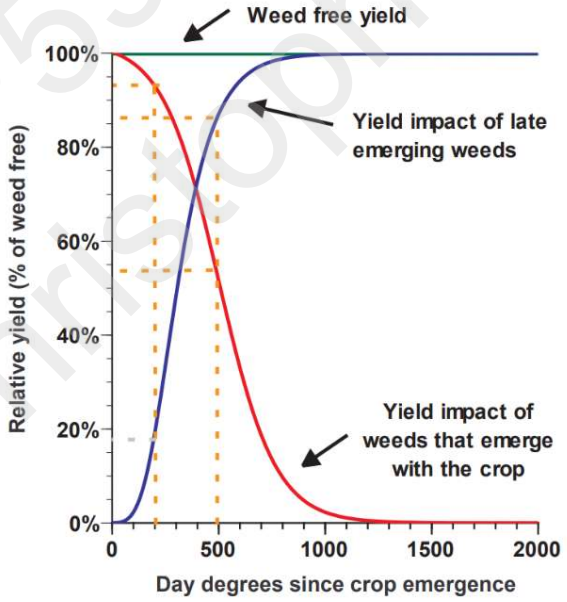
b. Critical Period of Competition (Critical Weed-Free Period Concept or Critical Period for Weed Control (CPWC))

- the minimum length of time during which the crop should be practically weed-free to avoid a yield reduction
- varies with crop, weed species, and the environment
- the critical period of weed competition is approximately 1/3rd of the duration of the crop.

To have a full grasp of CTL and CPWC, the following illustrations are shown below:

- ***Determining the Economic Threshold for Weed Control:*** The decision to control weeds is influenced by crop growth stage, the availability of suitable herbicides, labor and equipment, the weather, and financial aspects, and the cost of weed control. The actual level of the economic threshold (the critical number of weeds that triggers a grower to control a weed infestation) is a personal choice reflecting how much loss a grower is willing to tolerate before deciding to control the weed.

- ***Determining Yield Loss from Weeds***: To understand how weed(s) affects yield loss, try to understand the given figure:



Interpretation (refer to Figure 9):

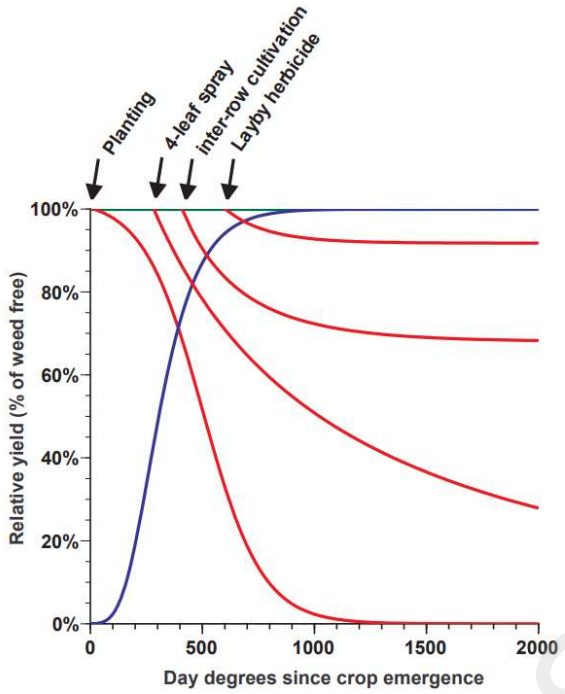
- ***Green line*** across the top is the yield if there were no weeds in the field (the weed free yield).
- ***Red line*** is the yield loss from a thorn apple infestation where the weeds emerged with the crop and were removed some time after emergence.
- ***Blue line*** is the yield loss from a thorn apple infestation where the weeds emerged after the crop and were not subsequently controlled.

Examples:

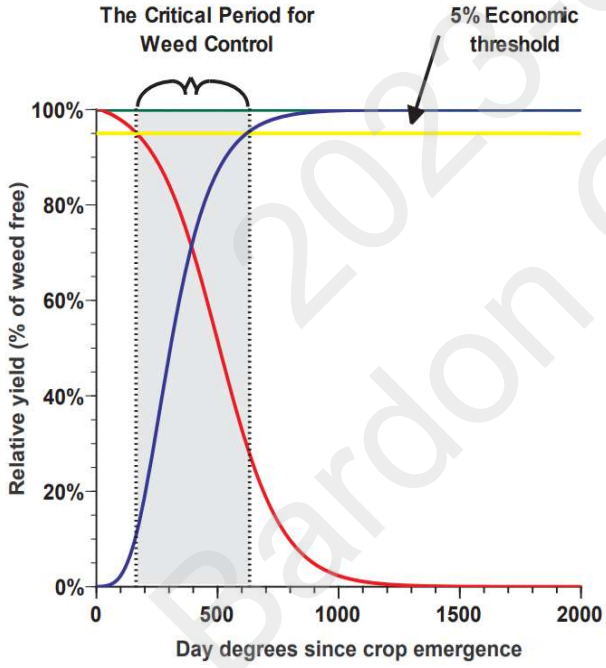
1. If the thorn apples were controlled at 200-day degrees, crop yield would be reduced to 93%, a 7% yield reduction (indicated by where the ***orange line*** at 200-day degrees hits the *red line*).
2. If the thorn apples were removed at 500-day degrees, the yield would be reduced to 54%, a 46% yield reduction (500-degrees days ***orange line***).
3. When thorn apples emerged at 200-day degrees and were not controlled, yield would be reduced to 18%, an 82% yield reduction (where the *orange line* at 200-day degree hits the *blue line*).

Impacts of Different Interventions on Yield Loss and Establishment of Critical Period for Weed Control

A



B



Impacts of different interventions employed in a field infested with thorn apples on the yield (A) and the establishment of critical period for weed control (B). Photo Courtesy of Charles, G., and Taylor, I. (2008).

- *Figure A* shows the different interventions that can be employed in a field and the possible shifting on the yield impact of thorn apples that emerge with the crop.
- *Figure B* shows the *critical period for weed control where it starts at the intersection of the first red line with the economic threshold (yellow line) and ends with the intersection of the blue line with the economic threshold*. The critical period for weed control is defined by the economic threshold chosen, the weed species and the weed density. In the given illustration above, the critical period for weed control for four (4) thorn apples per meter of cotton row is *166 to 621-day degrees at a 5% economic threshold*. *Thorn apples not controlled during this period will cause economic yield loss.*

Note:

A strength of the critical period for weed control concept is that it clearly defines the period during which weed control is required, and conversely, the periods during which weeds cause insufficient yield loss to justify their control.

Need to control weeds before 166-day degrees? By interpreting Figure 9B, there is no justification for controlling them before 166-day degrees of crop development.

Need to control weeds after 621-day degrees? **It** will not cause an economic yield loss (using a 5% yield loss threshold). However, they might still need to be controlled to avoid seed production, harvesting difficulties and thorn apple problems in later seasons.

Assumptions in using CPWC: Weeds are equally easily controlled at all growth stages, that the cotton grower has the capacity to control all weeds at the required time, and that the weeds have no negative impact except on crop yield.

It is very crucial in making decisions on the need for and timing of weed control and in achieving efficient herbicide use from both biological and economic perspectives.

UNIT IV: WEED MANAGEMENT

Introduction

Effective weed management practices are crucial when it comes to crop production. Like pests and diseases, weed infestations if not controlled properly could pose serious threats to crop growth, yield and even farmers economic returns.

These practices often allow the crop to utilize all available resources necessary to achieve its yield potential. Weeds require many of the same resources for growth as crop plants, and any resource utilized by the weed is unavailable for use by the crop. Thus, proper, and immediate interventions are important.

Goals

1. Reduce weed population to levels that will not result in significant yield reduction

2. Control measures must be directed to organs responsible for reproduction and spread of weeds.

3. Management practices must be started at the early stages of weed development and sustained until the crop is able to compete independently.

General Approaches

1. **Preventive/Protective:** preventing a weed from being introduced or invading an area

2. **Eradicative:** measures for its complete removal or elimination (vegetative parts and propagules) of a living weed species

3. **Control:** limit weed infestation and minimize competition; balance between cost of control and yield loss; used when problem already exists

4. **Management:** combination of the methods of prevention, control and eradication

PREVENTIVE METHODS

(legal and quarantine procedures, and others at the farm level)

Practices to prevent introduction and spread of weeds:

1. Buy and plant clean seed.
2. Isolation of introduced livestock to prevent spread of weed seeds from their digestive tract.
3. Use of clean farm equipment.
4. Cleaning irrigation water.
5. Mowing and appropriate weed control practices on irrigation ditch banks.
6. Inspection of imported nursery stock for weeds, seeds, and vegetative reproductive organs.
7. Inspection and cleaning of imported gravel, sand and soil.
8. Special attention must be paid to fence lines, right-of-way, railroads, etc. as sources of new weeds.
9. Prevent deterioration of range and pasture to stop easy entry of invaders

CONTROL METHODS

A. Physical / Mechanical weeding

- **Hand weeding**
- **Hand Hoeing**
- **Tillage**
- **Mowing**
- **Soil solarization**
  - also called solar heating, plastic mulching, or soil tarping
  - an approach for thermal weed suppression
- **Steam**
  - (heated water vapor) has been used to sterilize greenhouse and nursery soil for many years.
  - The amount of steam applied, the speed of application, the weed species, and their growth stage at application determined steam's effectiveness.
- **Flame weeding**
  - Pulses of heat or flames are directed on weeds in the field

• Mulching

- Excludes light and prevents shoot growth of weeds
- Increase soil temperature and may promote better plant growth
- Several different materials have been used for mulch, including straw, hay, manure and black plastic

B. Cultural methods

• Crop Rotation

- the unstable environment created by variation of the cropping sequence helps to prevent the annual recurrence of conditions that favor a particular weed
- changing or rotating the crops planted result in breaking the crop-weed association as cultural practices associated with growing the crop changes

• Planting date and density

- adjusting the planting date to coincide with low weed emergence, thus crops are provided ample time to establish first

• Intercropping

• Nutrient management

- focuses on the timing of nutrient application and placement
- The idea is to have the nutrients applied absorbed by the crop and not by the weeds

C. Biological Control

- Use of living organisms to manage weed populations
- classical methods through the introduction of exotic natural enemies and increasing the population of already existing natural enemies

• **Devine (Abott Laboratories)**

- liquid formulation of chlamydospores of *Phythopthora palmivora* and it is used for the control of milkweed *(Morrenia odorata)*

• **Collego (Upjohn Company)**

- wettable powder formulation of dried spores of *Colletotrichum gloeosporioides* f.sp.

D. Chemical methods (use of herbicides)

Herbicides

- *herba* = "plant," *caedere* = "to kill."
- synthetic chemicals that affects plant processes

For the herbicides to be effective:

1. It must adequately contact the plant
2. It must be absorbed and translocated to the site of action without being deactivated
3. accumulate to reach toxic levels in the site of action
4. Then, the herbicide should bind to the target protein and inhibit the activity of the target protein
5. Finally, it must exert its oxidative damages to the cell and insinuate plant death

Some commonly used herbicides

Herbicide	Trade name	Target weed
2,4-D	Hedonal	Broadleaves
Paraquat	Gramoxone	Grasses, sedges, broadleaves
Butachlor	Machete	Grasses
Glyphosate	Roundup	Grasses, sedges, Broadleaves
Fenoxaprop	Whip	Grasses
Atrazine	Gesaprim	Grasses, Broadleaves
Fluazifopbutyl	Onecide	Grasses

Formulation and State of Application

• ***Dry*** (dust, granules, or pellets)
• ***Liquid*** (suspension concentrate, wettable powder, emulsifiable concentrate,)
• ***Vapor form***

Spray Supplements

- **Dispersing agents:** operate at the spray-tank level
- **Spreading agents:** reduce surface tension; increase contact between spray droplets and sprayed surface
- **Sticking agents:** improves the adhesion of spray droplets/deposits

- **Humectants:** are defined as materials that increase the water content and slow the drying time of spray deposits.
- **Synergists: enhances** the effectiveness of an active agent which usually acts at the biochemical level.

Herbicide Classifications

A. Time of Application

- **Preplant**: applied before the crop is planted which is usually after land preparation.
- **Pre-emergence:** applied before the crop and weed emerge
- **Post-emergence**: applied after the crop and weed emerge
- **Post-directed:** applied emergence but directed only to the weeds

B. Selectivity

- **Selective**: involves destruction of weeds without damage to crops
- **Non-Selective**: general weed killers

C. Mode of action (effect on plant growth)

- Lipid synthesis inhibitors
- Amino acid synthesis inhibitors
- Plant growth regulators
- Photosynthesis inhibitors
- Nitrogen-metabolism inhibitors
- Pigment inhibitors
- Cell-membrane disruptors
- Seedling root growth inhibitors
- Seedling shoot growth inhibitors

D. Mobility in plants

- **Contact**: applied to foliage and kills only the plant part(s) that are very close to the site of application (generally most effective against broadleaves and seedlings of perennials)

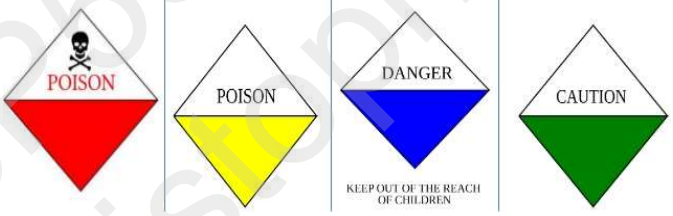
- **Systemic**: capable of movement within the plant to exert herbicidal effect away from the site of application

Herbicide groupings
(please refer to Appendix Table 1)

Herbicide Toxicity
– the level of toxicity to humans and possible impact to the environment

Categories of Herbicide Toxicity.
(Category I-IV from left to right)

Extremely toxic	Highly toxic	Moderately toxic	Less toxic
Colour:- Red	Colour:-Yellow	Colour:- Blue	Colour:- Green
Toxicity:- Skull & Pioson	Toxicity:- Pioson	Toxicity:- Danger	Toxicity:- Caution
Oral LD50 :- 1-50	Oral LD50 - 51-500	Oral LD50 - 501-5000	Oral LD50 - >5000
DermalLD50 :- 1-200	DermalLD50 - 201-2000	DermalLD50 - 2001-20,000	DermalLD50 - >20,000



Herbicide applications in the field:

- knapsack sprayer,
- tractor-power sprayer
- aerial sprayer
- drone technology

Negative impacts of increasing herbicide applications

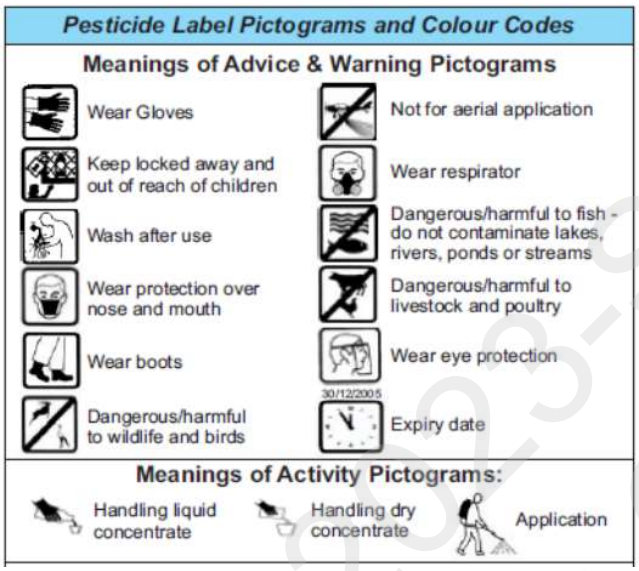
- Environmental degradation - groundwater contamination - residue
- Weed shift and succession
- Development of herbicide resistance in weed populations

Safety precautions in using herbicides

✓ Stick to the label
✓ Stick to the proper recommendations
✓ Safety gears

- **Always wear protective equipment**
  - Use appropriate cover for head, eyes, nose, mouth and hands
  - Wear long-sleeved shirts, long pants, and covered footwear
- **When mixing chemicals:**
  - always stand upwind and wear protective clothing, especially face protection
- **Wash contaminated clothes separately**
- **Clean blocked nozzles with a non-abrasive implement**
  - Never use your mouth to clean nozzles
- **Clean containers properly**

Pesticide label (Pictograms)



Source: FAO-UN. (2015). Guidelines on Good Labelling Practice for Pesticides (Revised).

International Code of Conduct on Pesticide Management. Rome.

(a) Purpose of Labelling: The purpose of the label is to provide the user with all the essential information about the product and how to use it safely and effectively.

According to FAO, the exact content is subject primarily to national regulations, harmonized as much as possible with international systems such as the *Globally harmonized system of classification and labelling of chemicals* (GHS) or the *WHO Recommended Classification of Pesticides by Hazard*, and the *Code of Conduct*.

Recommended Minimum Information on the Label (FAO-UN, 2015):

- Content of the container
- Acute and chronic hazard it represents and associated safety information
- Directions for use and disposal
- Supplier identification
- Clear indication on the label to read the safety instructions and directions for use before using the pesticide.
  e.g., the text: READ THE LABEL BEFORE USE or READ ALL SAFETY PRECAUTIONS AND DIRECTIONS FOR USE BEFORE USE

Product Content Information

- Product name
- Product category (e.g., herbicide, insecticide, fungicide, etc.)
- Type of formulation
- Active ingredient name
- Active ingredient content
- Name/identity and concentration of hazardous co-formulants
- Net contents of the pack
- Batch number
- Registration number

Hazard and Safety Information

- Hazard Symbol
- Signal Word
- Hazard Statement
- Precautionary Statement or Warnings
- Precautionary Pictograms
- Hazard Color Band
- First aid and medical advice
- Accidental spills advice

Directions for use

(1) Field of use
(2) Directions for use
(3) Storage and Disposal

Supplier Identification

Herbicide Resistance Management

• herbicides must be rotated so that the same herbicide is not used year after year
• implement crop rotation
  – allows for using different herbicides on different weeds in the different crops that are planted; herbicides with different modes of action can be utilized
• never make unregistered mixtures
  – stick to label recommendations at all times
• keep records of herbicides used and also the rates at which the herbicides were applied
• regularly monitor crops so that resistant patches of weeds can be observed in time
• apply the herbicides at the correct leaf stage of the weed and the crop
• ensure that the correct rate is always used because too high or too low can select for herbicide resistance
• ensure that the herbicide is properly applied, *i.e., correct calibration*
• always follow the instructions on the label
• combine different methods of control

UNIT V: SPRAYER SYSTEM

Important Parts of a Spray System (Adalla *et al.*, 2006)

a. **Tank:** a leak-proof storage of the spray material
b. **Pump:** develops the pressure which forces the liquid materials out of the tank
c. Pressure regulator: maintains pressure at the desired level
d. **Pressure gauge:** indicates pressure and at the same time tells if the other
e. **Boom:** distributes the spray solution to nozzles
f. **Nozzle:** breaks the liquid into spray droplets
g. **Strainer/filter:** keeps the larger particles from going to the pump or prevents foreign matter or dirt from clogging the nozzles

Types of Sprayer (Adalla *et al.*, 2006)

A. B. C.

The typical illustration of A) compressed air sprayer, B) knapsack sprayer, and C) tractor-mounted sprayer.

The type of sprayer used for a particular operation usually depends upon the type of job to be performed, area involved, and kind of crop.

a. Compressed air sprayer
- Useful for spot or small area
- Very simple to operate
- *Essential Parts:* spray tank, plunger-type pump, dip tube, spray hose, extension spray tube (lance), cut-off valve and nozzle.
- *Capacity:* 7.5 to 15 liters and pressure up to 50 pounds per square inches (psa).

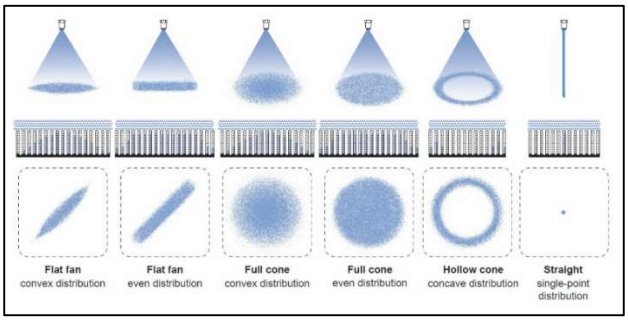
b. Knapsack sprayer
- Usually carried on the back by means of shoulder straps
- Operated by a hand lever which may be situated at the bottom of the sprayer
- A variety of nozzles can be used with these sprayers
- Helpful for boom spraying (series of four nozzles or more are operating at the same time)

c. Tractor-power sprayer or Tractor-mounted Sprayer
- Sprayer is mounted on the tractors
- The system place a limit of about 100 gallons on the tank capacity
- When larger capacities are required, the machine is trailed, or saddle tank is mounted on either side of the tractor.

Nozzle Type and Spray Pattern

Spray pattern

- refers to a cross-section of the main body of sprayed fluid as it disperses
- nozzle users themselves must choose a spray pattern that will suit their application or purpose
- a nozzle manufacturer's advice may be sought to aid in decision-making



Spray pattern for a given type of nozzle.

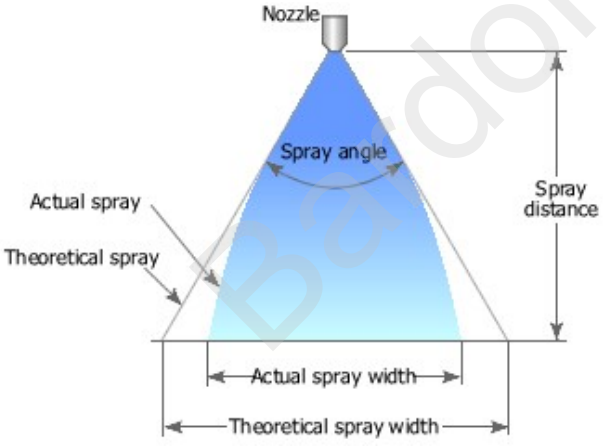
Spray angle and spray width

Spray angle

- refers to the angle at which the sprayed fluid fans out from the nozzle

Spray width

- represents the width/diameter to which the sprayed fluid has fanned out at a pre-determined distance from the orifice.



Comparison of the actual and theoretical spray width.

Important Note: When a nozzle is positioned to spray downwards, the spray width tapers off as the distance from the orifice increases. Therefore, the theoretical spray width that may be obtained based on the spray angle value given for a nozzle in the manufacturer's catalog may not match the actual spray width (Figure 14).

Calibration

Rationale: Calibration is defined as the process of determining the amount of spray solution delivered by a specific equipment. Aside from that, it can help prevent crop damage from pesticides, high pesticide residues, and environmental contamination. Proper calibration will also minimize, if not eliminate, left-over mixed pesticides in the sprayer tank which can be very difficult to properly dispose of.

Steps in Calibrating Sprayer System (Adopted from GE Reviewer, 2017)

1. Check the integrity of the sprayer (check for any leaks).
2. Look for an area in the field that will serve as "test area".
3. Place a known amount of water into the sprayer tank.
4. Established the spray swath.
5. Enter the test area and make a test run by spraying the area at the recommended pressure and speed.
6. After spraying the test area, measure the length of the test area sprayed.
7. Calculate the application rate in liters per hectare.
8. Calculate the amount of pesticide needed in each sprayer load

Sample Calculations

Sample Problem 1

Kween Yasmin has setup a 1000 L sprayer to spray potatoes with a fungicide at the recommended rate of 2.5 kg/ha in 500 L/ha of water to control late blight. The sprayer boom uses nozzles spaced at 30 cm and covers 6 rows spaced at 90 cm apart. After spraying a 100 m test strip with four runs, 105 L of water were required to refill the tank.

a. Calculate the sprayer swath width.

= Row crop swath width = 6 rows × 90 cm = 5.40 m
Note: row width = 90 cm = 0.90 m

b. Calculate the delivery rate (in liters per hectare) of the sprayer.
= 100 m (test area) × 5.4 m × 4 runs = 2160 m^2
= Delivery rate = 105 L ÷ 2160 m^2 × 10,000 m^2/ha = 486.11 L/ha

The sprayer is operating at a delivery rate of 486.11 L/ha. The delivery rate is close enough to the desired spray volume of 500 L/ha. Use the delivery rate of 486.11 L/ha when calculating how much pesticide to add to the tank.

c. Calculate the hectares covered with one full tank of spray.
= Area = 1000 L ÷ 486.11 L/ha = 2.06 ha
Thus, one full tank of spray will cover 2.06 hectares

b. Calculate the pesticide must be added to a full tank of water.
= 2.5 kg/ha × 2.06 ha = 5.15 L

Add 5.15 L of pesticide to make one full sprayer tank of spray mixture.

Try to answer the following problems:

1. Jihyo has set-up a 1200 L sprayer to spray broccoli with a pesticide to control aphids at the label rate of 440 L/ha. Jihyo chooses an approximate 400 L/ha delivery rate for thorough coverage. The broccoli is planted in beds 72 cm wide (72 cm. center to center of wheel tracks). There are three rows of broccoli planted in the bed and have grown a full leaf canopy filling the bed. The sprayer has nozzles spaced 12 cm apart covering 5 beds. After spraying a 330 m test strip with two passes (to discharge enough water from the spray tank to accurately measure it), 130 L of water were required to refill the tank.
2. To demonstrate the importance of pesticide calculations, Gojo conducted an experiment in an area of 50 square meters. He recorded the length of time needed to spray the said area maintaining a constant forward walking speed and pressure. The recorded average time was 1.14 mins. The sprayer boom uses nozzles spaced at 15 cm and covers 5 rows spaced at 100 cm apart. The amount of spray liquid discharged from the nozzles at the time to spray the area was 695 ml after making three runs. Using the given data in the experiment, calculate the volume of spray solution delivered per hectare.

Sample Problem 2

Tiger has a 10-liter sprayer, and you are task to apply 320 liters of spray solution per hectare. In addition, you are also instructed to apply 0.5 kg A.I. of herbicide per hectare and the formulated pesticide is 25 EC.

a. Calculate the number of sprayer loads needed per hectare.

Number of Sprayer Loads = (liters of spray solution per hectare) / (sprayer capacity in liters)
= (320 L)/(10L) = 32 sprayer loads

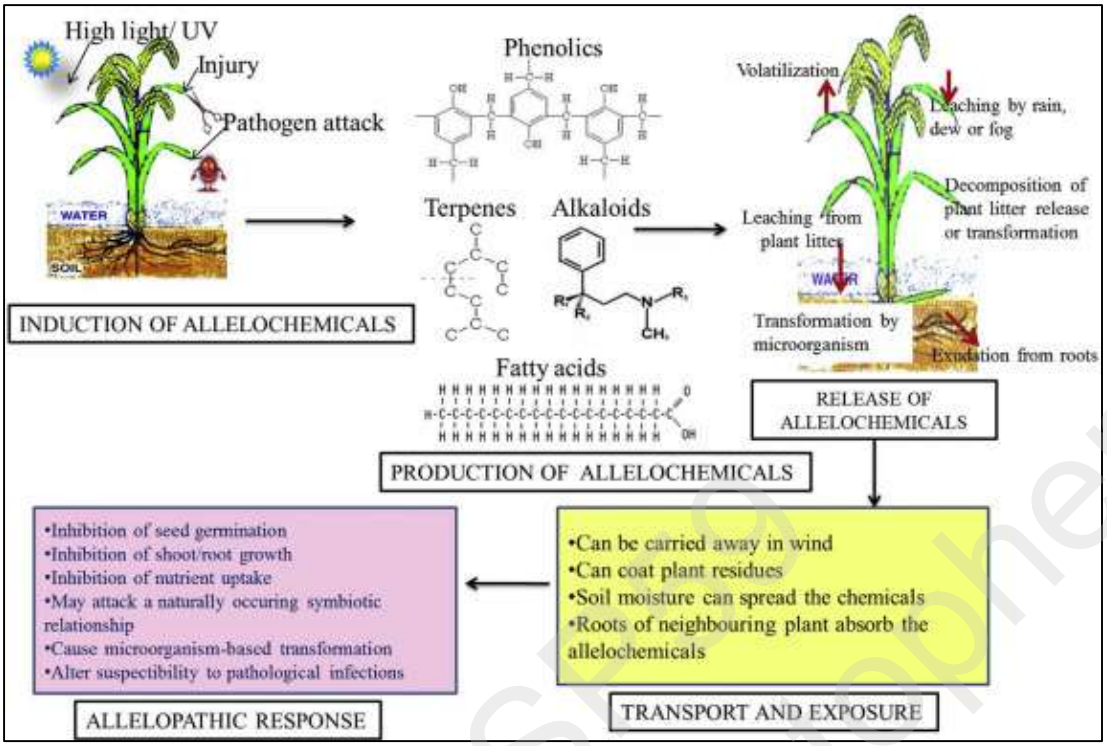
b. Calculate the amount of commercial formulation to be applied per hectare.

Amount of Commercial Formulation = (rate in kg/ha) / (% A.I. in the formulation)
= (0.5 kg)/ (0.25) = 2 kg/ha

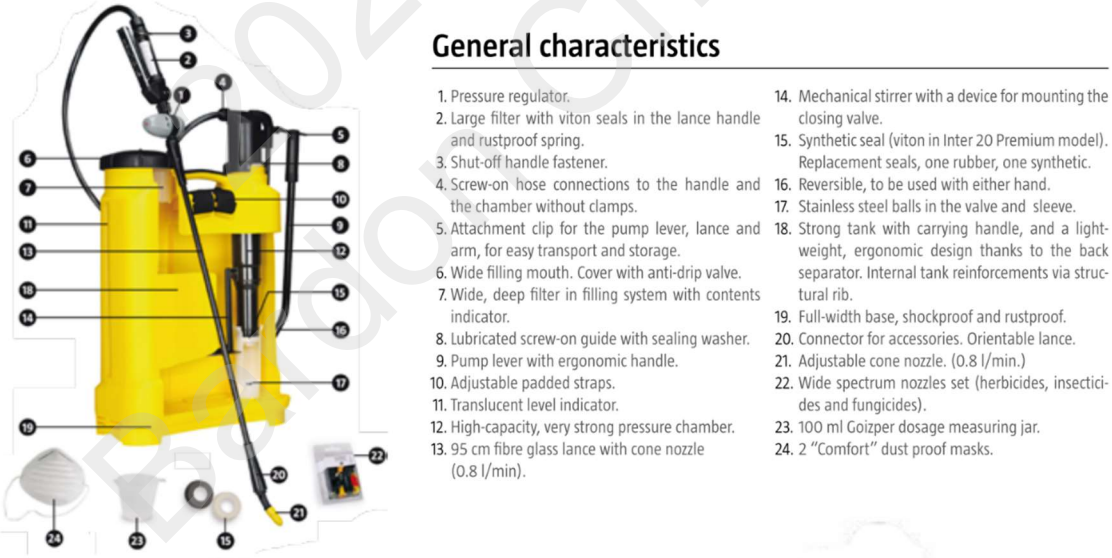
c. Calculate the amount of commercial formulation per sprayer load.

Amount of commercial formulation per sprayer load = (amount of commercial formulation per hectare)/ (number of sprayer loads)
= (2kg)/ (31) = 0.0625 kg of the commercial pesticide formulation per sprayer load

APPENDICES



Induction, production, release and transport of allelochemicals and their effects. Lifted from the study of M. K. Amba., and S. Ahluwalia (2016).



General characteristics

1. Pressure regulator.
2. Large filter with viton seals in the lance handle and rustproof spring.
3. Shut-off handle fastener.
4. Screw-on hose connections to the handle and the chamber without clamps.
5. Attachment clip for the pump lever, lance and arm, for easy transport and storage.
6. Wide filling mouth. Cover with anti-drip valve.
7. Wide, deep filter in filling system with contents indicator.
8. Lubricated screw-on guide with sealing washer.
9. Pump lever with ergonomic handle.
10. Adjustable padded straps.
11. Translucent level indicator.
12. High-capacity, very strong pressure chamber.
13. 95 cm fibre glass lance with cone nozzle (0.8 l/min).
14. Mechanical stirrer with a device for mounting the closing valve.
15. Synthetic seal (viton in Inter 20 Premium model). Replacement seals, one rubber, one synthetic.
16. Reversible, to be used with either hand.
17. Stainless steel balls in the valve and sleeve.
18. Strong tank with carrying handle, and a lightweight, ergonomic design thanks to the back separator. Internal tank reinforcements via structural rib.
19. Full-width base, shockproof and rustproof.
20. Connector for accessories. Orientable lance.
21. Adjustable cone nozzle. (0.8 l/min.)
22. Wide spectrum nozzles set (herbicides, insecticides and fungicides).
23. 100 ml Goizper dosage measuring jar.
24. 2 "Comfort" dust proof masks.

The typical 16-liters Knapsack Sprayer System of Inter by Goizper Group.

(Important Note: This is not the STANDARD knapsack sprayer recommended for all type of farms. Knapsack sprayer usually comes with different capacities (12, 16 and 20L sprayer system) depending on the needs of farm, area, and crops planted. This is for ILLUSTRATION PURPOSES ONLY.)

Herbicide Groupings and Site of Action Classification List.

Herbicide Groupings and Site of Action Classification List			
Group/Class	**Site of Action**	**Herbicide**	**Chemical Family**
1[(A)]	Acetyl CoA Carboxylase (ACCase) Inhibitor	alloxydim	Cyclohexanedione ('DIMs')
		butroxydim	Cyclohexanedione ('DIMs')
		clethodim	Cyclohexanedione ('DIMs')
		clodinafop-propargyl	Aryloxyphenoxy-propionate ('FOPs')
		cycloxydim	Cyclohexanedione ('DIMs')
		cyhalofop-butyl	Aryloxyphenoxy-propionate ('FOPs')
		diclofop	Aryloxyphenoxy-propionate ('FOPs')
		fenoxaprop-P	Aryloxyphenoxy-propionate ('FOPs')
		fluazifop-P	Aryloxyphenoxy-propionate ('FOPs')
		haloxyfop	Aryloxyphenoxy-propionate ('FOPs')
		metamifop	Aryloxyphenoxy-propionate ('FOPs')
		pinoxaden	Phenylpyrazoline ('DEN')
		propaquizafop	Aryloxyphenoxy-propionate ('FOPs')
		quizalofop-P	Aryloxyphenoxy-propionate ('FOPs')
		sethoxydim	Cyclohexanedione ('DIMs')
		tepraloxydim	Cyclohexanedione ('DIMs')
		tralkoxydim	Cyclohexanedione ('DIMs')
2[(B)]	Acetolactate Synthase (ALS) or Acetohydroxy Acid Synthase (AHAS) inhibitor	amidosulfuron	Sulfonylurea
		azimsulfuron	Sulfonylurea
		bensulfuron-methyl	Sulfonylurea
		bispyribac-sodium	Pyrimidinyl(thio)benzoate
		chlorimuron-ethyl	Sulfonylurea
		chlorsulfuron	Sulfonylurea
		cinosulfuron	Sulfonylurea
		cloransulam-methyl	Triazolopyrimidine
		cyclosulfamuron	Sulfonylurea
		diclosulam	Triazolopyrimidine
		ethametsulfuron-methyl	Sulfonylurea
		ethoxysulfuron	Sulfonylurea

		flazasulfuron	Sulfonylurea
		florasulam	Triazolopyrimidine
		flucarbazone-sodium	Sulfonylaminocarbonyl-triazolinone
		flucetosulfuron	Sulfonylurea
		flumetsulam	Triazolopyrimidine
		flupyrsulfuron-methyl-sodium	Sulfonylurea
		foramsulfuron	Sulfonylurea
		halosulfuron-methyl	Sulfonylurea
		imazamethabenz methyl	Imidazolinone
		imazamox	Imidazolinone
		imazapic	Imidazolinone
		imazapyr	Imidazolinone
		imazaquin	Imidazolinone
		imazethapyr	Imidazolinone
		imazosulfuron	Sulfonylurea
		iodosulfuron	Sulfonylurea
		mesosulfuron	Sulfonylurea
		metazosulfuron	Sulfonylurea
		metsulfuron-methyl	Sulfonylurea
		nicosulfuron	Sulfonylurea
		penoxsulam	Triazolopyrimidine
		primisulfuron-methyl	Sulfonylurea
		propoxycarbazone-sodium	Sulfonylaminocarbonyl-triazolinone
		prosulfuron	Sulfonylurea
		pyrazosulfuron-ethyl	Sulfonylurea
		pyribenzoxim	Pyrimidinyl(thio)benzoate
		pyrimisulfan	Pyrimidinyl(thio)benzoate
		pyrithiobac-sodium	Pyrimidinyl(thio)benzoate
		pyroxsulam	Triazolopyrimidine
		rimsulfuron	Sulfonylurea
		sulfometuron-methyl	Sulfonylurea
		sulfosulfuron	Sulfonylurea
		thiencarbazone-methyl	Sulfonylaminocarbonyl-triazolinone
		thifensulfuron-methyl	Sulfonylurea

		triasulfuron	Sulfonylurea
		tribenuron-methyl	Sulfonylurea
		trifloxysulfuron	Sulfonylurea
		triflusulfuron-methyl	Sulfonylurea
$3^{(K1)}$	Inhibitor of microtubule assembly	benefin	Dinitroaniline
		trifluralin	Dinitroaniline
		DCPA	Benzoic acid
		dithiopyr	Pyridine
		ethalfluralin	Dinitroaniline
		oryzalin	Dinitroaniline
		pendimethalin	Dinitroaniline
		prodiamine	Dinitroaniline
		pronamide	Benzamide
		thiazopyr	Pyridine
$4^{(O)}$	Synthetic Auxin	2,4-D	Phenoxy-carboxylic-acid
		2,4-DB	Phenoxy-carboxylic-acid
		aminocyclopyrachlor	Pyrimidine-carboxylic-acid
		aminopyralid	Pyridine carboxylic acid
		clopyralid	Pyridine carboxylic acid
		dicamba	Benzoic acid
		dichlorprop	Phenoxy-carboxylic-acid
		florpyrauxifen	Pyridine carboxylic acid
		fluroxypyr	Pyridine carboxylic acid
		halauxifen methyl	-
		MCPA	Phenoxy-carboxylic-acid
		MCPB	Phenoxy-carboxylic-acid
		mecoprop	Phenoxy-carboxylic-acid
		picloram	Pyridine carboxylic acid
		quinclorac	Quinoline carboxylic acid
		triclopyr	Pyridine carboxylic acid
$5^{(C1)}$	Inhibitor of photosynthesis at photosystem II site A	ametryn	Triazine
		amicarbazone	Triazolinone
		atrazine	Triazine
		bromacil	Uracil
		cyanazine	Triazine
		desmedipham	Phenyl-carbamate

		desmetryn	Triazine
		hexazione	Triazinone
		metamitron	Triazinone
		metoxuron	Urea
		metribuzin	Triazinone
		phenmedipham	Phenyl-carbamate
		prometon	Triazine
		prometryn	Triazine
		propazine	Triazine
		pyrazon	Pyridazinone
		simazine	Triazine
		simetryn	Triazine
		terbacil	Uracil
		terbumeton	Triazine
$6^{(C3)}$	Inhibitor of photosynthesis at photosystem II site B	bentazon	Benzothiadiazinone
		bromoxynil	Nitrile
		ioxynil	Nitrile
		pyridate	Phenyl-pyridazine
$7^{(C2)}$	Inhibitor of photosynthesis at photosystem II site A; different behavior from group 5	chlorotoluron	Urea
		dimefuron	Urea
		diuron	Urea
		fluometuron	Urea
		isoproturon	Urea
		linuron	Urea
		methibenzuron	Urea
		monolinuron	Urea
		propanil	Amide
		siduron	Urea
		tebuthiuron	Urea
$8^{(N)}$	Inhibitor of lipid synthesis; not ACCase inhibition	bensulide	Phosphorodithioate
		butylate	Thiocarbamate
		cycloate	Thiocarbamate
		EPTC	Thiocarbamate
		esprocarb	Thiocarbamate
		ethofumesate	Benzofuran
		molinate	Thiocarbamate

		pebulate	Thiocarbamate
		prosulfocarb	Thiocarbamate
		thiobencarb	Thiocarbamate
		triallate	Thiocarbamate
		vernolate	Thiocarbamate
9[G]	Inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	glyphosate	Glycine
10[H]	Inhibitor of glutamine synthetase	glufosinate	Phosphinic acid
11[F3]	Inhibitor of carotenoid biosynthesis (unknown target)	aclonifen	Diphenylether
		amitrole	Triazole
12[F1]	Inhibitor of phytoene desaturase (PDS)	beflubutamid	-
		diflufenican	Pyridinecarboxamide
		fluridone	-
		flurochloridone	-
		flurtamone	
		norflurazon	Pyridazinone
		picolinafen	Pyridinecarboxamide
13[F3]	Inhibitor of 1-deoxy-D-xyulose 5-phosphate sunthatase (DOXP synthase)	clomazone	Isoxazolidinone
14[E]	Inhibitor of protoporphyrinogen oxidase (Protox, PPO)	aclifluorfen	Diphenylether
		azafenidin	Triazolinone
		bifenox	Diphenylether
		butafenacil	Pyrimidinedione
		carfentrazone-ethyl	Triazolinone
		flufenpyr-ethyl	-
		flumiclorac	N-phenylphthalimide
		flumioxazin	N-phenylphthalimide
		fluoroglycofen	Diphenylether
		fluthiacet-methyl	Thiadiazole
		fomesafen	Diphenylether
		lactofen	Diphenylether
		oxadiargyl	Oxadiazole
		oxadiazon	Oxadiazole
		oxyfluorfen	Diphenylether

		pyraclonil	-
		pyraflufen-ethyl	Phenylpyrazole
		saflufenacil	Pyrimidinedione
		sulfentrazone	Triazolinone
		trifludimoxazin	N-Phenyl-imide
15$^{(K3)}$	Mitosis Inhibitor	acetochlor	Chloroacetamide
		alachlor	Chloroacetamide
		anilofos	-
		butachlor	Chloroacetamide
		dimethenamid	Chloroacetamide
		fentrazamide	Tetrazolinone
		flufenacet	Oxyacetamide
		mefenacet	Oxyacetamide
		metazachlor	Chloroacetamide
		napropamide	Acetamide
		pretilachlor	Chloroacetamide
		propachlor	Chloroacetamide
		pyroxasulfone	Isoxazoline
18$^{(I)}$	Inhibitor of 7,8-dihydro-preroate synthetase (DHP)	asulam	Carbamate
19$^{(P)}$	Inhibitor of indoleacetic acid transport	diflufenzopyr	Phthalamate Semicarbazone
		naptalam	Phthalamate Semicarbazone
20$^{(L)}$	Inhibitor of cell wall synthesis site A	dichlobenil	Nitrile
21$^{(L)}$	Inhibitor of cell wall synthesis site B	isoxaben	Benzamide
22$^{(D)}$	Photosystem I electron diverter	diquat	Bipyridylium
		paraquat	Bipyridylium
23$^{(K2)}$	Inhibitor of mitosis	carbetamide	Carbamate
24$^{(M)}$	Membrane disruptor (uncouplers)	dinoterb	Dinitrophenol
26$^{(Z)}$	Unknown site of action	dazomet	-
		difenzoquat	Pyrazolium
		metham	-
		pelargonic acid	-
27$^{(F2)}$	Inhibitor of 4-hydroxyphenyl-	benzofenap	Pyrazole
		benzobicyclon	Benzoylbicyclooctanedione

	pyruvatedioxygenase (4-HPPD)	isoxaflutole	-
		mesotrione	Triketone
		pyrasulfotole	Pyrazole
		pyrazolynate	Pyrazole
		pyrazoxyfen	Pyrazole
		sulcotrione	Triketone
		tembotrione	Triketone
		topramezone	-
$28^{(Z)}$	Unknown site of action	DSMA	Organoarsenical
		fosamine	-
		MSMA	Organoarsenical
$29^{(L)}$	Inhibitor of cell wall synthesis site C	indaziflam	-
$30^{(R)}$	Tyrosine Aminotransferase	cinmethylin	-
		methiozolin	-
NC	Not Classified	acrolein	-
		AMS	-
		benazolin	-
		benoxacor	-
		cacodylic acid	-
		cloquintocet-mexyl	-
		copper chelate	-
		copper sulfate	-
		cyprosulfamide	-
		dichlormid	-
		dietholate	-
		dimethipin	-
		endothall	-
		fenchlorazole-ethyl	-
		fenclorim	-
		fluxofenim	-
		maleic hydrazide	-
		mefenpyr-diethyl	-
		mefluidide	-
		metaborate	-
		oxaziclomefone	-
		sodium chlorate	-

Source: Weed Science Society of America - Herbicide Site of Action (SOA) Classification List
Modified Last July 17, 2020

List of Major Weeds in the Philippines.

LOWLAND WEEDS				
Scientific name	**Common name**	**Mode of Reproduction**	**Life cycle**	**Morphology**
Cyperus iria	Rice flat sedge	Sexual	Annual	Sedge
Cyperus difformis	Flat flower umbrella plant	Sexual	Annual	Sedge
Echinochloa colona	Jungle rice	Sexual	Annual	Grass
Echinochloa crus-galli	Barnyard grass	Sexual	Annual	Grass
Echinochloa glaberescens	Barnyard grass	Sexual	Annual	Grass
Fimbristylis littoralis	Fimbristylis	Sexual	Annual	Grass
Ludwigia octovalvis	Water purslane	Sexual	Annual	Broadleaf
Monochoria vaginalis	Pickerel weed	Sexual	Annual	Broadleaf
Pistia stratiotes	Water lettuce	Asexual	Perennial	Broadleaf
Ischaemum rugosum	Saromatta grass	Sexual	Perennial	Grass
Bolboschoenus maritimus	Bulrush	Asexual	Perennial	Grass
Paspalum distichum	Knotgrass	Asexual	Perennial	Grass
Leptochloa chinensis	Sprangle top	Sexual	Annual	Grass
Sphenochlea zeylanica	Gooseweed	Sexual	Annual	Broadleaf

UPLAND WEEDS				
Scientific name	**Common name**	**Mode of Reproduction**	**Life cycle**	**Morphology**
Amaranthus spinosus	Spiny amaranth	Sexual	Annual	Broadleaf
Amaranthus viridis	Slender amaranth	Sexual	Annual	Broadleaf
Ageratum conyzoides	Tropic ageratum	Sexual	Annual	Broadleaf
Biden pilosa	Beggarsticks	Sexual	Annual	Broadleaf
Cynodon dactylon	Bermuda grass	Asexual	Perennial	Grass
Digitaria ciliaris	Crabgrass	Sexual	Annual	Grass
Euphorbia hirta	Garden spurge	Sexual	Annual	Broadleaf
Cleome rutidosperma	Spindle top	Sexual	Annual	Broadleaf
Commelina benghalensis	Dayflower	Asexual	Perennial	Broadleaf
Commelina diffusa	Spreading dayflower	Asexual	Perennial	Broadleaf
Rottboellia cochinchinensis	Itchgrass	Sexual	Annual	Grass
Paspalidium flavidum	Paspalidium	Sexual	Perennial	Grass
Echinochloa colona	Jungle rice	Sexual	Annual	Grass
Vernonia cinerea	Little Iron weed	Sexual	Annual	Broadleaf
Imperata cylindrica	Cogon	Asexual	Perennial	Grass
Cyperus rotundus	Purple nutsedge	Asexual	Perennial	Sedge
Eleusine indica	Goose grass	Sexual	Annual	Grass
Portulaca oleracea	Common purslane	Sexual	Annual	Broadleaf
Trianthema portulacastrum	Horse purslane	Sexual	Annual	Broadleaf
Lantana camara	Lantana	Asexual	Perennial	Broadleaf
Ipomoea triloba	Three-lobe morning glory	Sexual	Annual	Broadleaf
Mimosa pudica	Sensitive Plant	Asexual	Perennial	Broadleaf
Chromolaena odorata	Devilweed	Sexual	Perennial	Broadleaf

ENTOMOLOGY

branch of Zoology dealing with the **study of insects**

UNIT I: HISTORY OF PHILIPPINE ENTOMOLOGY

Spanish Period (1521 – 1899: 6th –19th Century)

1521
- Pigafetta recorded leaf insects in Palawan (**1st recorded insect in the Philippines**)

1569
- earliest recorded account of locust swarm in the Philippines (Panay Island)

1593
- sericulture and mulberry planting introduced by Fr. Antonio Sedeno

1780
- Augustinian Missionary **Father Manuel Galliana introduced sericulture** for the second time.

1826 & 1861
- cochineal insects were introduced but both attempts did not succeed

1831
- Hugh Cuming made a publication about Philippine Insects

1849
- Successful introduction of a starling, locally known as *"Martinez" Aetheopsar cristalellus* L. from Southern China to control locust

1895
- first comprehensive description on locust ecology by Francisco Alvarez

Early American Occupation (1900 – 1920)

1902
- Creation of Bureau of Agriculture to control migratory locust
- First Biocon (microbial agent: fungus) to control migratory locusts.
- **Charles S. Banks,** an American, first government entomologist in the Philippines and made publications in medical entomology and systematics

1908
- first extensive publication on mosquitoes of the Philippines by **C. Ludlow**

1909
- Department of Entomology establishment at UPCA; first headed by **E.M. Ledyard**

1910
- establishment of Entomology Section in the Bureau of Agriculture, Plant Industry Division

1911
- **F. Cevallos** worked on the use of chemicals (kerosene, Bordeaux mixture, emulsions, white arsenic, carbon disulphide and etc.) to control insect pests

1912
- **Charles F. Baker**
  - First UPCA Dean
  - spearheaded the first collection of insects of the Entomology Department
  - Collaborated with 115 world authorities which had resulted in the Publication of 400 papers on Philippine Insects

1913
- **Mitzmain** first established Veterinary Entomology in the Philippines. Discovered that surra disease in carabao is striated and transmitted by common housefly.
- **C.H Schultz** introduced beekeeping in the Philippine using Italian Honeybees

1915
- Locust Act No 2472 enacted

1916-1917
- Hymenoptera catalogue by Schultz

1921-1922
- the first comprehensive host-index of insect pests associated to Philippine Crops published by **H.E. Woodworth**

Rise of the Filipino Entomologists (1922 – 1940)

1922

- **Leopoldo B. Uichanco**
  - "*Father of Philippine Entomology*"
  - First to obtain doctoral degree (Harvard University).
  - First Filipino to describe insects (new species of Psyllids)
  - first Filipino MS in entomology UPCA (1918)
  - first instructor of the Entomology Dept, UPCA (1915)
- **Silverio M. Cendaña** reported about the biology of banana weevil, a serious pest of banana

1923

- The use of soap was found to be effective in the control of migratory locust especially the soft yellow soap

1924

- **Locust Scouting Act (Act 3163)** was passed by the Philippine Legislature which provided PhP100,000.00 to locate and fight locusts

1925

- Aerial spraying by means of airplane was first utilized to control migratory locust

1926

- **Gerardo O. Ocfemia** reported that bunchy top virus of abaca was transmitted by an aphid (*Pentalonia nigronervosa)*
- first report of insect transmission of a plant virus in the country
- **Castillo** discovered insecticidal properties of Derris plant

1927

- **Manalang** tested Paris green [copper (II) acetate + arsenic trioxide] as larvicide for mosquitoes

1929

- **C. Bulligan** studied the biology of corn borer (*Ostrinia furnacalis)*

1934

- **Cendaña** was the first to be trained on biological control of insects
- First report on mites of crop plants in the Philippines by **Fajardo** and **Bellosillo**

1941

- **Viado** considered as pioneer insecticide toxicologist in the Philippines

War Setback and Rebuilding (1941 – 1960)

1946

- DDT an organic insecticide was introduced to control houseflies and migratory locusts

1947

- **Clare R. Baltazar**
  - first postwar entomology graduate
  - first Filipina Entomologist who earned her degree as *Summa cum laude*
  - studied leafhopper of cotton with Cendaña, the first publication after the war

1954

- first studies conducted on plant resistance to insects by Cendaña using corn hybrid, and inbred strain against corn earworm and corn borer

Developments and Directions in the Sixties and Seventies (1961 –1979)

1960

- **Establishment of IRRI** - maintains an Entomology Department especially on the insect pest of rice

1961

- **L.C. Rimando**
  - first Filipino acarologist
  - spearheaded the study of mites in the Philippines
  - described two species of spider mites, *Aponychus corpuzae* (1966) and *A. vannus* (1968)

1962

- (July 22) was the founding of the **Philippine Entomological Society (PES)** now **Philippine Association of Entomologist, Inc. (PAE),** the first entomological organization with C.M. Cendaña as President.

1964

- **B.P. Gabriel,** first Filipino insect pathologist

1966
- C.R. Baltazar catalogued and published about Philippine Hymenoptera

1968
- PAE maintained a journal (The Philippine Entomologist) with L.C. Rimando as first editor

1976
- **F.F. Sanchez** founded the National Crop Protection Center who also served as the first director.

UNIT II: PRINCIPLES OF ENTOMOLOGY

Importance of Studying Insects

1. Vital to our survival on earth
2. Vectors of Various Pathogens
3. Agricultural and Urban Pests
4. Medical and Veterinary Importance
5. Used as Food
6. Source of Industrial and Chemical Products
7. Bio-indicators
8. Good Biological Models

Specialized Fields of Entomology

Insect morphology
- form and structure of insects

Insect physiology
- physical and chemical changes in an insect body

Insect taxonomy and systematics
- naming, classifying & study of insect diversity

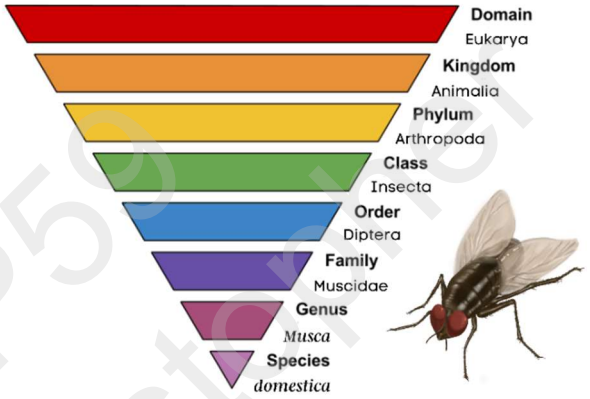
Insect ecology
- interrelationship of insects with environment

Insecticide toxicology
- how insecticides affect insects

Other fields:

- Biological Control
- Medical and Veterinary Entomology
- Insect Molecular Biology
- Insect Pathology and Microbiology
- Insect Transmission of Plant Pathogens
- Urban Pest Management
- Acarology

Taxonomy and Classification of Insects



- **Taxonomy**
  - study of nomenclature and classification through comparison of their morphological characteristics
- **Classification**
  - process of related categorization, in which ideas and objects are recognized, differentiated and understood; includes grouping and ranking
- **Nomenclature**
  - Applying distinctive names to every group that are recognized in the classification system
- **Identification**
  - applying deductive procedures to assign individuals into previously established classes using pertinent keys or literatures

INSECTS

classified under

Phylum Arthropoda: Class Insecta

Phylum Arthropoda
- "*arthron*" = joint, "*podos*" = foot
- Joint-footed animals

Characteristics of Arthropods

1. have jointed legs or appendages
2. segmented body that bears varying number of paired and segmented appendages
3. bilaterally symmetrical body
4. sclerotized exoskeleton that contains chitin (nitrogenous polysaccharide)
5. various internal features such as open circulatory system, Malpighian tubules and a system of ventilatory tubules, tracheoles and tracheae
6. exhibits tagmosis (division of the arthropod body plan into discrete regions/tagmata)

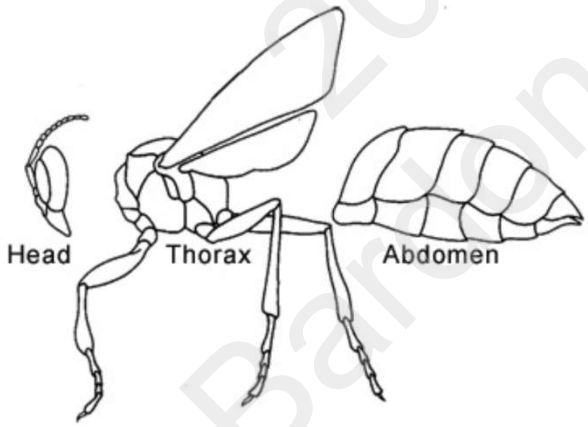
Class Insecta

- has several distinct traits

1. three well-defined body regions or tagmata, i.e., ***head***, ***thorax*** and ***abdomen***
2. three pairs of legs
3. a pair of segmented antennae on the head
4. 2 kinds of eyes (compound and simple)
5. one or two pairs of wings, if any

INSECT MORPHOLOGY

External Morphology



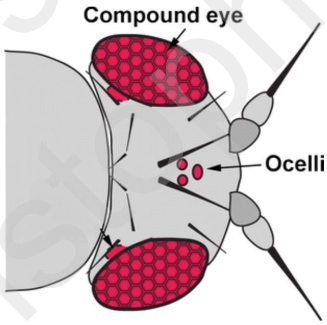
A. HEAD

- Anterior segment which bears the eyes, antennae and mouthparts
- for sensory input, communication and food intake

Insect Head Orientation

- **Prognathous**
  mouthparts projected forward; head horizontal
- **Hypognathous**
  mouthparts located ventrally; head vertical
- **Opisthognathous**
  mouthparts directed backwards

Insect Eyes



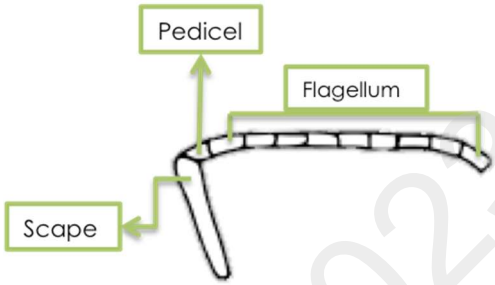
- **Simple eyes/ocelli (*sing. ocellus*)**
  - typically positioned in top of the insect head in a triangular or linear arrangement
  - number of ocelli present varies between 0-3
  - highly sensitive to changes in light intensity, hence, important for insects that are active during twilight or low-light conditions
  - Function: responsible for detecting changes in light intensity and direction; aids direction and stability of insects during flight

- **Compound eyes**
  - large, complex pair of structures composed of individual visual units called ommatidia
  - each ommatidium contains a lens/facet, photoreceptor cells and associated support cells
  - Function: provide insects with a wide field of vision, and detects movement, shapes and colors; essential for prey detection, navigation, and predator avoidance

Insect Antennae

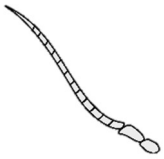
- pair of segmented appendages found in between or below the compound eyes
- serve as highly specialized sensory organs, detecting and interpreting environmental cues critical for communication, navigation, and survival
- outer surface may be smooth, hairy, or equipped with specialized structures such as sensilla
  - ***sensilla****:* tiny sensory organs responsible for detecting various environmental cues, including odors, vibrations, temperature, humidity, and even air currents
- can also play a role in courtship rituals, species recognition, and serve as organs for balance and orientation

a. Main segments



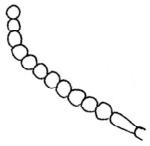
- **Scape**
  - first segment of the antenna, segment that is attached to the head
- **Pedicel**
  - second segment; responsible for movement of antennae in any direction in combination with the scape
- **Flagellum**
  - final segment; most variable in morphology among insects

b. Types of antennae



- **Filiform**
  - Latin: "*filum*" = thread
  - slender and thread-like in form
  - found in mantids, cockroaches and grasshoppers

- **Setaceous**
  - Latin: "*seta*" = bristle
  - have a bristle-like appearance
  - found in dragonflies, damselflies



- **Moniliform**
  - Latin: "*monile*" = necklace
  - appears like strings of beads
  - found in termites

- **Capitate**
  - Latin: "*caput*" = head
  - have prominent knob at its ends
  - found in butterflies and beetles

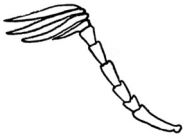
- **Clavate**
  - Latin: "*clava*" = club
  - terminates in a gradual club
  - found in butterflies

- **Flabellate**
  - Latin: "*flabellum*" = fan
  - similar to a folded paper fan
  - found in several insect groups (beetles, wasps, moths)

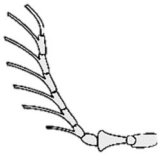
- **Geniculate**
  - Latin: "*genu*" = kneel
  - similar to a knee or elbow joint
  - found in ants, bees, and wasps

- **Plumose**
  - Latin: "*pluma*" = feather
  - have a feather-like appearance
  - found in mosquitoes and moths

- **Serrate**
  - Latin: "*serra*" = saw
  - have a saw-like appearance
  - found in pulse beetles

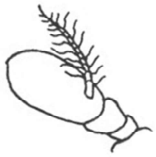


- **Lamellate**
  - Latin: "*lamella*" = thin plate
  - have flattened and nested tip segments
  - found in scarab beetles



- **Pectinate**
  - Latin: "*pectin*" = comb
  - have a comb-like appearance
  - found in cardinal beetles and sawflies

- **Bipectinate**
  - Latin: "*bi*" = two; "*pectin*" = comb
  - have comb-like branches or projections on both sides
  - found in moths



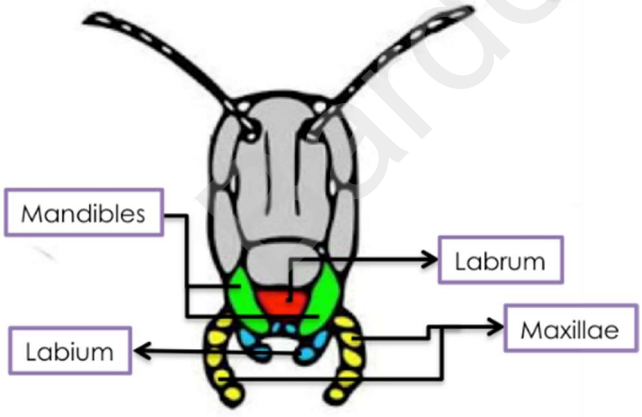
- **Aristate**
  - enlarged last segment with prominent dorsal bristle called *arista*
  - found in flies

- **Ensiform**
  - Latin: "*ensis*" = sword
  - broad at base, narrowing to tip
  - found in some grasshoppers

- **Stylate**
  - knife-like
  - terminal segment bears a style or finger-like process
  - found in robber flies & hoppers

Insect Mouthparts

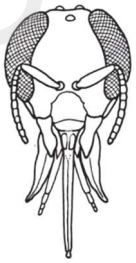
a. Main structures



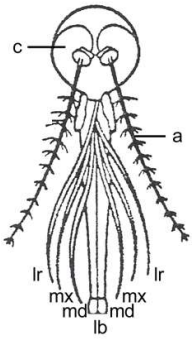
- **Labrum**
  - the "upper lip"
  - serves as a cover of the mouth
- **Mandibles**
  - hard, powerful tooth-like structures for tearing, grinding and chewing food
- **Maxilla**
  - the "pincers"
  - used to steady the food
  - has 5 segmented palpi which is sensory for taste
- **Hypopharynx**
  - the "central tongue"
  - Contains the opening of the salivary duct
- **Labium**
  - the "lower lip"
  - serves as the lower cover

b. Types of mouthparts

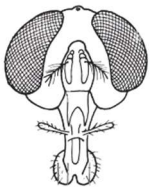
- **Chewing mouthparts** (majority of Insects)
  - most primitive type of mouth parts
  - with pair of heavily sclerotized mandibles used in grinding and cutting of solid food



- **Chewing-lapping** (honeybees)
  - Characterized by the presence of mandibles and proboscis
  - Mandibles act as "teeth" to chew, manipulate wax, clean other bees, bite pests
  - Proboscis is mainly used for sucking nectar, water, or for exchanging food with other bees (trophallaxis)

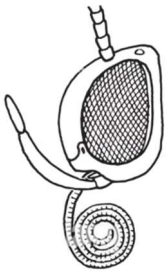


- **Piercing-sucking** (mosquitoes, true bugs)
  - characterized by the union of mandibles and maxillae into needle-like structure called "stylet"
  - enclosed by labium
  - the labrum acts like a tongue and is used to suck fluids from its host

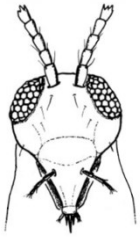


- **Sponging**
(flies)
  - portion of labellum terminates in a spongy pad
  - used to "slurp" food

- **Siphoning**
(butterflies and moths)



  - fusion of maxillary galeae resulted to a modified tube mouthpart called proboscis
  - used to suck up nectar and other fluids such as tears and blood
  - when not in use, proboscis coils up and held close to the underside of the head



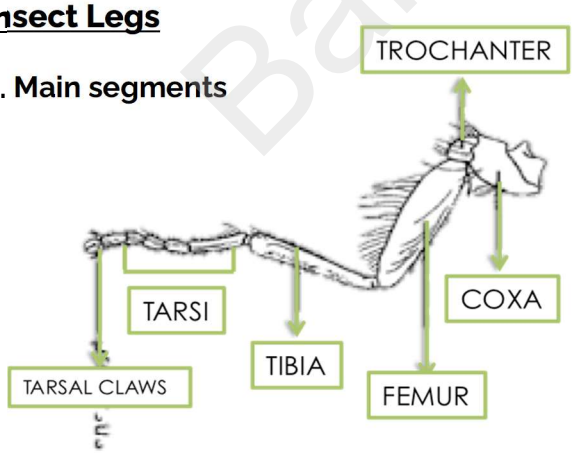
- **Rasping-sucking**
(thrips)
  - has cone-shaped, serrated beak used to scrape/rasp away plant tissues to access plant sap
  - uses its proboscis to suck on fluids

B. THORAX

- middle body region where appendages for locomotion are attached
- has 3 segments: prothorax, mesothorax and metathorax

Insect Legs

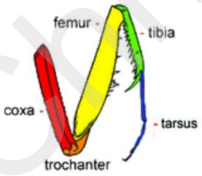
a. Main segments



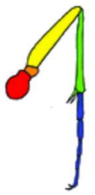
- **Coxa**
  - the proximal leg segment; freely moveable
- **Trochanter**
  - second leg segment; usually small and single segmented
- **Femur**
  - largest and stoutest segment
- **Tibia**
  - has downward projecting spines that aids in climbing and footing
- **Tarsi**
  - subdivided into "tarsomeres" which varies from one to five
  - basal tarsal segment is the largest and termed as "basitarsus"

b. Types of Insect Leg (modifications)

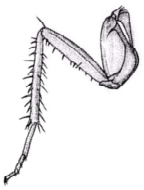
- insect legs are modified to several types and are based on the habitat, food habit, and variety of functions



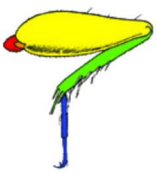
- **Raptorial legs**
  - legs for predation/ grasping
  - example: forelegs of preying mantis



- **Ambulatory/Gressorial legs**
  - legs for walking
  - long femur and tibia
  - example: foreleg and middle leg of grasshopper

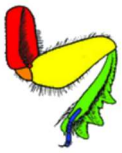


- **Cursorial legs**
  - legs for running
  - example: all legs of tiger beetles and cockroaches

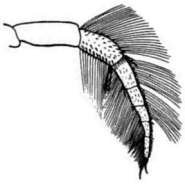


- **Saltatorial legs**
  - legs for leaping/ jumping
  - example: hindlegs of fleas and grasshopper

- **Scansorial legs**
  - legs for climbing/ clinging
  - example: all legs of lice



- **Fossorial legs**
  - legs for digging/ burrowing
  - example: fore legs of mole cricket



- **Natatorial legs**
  - legs for swimming

  example: hindlegs of water bugs and water beetles

- **Corbiculate legs**
  - legs adapted for assembling and carrying pollen;
  - the "basitarsus" lined with haired is meant for carrying pollen termed as "*corbicula*"
  - exhibited by honeybees

Insect Wings

- functional wings exist only during the adult stage of an insect's life cycle
- most insects have distinct two pairs of wings
- one pair on the mesothorax and one pair on the metathorax (never on the prothorax)
- a characteristic network of veins runs throughout the wing tissue
- veins are filled with hemolymph and contain a tracheal tube and a nerve

a. Types of Wings (modifications)

- **Membranous**
  - light and thin membrane for flight
  - veins provide the strength and reinforcement during flight.
  - example: dragonfly, hindwings of most insects

- **Elytra**
  - hard, sclerotized wings that protect the hindwings and abdomen
  - example: beetles, weevils and earwigs

- **Tegmen**
  - thicker than membranous wings; leathery
  - protects the hindwings; sound producers
  - example: grasshoppers, preying mantids, stick insects

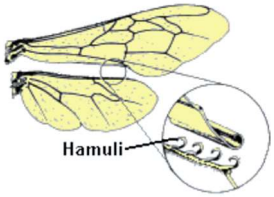
- **Hemelytra**
  - half leathery (basal), half membranous (apical)
  - example: shield bugs

- **Fringed**
  - slender wings composed of hairy fringes in the margins
  - example: thrips

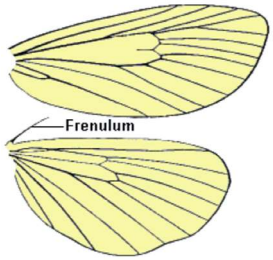
- **Halteres**
  - Small, knob-like modification of hindwings
  - functions as gyroscopic stabilizers in flight
  - example: hindwings of true flies

- **Scaly wings**
  - membranous wings covered with microscopic scales
  - showcase intricate patterns and colors for species recognition
  - also provides insulation and protection
  - example: wings of butterflies and moths

b. Wing Coupling Mechanisms



- **Hamuli**
  - Row of tiny hooks in the hind wings
  - Holds the forewings and hindwings together
  - present in wings of bees and wasps



- **Frenulum**
  - Bristle at the base of the hindwings
  - Holds the forewings and hindwings together
  - present in wings of moths and butterflies

C. ABDOMEN

- third functional region (tagma) of its body
- located just behind the thorax
- functions for respiration, digestion, excretion and reproduction
- each segment of the abdomen consists of a dorsal sclerite, the tergum, and a ventral sclerite, the sternum, joined to one another laterally by a pleural membrane

Abdominal structures

- **Pincers**
  - cerci are heavily sclerotized and forceps-like
  - used mostly for defense
  - also used during courtship, and sometimes to help in folding the wings
  - exhibited by earwigs

- **Cornicles**
  - paired secretory structures located dorsally on the abdomen
  - produce substances that repel predators
  - also used to elicit care-giving behavior by symbiotic ants
  - exhibited by aphids

- **Abdominal prolegs**
  - fleshy, locomotory appendages
  - found only in the larvae of certain orders (notably in Lepidopterans)

- **Sting**
  - a modified ovipositor
  - found only in the females of ants, bees, and predatory wasps

- **Abdominal gills**
  - respiratory organs found in the naiads of aquatic insects
  - in mayflies: paired gills are located along the sides of each abdominal segment
  - in damselflies and dragonflies: the gills are attached to the end of the abdomen

- **Furcula**
  - jumping organ found in springtails on the ventral side of the fifth abdominal segment
  - a clasp (tenaculum) on the third abdominal segment holds the springtail in its "cocked" position

- **Collophore**
  - a fleshy, peg-like structure found in springtails on the ventral side of the first abdominal segment
  - maintain homeostasis through regulation of absorption of water from the environment

- **Median caudal filament**
  - a thread-like projection arising from the center of the last abdominal segment
  - only found in "primitive" orders (e.g., Diplurans, silverfish, mayflies)

Internal Morphology

Circulatory System

- insects, like all other arthropods, have an open circulatory system
- in an open system, blood (hemolymph) spends much of its time flowing freely within body cavities where it makes direct contact with all internal tissues and organs
- responsible for movement of nutrients, salts, hormones, & metabolic wastes throughout the insect's body
- the contraction rate of the heart varies considerably from species to species; typically, in the range of 30 to 200 beats per minute

a. Parts of the Circulatory system

- **Dorsal vessel**
  - major structural component of an insect's circulatory system
  - this tube runs longitudinally through the thorax and abdomen, along the inside of the dorsal body wall

- **Heart**
  - dorsal vessel in the abdomen portion
  - divided segmentally into chambers that are separated by valves (ostia) to ensure one-way flow of hemolymph

- **Alary muscles**
  - a pair attached laterally to the walls of each chamber
  - peristaltic contractions of these muscles force the hemolymph forward from chamber to chamber

- **Hemolymph**
  - the extracellular fluid, usually clear or colored, with green and yellow pigments coming from food
  - circulated by the heart or dorsal vessel
  - contains blood cells, salts, proteins, amino acids and minerals
  - 90% of hemolymph is water
  - responsible for 16-20% of insect weight

Functions of the Hemolymph

- transport mechanism for nutrients, hormones, waste products
- transport cells, blood cells, to get access of nutrients
- storage site for water and substances important in molting and reproduction
- hydraulic medium: important for its hydrostatic pressure (needed in molting)
- thermoregulation: allows changes in hemolymph circulation patterns to increase body temperature for frost protection and defense against hazards

Digestive System

- composed of buccal cavity, salivary glands and alimentary canal (gut)
- divided into three, namely the foregut, midgut and hindgut

- **Digestion**
  - a series of activities and hydrolytic reactions (involving enzymes) that convert complex substances (foodstuffs that insect eats like proteins, carbohydrates, fats and lipids) to simpler ones (amino acids, fatty acids, glycerol, sugars)

a. Stomodaeum (foregut)

- has a cuticle with spines (intima), hair or teeth
- for entry and storage of food

Parts of the foregut

- **Pharynx**
  - for ingestion of food

- **Esophagus**
  - narrow tube that leads to the crop

- **Crop**
  - dilatation of posterior part of foregut
  - for food storage as well as defensive substances

- **Proventriculus**
  - contains tooth-like denticles that grind and pulverize food particles.
  - serves much the same function as a gizzard in birds

- **Cardiac sphincter**
  - invagination of foregut into midgut
  - regulates the passage of food from foregut to midgut

b. Mesenteron (midgut)

- lined with peritrophic membrane
- site for enzymatic digestion of food and absorption of nutrients

Parts of the midgut

- **Gastric ceca**
  - end of foregut and beginning of midgut
  - provide extra surface area for secretion of enzymes or absorption of water (and other substances) from the alimentary canal

- **Peritrophic membrane**
  - a temporary lining that is delicate and perforated that serves to protect the midgut from particles or food coming from the foregut
  - protects the delicate digestive cells without inhibiting absorption of nutrient molecules

- **Ventriculus (Stomach)**
  - primary site for enzymatic digestion of food and absorption of nutrients.
  - digestive cells lining the walls of the ventriculus have microscopic projections (microvilli) that increase surface area for nutrient absorption

- **Pyloric sphincter**
  - demarcation line between midgut and hindgut
  - furnished with muscles to regulate deposition of waste to hindgut

c. Proctodaeum (hindgut)
- lined with cuticle but more permeable to water
- functions for water, salt and amino acid absorption
- serves as storage for cellulose digestion in termites and scarab beetles
- modified into rectal pads for water, amino acid and salt reabsorption

Parts of the hindgut

- **Malpighian tubules**
  - long, spaghetti-like structures that extend throughout most of the abdominal cavity
  - serve as excretory organs
  - removes nitrogenous wastes (principally ammonium ions, NH_4^+) from the hemolymph
  - toxic NH_4^+ is quickly converted to urea and then to uric acid by a series of chemical reactions within the Malpighian tubules
  - uric acid, a semisolid, accumulates inside each tubule and is emptied into the hindgut for elimination as part of the fecal pellet

- **Rectal pads**
  - embedded in the walls of the rectum
  - recovers more than 90% of the water from a fecal pellet before it passes out of the body through the anus

Respiratory System

- responsible for delivering sufficient oxygen to all cells of the body and for removing carbon dioxide that is produced as a waste product of cellular respiration
- the respiratory system of insects is separate from the circulatory system
- a complex network of tubes called a tracheal system that delivers oxygen-containing air to every cell of the body

- **Spiracles**
  - valve-like openings in the exoskeleton where air enters the insect's body
  - located laterally along the thorax and abdomen of most insects, usually one pair of spiracle per body segment

Reproductive System

- similar in structure and function to those of vertebrates: male's testes produce sperm and female's ovaries produce eggs (ova)

- **Spermatheca**
  - a pouch-like chamber in female insects for storage of sperm

- **Aedeagus**
  - other term for male genitalia

- **Ootheca**
  - egg case produced by certain insects, such as mantises and cockroaches, to protect and encase their eggs

INSECT DEVELOPMENT

a. Definition of terms

- **Metamorphosis**
  - a biological process involving changes in the body size, shape, and form of an animal through cell growth and differentiation

- **Molting**
  - the process of shedding off of exoskeleton periodically to accommodate the growth and development
  - most insects molt at least three to four times
  - has two stages:
    - ***Apolysis*** = separation of old exoskeleton from the underlying epidermis
    - ***Ecdysis*** = shedding/removal of exoskeleton

- **Exuviae**
  - the old skin (cuticle) left after undergoing molting

- **Instar**
  - the actual appearance of the insect between each molt
  - in general, insects have 4-6 instars

- **Stadium**
  - duration of time in between two molts

- **Incubation period**
  - duration of time from egg-laying to hatching

- **Total developmental period**
  - sum of durations of all stages from egg to adult stage

- **Adult longevity**
  - lifespan of adult
  - from adult emergence to death

- **Fecundity**
  - number of eggs/live young laid in a lifetime of a female insect

b. Developmental Stages of Insects

1. Egg stage

- first stage of development
- inactive and inconspicuous
- laid either individually or in groups (egg mass)

Egg modifications

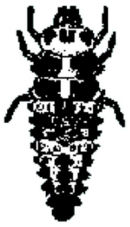
- Ootheca (mantids, cockroaches)
- Nit (lice)
- Eggs with floats (mosquitoes)
- Egg rafts (mosquitoes)
- Pedicellate eggs (lacewings)

2. Immature stage

- feeding stage
- young that hatched from the egg
- may be a juvenile, nymph, naiad or larva

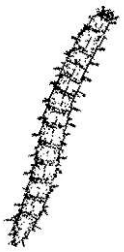
Types of larvae

- **Eruciform**
  - cylindrical body with well-developed head capsule and a short antennae
  - has short thoracic legs and 2 to 10 pairs of fleshy abdominal prolegs
  - slow and sluggish
  - caterpillars

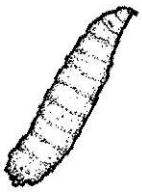


- **Campodeiform**
  - elongated, slightly flattened body with prominent antennae/cerci
  - active and predatory
  - thoracic legs adapted for running

- **Scarabaeiform**
  - robust c-shaped body with well-developed head capsule
  - has thoracic legs but no abdominal prolegs
  - grubs



- **Elateriform**
  - long and smooth cylindrical body
  - with hard exoskeleton and very short legs
  - has both thoracic and abdominal legs
  - worms with hardened bodies



- **Vermiform**
  - fleshy and worm-like body
  - may or may not have well-developed head capsules
  - no functional legs
  - maggots

3. Pupal stage

- the resting and inactive/quiescent stage of holometabolous insects

Types of pupae based on:

i. Mandibles

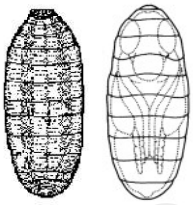
- **Decticous pupa**
  - with movable articulated mandibles (used to chew pupal cell)
  - Tend to be active

- **Adecticous pupa**
  - with non-movable mandibles
  - are attached to the head rendering them immobile
  - May be either be obtect or exarate

ii. Appendages

- Exarate
  - appendages project freely from the body and are able to move
  - lacks cocoon; looks like a mummified adult

- **Obtect**
  - appendages are cemented to the body wall as exoskeleton hardens
  - cuticle is often heavily sclerotized
  - enclosed within a cocoon or chrysalis



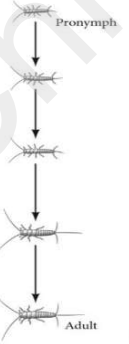
- **Coarctate**
  - with covering called puparium which is usually the hardened cuticle of the final larval instar

4. Adult/Imago stage

- the final stage
- all external characteristics are well-defined
- stage used for insect species identification (especially in paurometabolous insects)

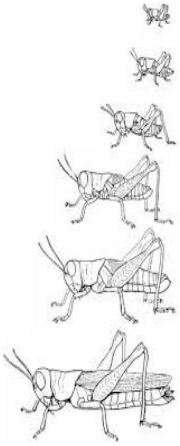
b. Types of Metamorphosis

- **Ametabolous**



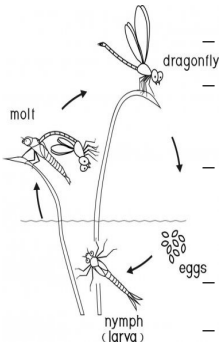
  - no metamorphosis
  - immatures on increase in size until adulthood is reached
  - immature forms resemble the adults
  - immature stage: juvenile
  - example: silverfish

- **Paurometabolous**



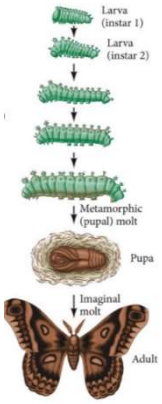
  - gradual metamorphosis
  - immature forms resemble the adults, but immature forms has underdeveloped genitalia and has wing pads
  - immature forms have the same habitat and food compared to its adults
  - immature stage: nymph
  - example: true bugs, mantids, grasshoppers, cockroaches

- **Hemimetabolous**



  - incomplete metamorphosis
  - immature forms do not resemble the adults
  - immature forms have different habitat and food compared to its adults
  - immature stage: naiad
  - example: dragonflies, mayflies

- **Holometabolous**



  - complete metamorphosis
  - have four distinct life stages: egg, larva, pupa, adult
  - immature forms have the same habitat as to its adults but different food
  - usually. only the immature forms are destructive
  - immature stage = larva
  - example: butterflies, beetles

d. Modes of Reproduction

- **Bisexual reproduction**
  - both males and females are involved
  - eggs are fertilized by male sperm
  - most insects reproduced this way

- **Parthenogenesis**
  - only females are required to produce eggs or live young
  - eggs are developed without fertilization
  - common to aphids in tropical countries

- **Special types of reproduction:**
  - **Paedogenesis**
    - larvae are capable of reproduction
    - exhibited by some wasps and beetles
  - **Polyembryony**
    - Production of more than one embryos from one fertilized egg
    - exhibited by some Braconid wasps

UNIT III: INSECT ORDERS

Superclass Hexapoda (six-legged arthropods)
Class Insecta (ectognathous hexapods)
Subclass Apterygota (primitively wingless)
Subclass Pterygota (winged)
Infraclass Paleoptera (non-foldable wings)
Infraclass Neoptera (foldable wings)
Exopterygotes (externally developing wings)
Endopterygotes (internally developing wings)
Orders

Note: **27 insect orders** are found in the Philippines;

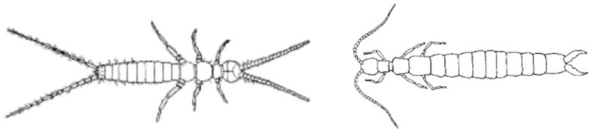
14 orders are agriculturally important

I. Entognathous Hexapods

Class and Order
Protura
"*protos*" = first; "*oura*" = tail

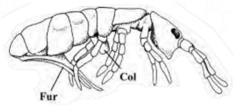
Common Name: telsontails, coneheads
Antennae: reduced
Mouthpart: chewing
Wings: apterous
Legs: gressorial
Development: ametabolous
Notes: minute, no cerci and compound eyes; usually found in damp forest floors

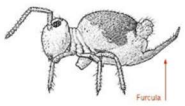
Class and Order
Diplura
"*diploos*" = double; "*oura*" = tail



Common Name: Diplurans
Antenna: moniliform
Mouthpart: chewing
Wings: apterous
Legs: gressorial
Development: ametabolous
Notes: may have tail-like or forceps-like cerci, predatory

Class and Order
Collembola
"*kolla*" = glue; "*embolon*" = peg/wedge

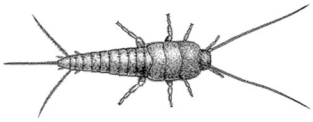




Common Name: springtails
Antenna: filiform
Mouthpart: chewing
Wings: apterous
Legs: gressorial
Development: ametabolous
Notes: has collophore & furcula in the abdomen

II. Class Insecta (Ectognathous Hexapods)
A. Subclass Apterygota

Order
Zygentoma/Thysanura
"*zygon*" = yolk/bridge; "*entoma*" = insect/cut into
"*thysanos*" = fringe; "*oura*" = tail



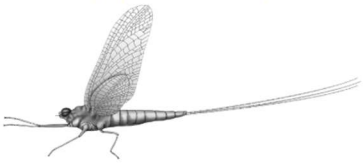
Common Name: silverfish, firebrats
Antenna: filiform
Mouthpart: chewing
Wings: apterous
Legs: gressorial
Development: ametabolous
Economic Importance: pest
Notes: compound eyes are small and widely separated; dorsoventrally flattened body

Order
Archaeognatha
"*archaios*" = ancient; "*gnathos*" = jaw

Common Name: jumping bristletails
Antenna: filiform
Mouthpart: chewing
Wings: apterous
Legs: gressorial
Development: ametabolous
Notes: compound eyes are large and touching; body laterally compressed

B. Subclass Pterygota
a. Infraclass Paleoptera

Order
Ephemeroptera
"*ephemeros*" = but a day; "*ptera*" = wings

Common Name: mayflies
Antenna: setaceous
Mouthpart: chewing (naiad); vestigial (adult)
Wings: membranous
Legs: gressorial, perching legs
Economic Importance: ecological indicators
Development: hemimetabolous
Notes: adults are short-lived (1 –2 days)

Order
Odonata
"*odonto*" = tooth

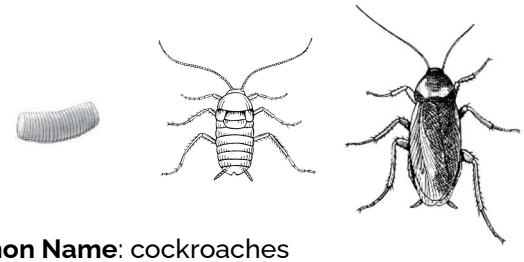
Common Name: dragonflies, damselflies
Antenna: setaceous
Mouthpart: chewing
Wings: membranous
Legs: gressorial, perching legs
Development: hemimetabolous
Economic Importance: predators
Notes: has "*nodus*" on wings and "*stigma*" at the middle of the front margin of each wing

- **Suborder Anisoptera: *dragonflies***
  - wings differ in size
  - compound eyes are large and touching
  - wings extended horizontally at rest

- **Suborder Zygoptera: *damselflies***
  - wings identical in size
  - compound eyes are smaller and widely separated
  - wings folded vertically at rest

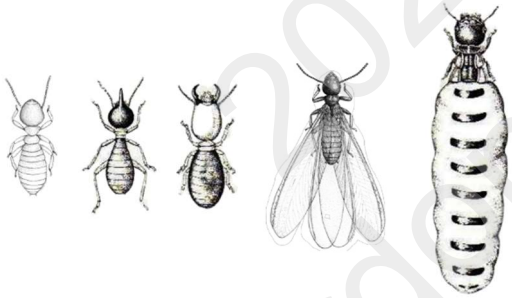
b. Infraclass Neoptera
i. Exopterygotes

Order
Blattodea
"*blatta*" = cockroach; "*eidos*" = form/type



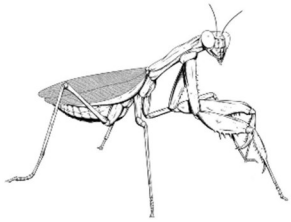
Common Name: cockroaches
Antenna: filiform
Mouthpart: chewing
Wings: tegmina (forewings), membranous (hindwings)
Legs: cursorial
Development: paurometabolous
Economic Importance: urban pests, scavengers
Notes: dorsoventrally flattened, shield-like pronotum, eggs contained in *ootheca,* feed on starches

Order
Isoptera
"*iso*" = equal; "*ptera*" = wings



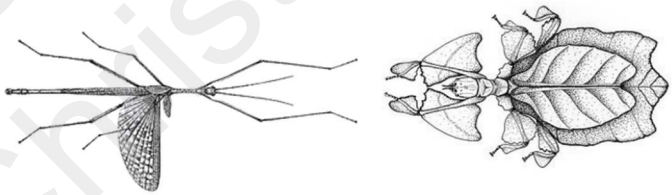
Common Name: termites
Antenna: moniliform
Mouthpart: chewing
Wings: membranous
Legs: **gressorial**
Development: paurometabolous
Economic importance: urban pests; decomposers
Notes: polymorphic and has a caste system (reproductives, workers, soldiers); "white ants", termites are now under the Order Blattodea

Order
Mantodea
"*mantis*" = prophet; "*eidos*" = form/type



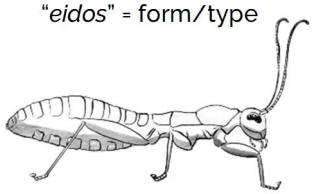
Common Name: praying mantis
Antenna: filiform
Mouthpart: chewing
Wings: tegmina
Legs: raptorial
Development: paurometabolous
Economic Importance: predators
Notes: with elongated prothorax, produces grayish spongy egg case; generalist predators

Order
Phasmatodea
"*phasm*" = phantom/apparition; "*eidos*" = form/type



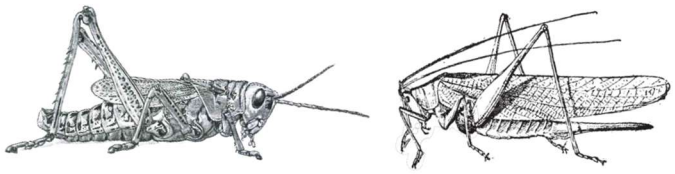
Common Name: walking sticks, leaf insects
Antenna: **filiform,** moniliform
Mouthpart: chewing
Wings: tegmina (if present), most Phasmids are brachypterous (reduced wings) or secondarily wingless
Legs: gressorial
Development: paurometabolous
Economic Importance: pests of forests (defoliators)
Notes: stick-like or leaf-like appearance

Order
Mantophasmatodea
"*mantis*" = prophet; "*phasm*" = phantom/apparition; "*eidos*" = form/type



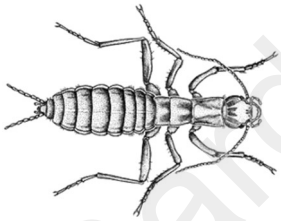
Common Name: gladiators
Antenna: filiform
Mouthpart: chewing
Wings: apterous
Legs: gressorial
Development: paurometabolous
Economic Importance: predator
Notes: walking stick-like insect with eyes of a mantis, very rare (only in South Africa)

Order
Orthoptera
"*ortho*" = straight; "*ptera*" = wings



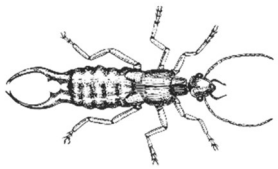
Common Name: grasshoppers, katydids, crickets
Antenna: filiform
Mouthpart: chewing
Wings: tegmina (forewings), membranous (hindwings)
Legs: saltatorial
Development: paurometabolous
Economic Importance: pests, predators
Notes: sounds produced by rubbing body parts are termed as "*stridulation*"

Order
Grylloblattodea
"*gryll*" = cricket; "*blatta*" = cockroach; "*eidos*" = form/type



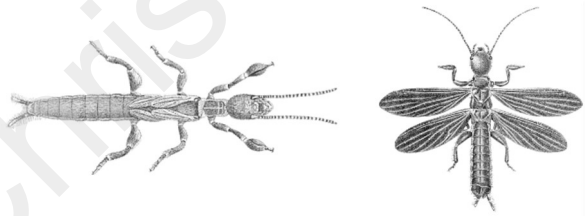
Common Name: ice crawlers, rock crawlers
Antenna: filiform
Mouthpart: chewing
Wings: apterous
Legs: gressorial
Development: paurometabolous
Economic Importance: scavengers
Notes: has cockroach and cricket characteristics; usually found in temperate regions

Order
Dermaptera
"*derma*" = skin; "*ptera*" = wings



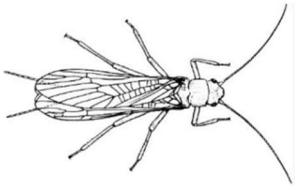
Common Name: earwigs
Antenna: filiform
Mouthpart: chewing
Wings: tegmina (forewings), membranous (hindwings)
Legs: gressorial
Development: paurometabolous
Economic importance: predators, pests
Notes: lay eggs at burrows; exhibits mother instincts, with prominent forceps-like cerci at the tip of the abdomen

Order
Embioptera
"*embios*" = lively; "*ptera*" = wings



Common Name: webspinners
Antenna: filiform
Mouthpart: chewing
Wings: membranous; males are usually winged, **females** apterous
Legs: gressorial
Development: paurometabolous
Economic Importance: scavengers, predators
Notes: fluttery movement of wings, have web spinners on forelegs

Order
Plecoptera
"*plekein*" = to fold; "*ptera*" = wings

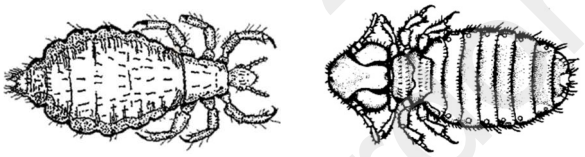


Common Name: stoneflies
Antenna: filiform, setaceous
Mouthpart: chewing (naiad); vestigial (adult)
Wings: membranous
Legs: gressorial
Development: hemimetabolous
Economic Importance: predator
Notes: live under stones, have large thoracic sclerites

Order
Psocoptera
"*psocus*" = biting/gnawed; "*ptera*" = wings

Common Name: Psocids, booklice, barklice
Antenna: filiform
Mouthpart: chewing
Wings: membranous (if present)
Legs: gressorial
Development: paurometabolous
Economic Importance: pest of museums
Notes: has prominent neck

Order
Phthiraptera
"*phtheir*" = louse; "*apteros*" = wingless



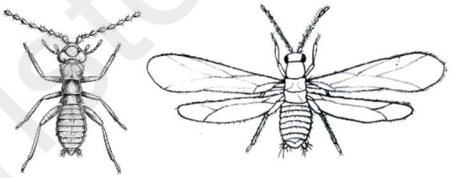
Common Name: sucking and chewing lice
Antenna: filiform
Mouthpart: piercing-sucking, chewing
Wings: secondarily wingless
Legs: scansorial
Development: paurometabolous
Economic Importance: pests of livestock and poultry; medically important pests
Notes: dorsoventrally flat

- **Suborder Mallophaga**: *chewing lice*
- **Suborder Anoplura**: *sucking lice*
- **Suborder Rhynchophthirina**: *elephant lice*

Order
Thysanoptera
"*thysanos*" = fringe; "*ptera*" = wings

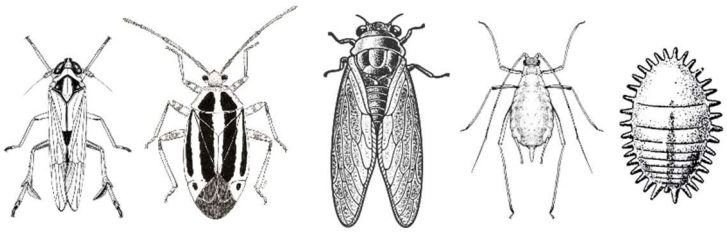
Common Name: thrips
Antenna: filiform
Mouthpart: rasping-sucking
Wings: fringed
Legs: gressorial
Development: paurometabolous
Economic Importance: pests
Notes: scars fruits, white eggs inserted in plant tissues, right mandible is rudimentary while left mandible is functional

Order
Zoraptera
"*zor*" = pure; "*apteros*" = wingless



Common Name: Zorapterans, angel insects
Antenna: moniliform or filiform
Mouthpart: chewing
Wings: membranous, apterous
Legs: gressorial
Development: paurometabolous
Economic importance: predator
Notes: polymorphic (winged form has eyes; wingless form without eyes); only 1 species present in the Philippines

Order
Hemiptera
"*hemi*" = half; "*ptera*" = wings



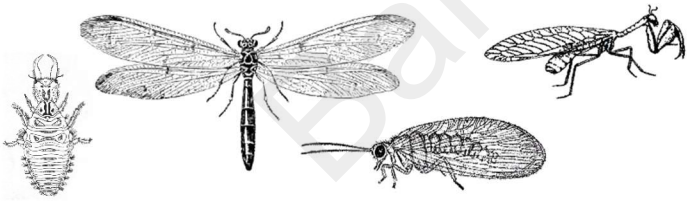
Common Name: true bugs, aphids, hoppers, psyllids, scale insects, mealybugs, bedbugs

Antenna: filiform
Mouthpart: piercing-sucking
Wings: hemelytra, membranous, apterous
Legs: gressorial, natatorial, saltatorial, raptorial
Development: paurometabolous
Economic Importance: pests, predators, vectors of plant and human diseases
Notes: has distinct triangular plate at the back called "*scutellum*"

- **Suborder Heteroptera**
  - characterized by their having hemelytron wings
  - stink bugs, assassin bugs, and leaf-footed bugs
- **Suborder Auchenorrhyncha**
  - known for their ability to produce sound through specialized sound-producing structures for communication
  - planthoppers, leafhoppers, and treehoppers
- **Suborder Sternorrhyncha**
  - often associated with the production of honeydew and are significant pests in agriculture
  - includes various insects that feed on plant sap, such as aphids, mealybugs, scale insects and whiteflies
- **Suborder Coleorrhyncha**
  - beetle-like bugs
  - have specialized adaptations to live on or near mosses
  - moss bugs

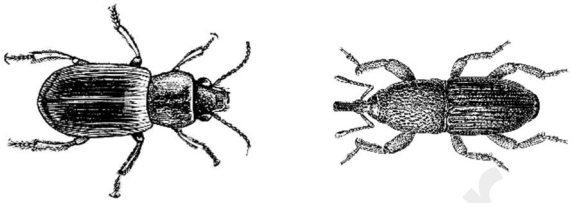
ii. Endopterygotes

Order
Neuroptera
"*neuron*" = sinew/nerve; "*ptera*" = wings



Common Name: lacewings, antlions, owlflies
Antenna: filiform
Mouthpart: piercing-sucking (antlion larvae); chewing (adults)
Wings: membranous
Legs: gressorial, raptorial
Development: holometabolous
Economic importance: predators
Notes: net-like venation on wings; eggs are suspended in hair-like filament (lacewings)

Order
Coleoptera
"*koleos*" = sheath/shield; "*ptera*" = wings

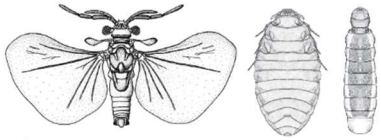


Common Name: beetles, weevils
Antenna: lamellate (scarabs), flabellate (blister beetles), clavate (ladybeetles), filiform, pectinate
Mouthpart: chewing
Wings: elytra (forewings), membranous (hindwings)
Legs: gressorial, natatorial, fossorial, cursorial
Development: holometabolous
Economic importance: pests, predators, scavengers
Notes: most diverse insect order

Order
Lepidoptera
"*lepis*" = scale; "*ptera*" = wings

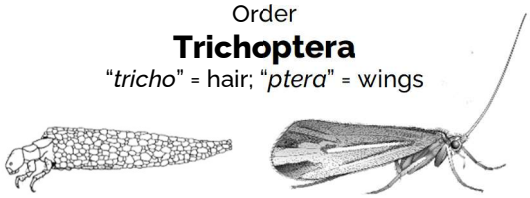
Common Name: moths, butterflies
Antenna: pectinate, filiform, bipectinate (moths), capitate (butterflies), capitate with hooks (skippers)
Mouthpart: chewing (larvae), siphoning (adults)
Wings: scaly membranous
Legs: gressorial
Development: holometabolous
Economic importance: larval stage: mostly pests; adult stage: pollinators, aesthetics in events such as weddings
Notes: most larval forms are destructive agricultural pests

Order
Strepsiptera
"*strepsos*" = twisted; "*ptera*" = wings



Common Name: twisted-wing parasites
Antenna: flabellate
Mouthpart: modified biting, vestigial (reduced)
Wings: club-shaped (forewings) membranous (hindwings) (males), apterous (females)
Legs: gressorial, apodous (no legs)
Development: holometabolous
Notes: endoparasites of other insects

Order
Trichoptera
"*tricho*" = hair; "*ptera*" = wings

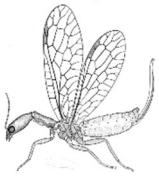


Common Name: caddisflies
Antenna: filiform
Mouthpart: chewing (larva); vestigial (adult)
Wings: hairy membranous
Legs: gressorial
Development: holometabolous
Economic importance: important in aquatic community (predators, bioindicators), pests
Notes: larvae are aquatic and many live in cases that they construct from small stones and twigs

Order
Mecoptera
"*meco*" = long; "*ptera*" = wings

Common Name: scorpionflies, hangingflies
Antenna: filiform
Mouthpart: chewing
Wings: membranous
Legs: gressorial
Development: holometabolous
Economic importance: predators
Notes: head modified into a beak-like elongated rostrum, have elaborate courtship behavior

Order
Raphidioptera
"*raphis*" = needle; "*ptera*" = wings

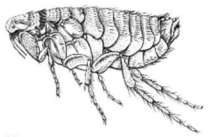


Common Name: snakeflies
Antenna: filiform
Mouthpart: chewing
Wings: membranous
Legs: gressorial
Development: holometabolous
Economic importance: predators
Notes: have elongated prothorax, females have a long, slender ovipositor that resembles a needle

Order
Megaloptera
"*megalo*" = large, to fold; "*ptera*" = wings

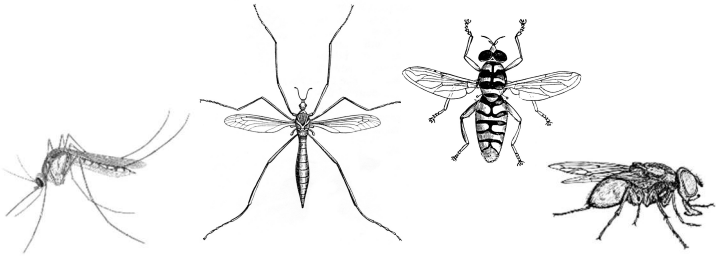
Common Name: alderflies, dobsonflies, fishflies
Antenna: filiform, moniliform
Mouthpart: chewing
Wings: membranous
Legs: gressorial
Development: holometabolous
Economic importance: important in aquatic community (predators, bioindicators)
Notes: larvae are aquatic predators; adults have conspicuous mandibles (larger in males)

Order
Siphonaptera
"*siphon*" = tube; "*apteros*" = wingless



Common Name: fleas
Antenna: filiform
Mouthpart: piercing-sucking
Wings: secondarily wingless
Legs: saltatorial
Development: holometabolous
Economic importance: pests, vectors of diseases
Notes: laterally flattened body

Order
Diptera
"*di*" = two; "*ptera*" = wings



Common Name: flies, mosquitoes, gnats
Antenna: aristate, stylate (true flies); plumose (mosquitoes)
Mouthpart: piercing-sucking (mosquitoes, gnats, blood-sucking flies), sponging (house flies)
Wings: membranous (forewings), halteres (hindwings). some are secondarily wingless
Legs: gressorial
Development: holometabolous
Economic importance: vectors of diseases (dengue, malaria, filariasis, cholera), pests, predators, scavengers
Notes: have scavenging characteristic, some maggots are used in medicine to clean fresh wounds

Order
Hymenoptera
"*hymen*" = membrane; "*ptera*" = wings

Common Name: bees, wasps, ants, sawflies
Antenna: geniculate, filiform (some wasps)
Mouthpart: chewing, chewing-lapping (bees)
Wings: membranous, apterous (ants)
Legs: gressorial, corbiculate (honeybees)
Development: holometabolous
Economic importance: parasitoids, predators, pollinators, some pests
Notes: mostly beneficial insects; exhibits social behavior, wings coupled by hamuli

UNIT IV: INSECT & NON-INSECT PESTS IN THE PHILIPPINES

Pest

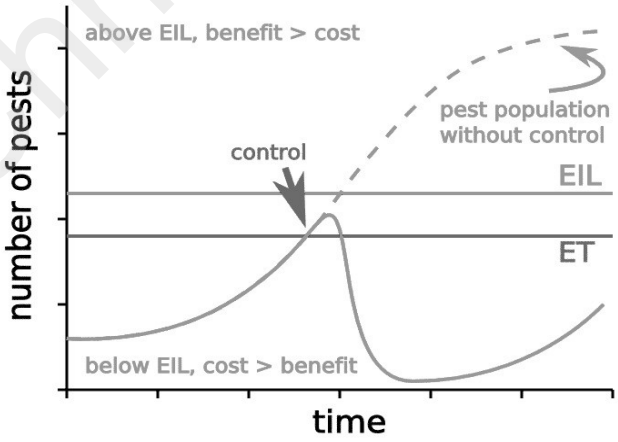
- species that interfere with human activities, property or health
- provide conflict with human interest or affect their welfare
- cause damage through its feeding habits

Economic Injury Level (EIL)

- smallest number of insects (amount of injury) that will cause yield losses EQUAL to the insect management costs

Economic Threshold Level (ETL)

- pest density at which management action SHOULD be taken to prevent an increasing pest population from reaching the economic injury level



Modes of Damage caused by Insects

a. Insects Attacking Cultivated Plants

- plant injury through feeding (**phytophagy**)
- plant injury by oviposition (in fruits, stems, leaves, twigs, terminal portion dies or may cause fruit drop)
- vectors of diseases (transmission of plant diseases from plant to plant)

b. Insects Attacking Stored Products

- destruction by termites, powder post beetles, carpet ants
- damage on material made from animal fibers (furs, clothing, blankets, rugs, and upholstery)
- fabric damage by dermestid beetles and clothes moth

c. Insects Attacking Stored Food

- contamination from tunneling/feeding in food (meats, cheese, milk products, flour, cereals, nuts, and fruits)
- decrease in quality and marketability

d. Insects Attacking Man and Animals

- annoyance caused by insects to man, and animals (e.g., cattle)
- annoyance through secreted odors or secretions
- annoyance to one's eyes or ears

e. Venomous Insects

- inject toxins to man and animals causing irritation, swelling, pain, and sometimes paralysis (biting flies, bugs, etc.)
- venom from sting of bees, wasps may cause swelling or even anaphylactic shock or death
- venom from stinging hairs of saddle-back caterpillars, tussock moth etc., can cause dermatitis/urticaria
- fluids secreted by blister beetles may cause irritation and/or burns
- toxic insects like rose chafer are toxic when accidentally ingested

f. Parasitic Insects

- insects may live inside bodies of humans or animals as parasites and cause irritations, damages to tissues or even death
- external parasites of birds, and mammals which feeds on feathers, hair, and dermal scales
- irritation from bites of fleas, bed bugs, and other biting insects
- infestation of larvae of botflies on nasal passages of sheep; alimentary tracts of horses, and damage on mucous membrane

g. Disease Transmission

- piercing-sucking insects (e.g., mosquitoes, Hemipterans) serve as vectors of diseases in plants, animals, or humans
- mechanical transmission of houseflies or blowflies feeding on fecal matter and contaminating food fed by man causing typhoid fever, cholera, and dysentery

Insect Pest Classifications

a. Based on origin

- **Endemic pest**
  – native; local in origin
- **Exotic pest**
  – introduced from outside the locality

b. Based on Population dynamics

- **Key/Major Pest**
  – always present in the field every season with high population
- **Potential/Minor pest**
  – always found in the field at a low population
- **Occasional/Sporadic pest**
  – usually strong fliers that can migrate from one place to another

c. Based on Feeding habits

- Chewing
- Sucking
- Boring

d. Based on Target host/plant parts

- **Phytophagous (herbivorous)**
  - leaf feeders/miners
  - fruit/seeds feeders
  - stem and root borers
  - sap feeders
  - gall makers
- **Zoophagous/Carnivorous**
  - parasites
  - predators
- **Entomophagous**
- **Saprophagous**
- **Mycetophagous**

e. Based on range of host

- **Monophagous**
– have only one host
- **Oligophagous**
– have only a few hosts
- **Polyphagous**
– have more than one hosts

Major Insect Pests of Important Crops

A. CEREALS

a. Rice

- **Fire ants**
  Solenopsis geminata geminata
  [Hymenoptera: Formicidae]
  Damage: collects and eats rice planted in soil

- **Mole cricket**
  Gryllotalpa orientalis
  [Orthoptera: Gryllotalpidae]
  Damage: feeds on seeds, roots and tillers, can cut base of plants causing loss of plant stand

- **June beetle/Root grub**
  Leucopholis irrorata
  [Coleoptera: Scarabaeidae]
  Damage: feeds on roots of plants

- **Rice whorl maggot**
  Hydrellia philippina
  [Diptera: Ephydridae]
  Damage: bores and feeds inside tillers

- **Green leafhopper**
  Nephotettix virescens/N. nigropictus/ N. cincticeps/N. malayanus
  [Hemiptera: Cicadellidae]
  Damage: transmit rice tungro bacilliform and spherical virus

- **Brown planthopper**
  Nilaparvata lugens
  [Hemiptera: Delphacidae]
  Damage: causes *"**hopperburn**"* transmits grassy stunt virus (excessive tillering and stunted growth) and ragged stunt (ragged/twisted) virus

- **Rice black bug (RBB)**
  Scotinophara coarctata
  [Hemiptera: Pentatomidae]
  Damage: remove the sap of the plant. cause browning of leaves, **deadheart**, and **bugburn**. also causes stunting in plants, reduced tiller number, and formation of whiteheads
  Note: flight patterns affected by the lunar cycle; on full moon nights, large numbers of adults swarm to light sources; common in rainfed and irrigated wetland environments

- **Rice stemborers**
  [Lepidoptera: Pyralidae]

  - **Striped stem borer** – *Chilo suppressalis*
  - **Yellow stem borer** – *Scipophaga incertulas*
  - **Pink stem borer** – *Sesamia inferens*
  - **White stem borer** – *Scirpophaga innotata*

  Damage: causes "**deadheart**" of young leaves, and "**whitehead**" = empty panicles

- **Grasshoppers and locusts**
  [Orthoptera: Acrididae]
  Damage: defoliates plants

- **Rice bug/Slender rice bug**
  Leptocorisa oratorius
  [Hemiptera: Alydidae]
  Damage: suck out contents of developing grains during milking stage. causing unfilled or empty grains and discoloration

b. Corn

- **Corn seedling maggot**
  Atherigona oryzae
  [Diptera: Muscidae]
  Damage: feed on and burrow into corn seeds

- **Corn semilooper**
  Chrysodeixis eriosoma
  [Lepidoptera: Noctuidae]
  Damage: defoliates plants, creates shotholes on leaves

- **Fall armyworm (FAW)**
  Spodoptera frugiperda
  [Lepidoptera: Noctuidae]
  Damage: feeds on young leaves, shoots, developing tassels and young ears of corn
  Note: First reported case in the Philippines: June 20, 2019, at Piat, Cagayan

- **Asian corn borer (ACB)**
  Ostrinia furnacalis
  [Lepidoptera: Crambidae]
  Damage: bores and feeds on corn stalks

- **Corn aphid**
  Rhopalosiphum maidis
  [Hemiptera: Aphididae]
  Damage: sucks on plant sap, may cause stunting and formation of sooty molds on leaves at severe infestations

- **Corn earworm**
  Helicoverpa armigera
  [Lepidoptera: Noctuidae]
  Damage: feeds on corn ears

c. Stored grains

- **Rice weevil**
  Sitophilus oryzae
  [Coleoptera: Curculionidae]
  Damage: feeds and lay eggs on stored grains

- **Corn weevil**
  Sitophilus zeamais
  [Coleoptera: Curculionidae]
  Damage: feeds and lay eggs on stored grains

- **Rice moth**
  Corcyra cephalonica
  [Lepidoptera: Pyralidae]
  Damage: feeds and lay eggs on stored grains

B. VEGETABLE CROPS

a. Legumes

cowpea, mungbean, soybean, bush sitao

- **Beanfly/Legume seedling fly**
  Ophiomyia phaseoli
  [Diptera: Agromyzidae]
  Damage: bores and feeds on stems

- **Black bean aphids**
  Aphis craccivora
  [Hemiptera: Aphididae]
  Damage: sucks on plant sap, may cause stunting, distorted growth and formation of sooty molds on leaves at severe infestations

- **Bean pod borers**
  Marucca testulalis, Etiella zinckinella
  [Lepidoptera: Pyralidae]
  Damage: bores and feeds on bean pods

- **Leafhoppers**
  Empoasca ricei
  [Hemiptera: Cicadellidae]
  Damage: sucks on plant saps

- **Shield bugs/Stink bugs**
  Nezara viridula, Plautia affinis
  [Hemiptera: Pentatomidae]
  Damage: sucks on leaves and bean pods

b. Crucifers

cabbage, pechay, mustard, lettuce

- **Diamondback moth (DBM)**
  Plutella xylostella
  [Lepidoptera: Plutellidae]
  Damage: very small, but numerous larvae feed on leaves voraciously resulting in complete removal of foliar tissue except for the leaf veins; particularly damaging to seedlings

- **Common cutworm**
  Spodoptera litura
  [Lepidoptera: Noctuidae]
  Damage: feeds on leaves

- **Green peach aphids**
  Myzus persicae
  [Hemiptera: Aphididae]
  Damage: feed directly on young tender plant tissues, causes water stress, wilting, distortion and reduced growth rate of the plant

c. Cucurbits
bottle gourd, ampalaya, squash, patola

- **Ampalaya/Melon fruit fly**
  Bactrocera cucurbitae
  [Diptera: Tephritidae]
  Damage: maggots feed on fruits causing fruit rot and secondary infections

- **Yellow Squash beetle**
  Aulacophora indica
  [Coleoptera: Chrysomelidae]
  Damage: adults feed on leaves while larvae feed on roots

- **28-spotted ladybeetle**
  Epilachna vigintioctopunctata philippinensis
  [Coleoptera: Chrysomelidae]
  Damage: adults and larvae strip the surface layers from both sides of the leaves

d. Solanaceous crops
tomato, eggplant, chili pepper, tobacco

- **Eggplant fruit and shoot borer (EFSB)**
  Leucinodes orbonalis
  [Lepidoptera: Pyralidae]
  Damage: bore and feed in the shoot and fruits of eggplants, leaves fruits hollowed and filled with frass

- **Tomato fruitworm/Tobacco budworm**
  Helicoverpa armigera
  [Lepidoptera: Noctuidae]
  Damage: young larvae feed on tender tomato foliage; mature larvae bore circular holes on tomato fruits and tobacco buds

- **Eggplant flea beetle**
  Psylliodes spp.
  [Coleoptera: Chrysomelidae]
  Damage: feeds on leaves, leaving tiny holes

e. Malvaceous crops
cotton, okra, kenaf

- **Cotton stainers**
  Dysdercus cingulatus, D. poecilus
  [Hemiptera: Pyrrhocoridae]
  Damage: feeds on mature pods and damages seeds when the pods break open

- **Cotton bollworm**
  Helicoverpa armigera
  [Lepidoptera: Noctuidae]
  Damage: feeds on cotton bolls

C. ROOT CROPS

a. Sweet Potato

- **Sweet Potato weevil**
  Cylas formicarius formicarius
  [Coleoptera: Curculionidae]
  Damage: larvae tunnel and feed into vines and tubers, tubers get hollowed and filled with frass, can cause secondary infections

- **Tortoise beetles**
  Cassida circumdata, Aspidomorpha miliaris
  [Coleoptera: Chrysomelidae]
  Damage: larvae and adults feed on leaves

b. Gabi

- **Gabi hornworm**
  Hippotion celerio
  [Lepidoptera: Sphingidae]
  Damage: larvae feed on the foliage, leaving only the veins, causing severe defoliation, may feed on young shoots

D. FRUIT CROPS

a. Mango

- **Mango leafhoppers**
  Idioscopus niveosparus, I. clypealis
  [Hemiptera: Cicadellidae]
  Damage: suck phloem sap from the leaves and inflorescences. affected florets dry up and turn brown

- **Mango twig borers**
  Niphonoclea albata, N. capito
  [Coleoptera: Cerambycidae]
  Damage: bores and feeds on mango tree trunks

- **Mango pulp weevil**
  Sternochetus frigidus
  [Coleoptera: Curculionidae]
  Damage: larvae feed and develop on the pulp

- **Oriental fruit fly**
  Bactrocera dorsalis
  [Diptera: Tephritidae]
  Damage: maggots feed on fruits causing fruit rot and secondary infections, infested young fruit becomes distorted, callused and drop

- **Mango gall midge/Cecid fly**
  Procontarinia spp.
  [Diptera: Cecidomyiidae]
  Damage:
  - ***P. pustulata*** - galls on mango leaves
  - ***P. robusta*** - galls on mango leaves
  - ***P. frugivora*** - feeds on mango fruits

b. Banana

- **Banana aphid**
  Pentalonia nigronervosa
  [Hemiptera: Aphididae]
  Damage: transmit Banana and Abaca bunchy top virus, and Banana bract mosaic virus

- **Banana leafroller**
  Erionota thrax
  [Lepidoptera: Hesperiidae]
  Damage: shred leaves and make numerous rolls of the leaf blade

- **Banana weevil**
  Cosmopolites sordidus
  [Coleoptera: Curculionidae]
  Damage: larvae tunnel in the corm, damaging the root and vascular system

- **Banana thrips**
  Thrips florum
  [Thysanoptera: Thripidae]
  Damage: cause discoloration, malformed buds, and scars the surface of young fruit

c. Citrus

- **Citrus Green locust**
  Melicodes tenebrosa tenebrosa
  [Orthoptera: Acrididae]
  Damage: feeds on citrus leaves

- **Citrus psyllid**
  Diaphorina citri
  [Hemiptera: Psyllidae]
  Damage: transmits pathogens causing citrus greening or leaf mottling

E. PLANTATION CROPS

a. Coconut

- **Rhinoceros beetle**
  Oryctes rhinoceros
  [Coleoptera: Scarabaeidae]
  Damage: adults eat the leaves and burrow into the crown, stunting plant development

- **Asiatic Palm weevil**
  Rhynchophorus ferrugineus
  [Coleoptera: Curculionidae]
  Damage: grubs feed on soft tissues inside the stem and crown, leads to rot and ooze of brown liquid

- **Coconut Leaf beetle**
  Brontispa longissima
  [Coleoptera: Chrysomelidae]
  Damage: feed on the soft tissues of the youngest leaf, leaves dry up, resulting in stunting and reduced coconut production

- **Coconut Scale insect**
  Aspidiotus destructor, A. rigidus
  [Hemiptera: Diaspididae]
  Damage: feeds on the lower leaf surfaces, blocking the stomata and destroying the chlorophyll, tree crown may collapse

b. Coffee

- Coffee berry borer
  Hypothenemus hampei
  [Coleoptera: Scolytidae]
  Damage: larval feeding on the coffee seed causes premature fall of young berries, and increased vulnerability to secondary infection

- **Coffee leaf folder/Tea tortrix**
  Homona coffearia
  [Lepidoptera: Tortricidae]
  Damage: feed on leaves, leaves are webbed together in larval nests

c. Cacao

- **Mosquito bug/Mirid bug**
  Helopeltis spp.
  [Hemiptera: Miridae]
  Damage: pods are deformed and may drop prematurely, also feed on young shoots and branches which cause dieback

- **Pachyrrhynchid weevil**
  Pachyrrhynchus moniliferus
  [Coleoptera: Curculionidae]
  Damage: feeds on cacao pods

d. Sugarcane

- **June beetle/Root grub**
  Leucopholis irrorata
  [Coleoptera: Scarabaeidae]
  Damage: feeds on roots of plants

- **Sugarcane deadheart borer**
  Tetramoera schistaceana
  [Lepidoptera: Tortricidae]
  Damage: larval feeding cause deadheart, distorted shoots, and broken stems

Non-agricultural Insect Pests

a. Medically Important Pests

- **Tiger mosquito/Dengue mosquito**
  Aedes aegypti
  [Diptera: Culicidae]
  Note: sucks blood, transmits dengue, chikungunya and yellow fever virus; has 2 lyre-shaped white marks on thorax

- **Asian tiger mosquito/Dengue mosquito**
  Aedes albopictus
  [Diptera: Culicidae]
  Note: sucks blood, transmits dengue, chikungunya and yellow fever virus; has 1 longitudinal mark on thorax

- **Anopheline mosquito**
  Anopheles flavirostris, Anopheles spp.
  [Diptera: Culicidae]
  Note: sucks blood, transmits protozoans that cause malaria

- **Mosquitoes**
  Culex quinquefasciatus, Aedes poecilus
  [Diptera: Culicidae]
  Note: sucks blood, transmits filarial worms that causes lymphatic filariasis/elephantiasis

- **Human head louse**
  Pediculus humanus capitis
  [Phthiraptera: Anoplura: Pediculidae]
  Note: human parasite, sucks blood

- **Human body louse**
  Pediculus humanus humanus
  [Phthiraptera: Anoplura: Pediculidae]
  Note: human parasite, sucks blood, causes trench fever, relapsing fever and epidemic typhus

- **Crab louse**
  Pthirus pubis
  [Phthiraptera: Anoplura: Pediculidae]
  Note: human parasite, sucks blood

- **Oriental rat flea**
  Xenopsylla cheopis
  [Siphonaptera: Pulicidae]
  Note: vector of Bubonic plague pathogen, *Yersinia pestis* (bacteria)

- **Bedbugs**
  Cimex hemipterus (tropical species),
  Cimex lectularius (temperate species),
  [Hemiptera: Cimicidae]
  Note: human parasite, sucks blood;

- **Common house fly**
  Musca domestica
  [Diptera: Muscidae]
  Note: mechanical vector of pathogens that cause diarrhea, cholera and typhoid fever; causes nuisance to humans and animals

- **Green bottle fly**
  Chrysomya megacephala
  [Diptera: Calliphoridae]
  Note: larvae secretes **allantoin** which helps in wound healing

- **Cockroaches**
  [Blattodea: Blattidae & Blattellidae]
  Note: mechanical vectors of pathogens that cause diarrhea, cholera and typhoid fever
    - *Periplaneta americana* – American cockroach
    - *Blattella germanica* – German cockroach
    - *Blattella asahinai* – Asian cockroach

b. Veterinary Pests

- **Fleas**
  Ctenocephalides felis (cats), *C. canis* (dogs)
  [Siphonaptera: Pulicidae]
  Note: parasites, suck blood and cause irritation

- **Chicken louse**
  [Phthiraptera: Mallophaga: Philopteridae]
  Note: parasites, suck blood and cause irritation

- **Carabao louse**
  [Phthiraptera: Anoplura: Haematopinidae]
  Note: parasites, suck blood and cause irritation

UNIT V: Management and Control of Insect Pests

Integrated Pest Management

– ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties.

Integrated Pest Management Concepts

1. Chemical control should be the last resort

2. Shift from "control" to "management"
"*Control subsumes the effect of elements that act independently of human interference. Management, on the other hand, implies human interference*."
(Kogan, 1998)

3. Addition of the word "Integrated"
"*Integration meant the harmonious use of multiple methods to control single pests as well as the impacts of multiple pests*" (Kogan, 1998)

4. There are decision rules that guide selection of control method
The ETL concept is an ideal decision-making guide. However, threshold levels vary with the stage of the crop, the variety of the crop, the growing conditions and the presence of predators and parasitoids

5. IPM Ecological Principles
The development of IPM is best guided by principles

Control Methods

A. Cultural Methods

– utilization of practices that are normally practiced growing a crop to suppress plant pest populations
– primary objective: to prevent pest damage, not the destruction of an existing and damaging pest population

Requirements to utilize effectively

Thorough understanding of:

- crop phenology
- life cycle of pest
- pest ecology and behavior

Examples of Cultural Control

- crop rotation
- multiple cropping
- tillage
- mulching
- pruning
- use of trap crops or repellent crops
- water management

B. Physical and Mechanical Methods

– using physical mechanical forces to manage pests
– kill pests directly and/or modify environment to be unfavorable for pest survival

a. Physical Methods

1. Physical Agents

- temperature
- moisture
- radiation
- light
- soil pH

2. Moisture/Water Regulation

- hot water treatment
- hot air treatment
- vapor heat treatment (45°c for 10 min)
- refrigeration
- burning

3. Radiation

- UV light
- X–ray

4. Visible Light

- light trap
- solarization
- laser

b. Mechanical Methods

1. Barriers

- modified terrain
- bagging
- screens
- shields

2. Mechanical destruction

- hand picking/hand-weeding
- shaking
- collecting devices
- trapping
- brushing
- swatting
- crushing
- sieving and separation

C. Biological Control Methods

– employment of any biological agent for control of a pest

- **Natural Enemies**

– naturally occurring beneficial organisms that attack or feed on pests

- **Biological Control Agent**

– mass-produced population and released to the environment to keep pests under control and prevent them from causing further economic damage

Characteristics of a Good Biological Control agent

- good searching ability (effective at low concentration)
- amenable to grow in an inexpensive media
- effective against wide range of pests
- non-toxic to human
- non-pest or pathogenic to the crop
- compatible with cultural practices
- resistant to pesticides

Types Biocontrol Agents against Arthropod Pests

a. Predators

– feed on several pest to complete its life cycle
– type of natural enemies which keep the population of their prey in check

Examples:

- **Coccinelid beetle**
  Cheilomenes sexmaculata, *Micraspis discolor*
  [Coleoptera: Coccinelidae]
  feed on aphids
- **Brown lacewing**
  Pseudomicromus igorotus
  [Neuroptera: Hemerobiidae]
  feed on aphids
- **Earwigs**
  Euborellia annulata
  [Dermaptera: Anisolabididae]
  prey on eggs, larvae and pupae of Lepidopterans, Coleopterans & Dipterans
- **Flower bug**
  Orius tantillus
  [Hemiptera: Anthocoridae]
  preys on eggs and larvae of lepidopterans
- **Praying mantis**
  Tenodera spp.
  [Mantodea: Mantidae]
  generalist predator

b. Parasitoids

– lay eggs in or on other insect species (host)
– the immatures kill the host as it feeds on it and develops within the host
– usually smaller than their host

Examples:

- ***Trichogramma evanescens***
  [Hymenoptera: Trichogrammatidae]
  parasitizes Asian corn borer eggs
- ***Xanthopimpla stemmator***
  [Hymenoptera: Ichneumonidae]
  parasitizes striped stem borer larvae
- ***Diadegma semiclausum, D. insulare***
  [Hymenoptera: Ichneumonidae]
  parasitizes diamondback moth (DBM) larvae
- ***Cotesia glomerata, C. plutellae***
  [Hymenoptera: Braconidae]
  parasitizes diamondback moth (DBM) & Asian corn borer (ACB) larvae

c. Pathogens

– debilitating disease-causing microorganisms (fungi, bacteria, virus, protozoans, nematodes, other microbes) that may be fatal

Examples:

- ***Metarhizium anisopliae***
  [Fungi]
  Infects rhinoceros beetle grubs
- ***Beauveria bassiana***
  [Fungi]
  Infects rhinoceros beetle grubs
- ***Bacillus thuringiensis***
  [Bacteria]
  Produces cryotoxins that kill several species of Lepidopteran larvae
- ***Nucleopolyhedrovirus***
  [Virus]
  Infects cutworm and DBM larvae
- ***Heterorhabditis indica***
  [Nematode]
  Attacks cutworms

Approaches to biological control

- **Classical**

– introduction of new species

- **Conservation**

– protection and encouragement of existing BCA
– ecological engineering (modification of environment)

- **Augmentation (Artificial Release)**

▫ ***inundative release***: release of large numbers of a natural enemy such that their population completely overwhelms that of the pest
▫ ***inoculative release***: releasing natural enemies periodically or seasonally

D. Host Plant Resistance Methods

- focused on plants' ability to resist insect invasions (damaging)
- some plants use their physical appearance as a deterrent such as plants that have hairs covering their leaves of plants with thick cuticle

Mechanisms of Host Plant Resistance

- **Anti-xenosis (non-preference)**
  - pest does not want to feed on the plant due to the plant's morphological or biochemical characteristics

- **Antibiosis**
  - plant contains toxic metabolites that may affect the physiology of the pest; absence or imbalance of essential nutrients

- **Tolerance**
  - plant is still capable of producing normal yield despite the pest infestation; plant can compensate for the damage

E. Biotechnological Methods

- utilization of living organisms (plants/animals) to improve the quality of plants or animals
- use of Genetically Modified Organisms (GMOs)

F. Autocidal Control Methods

- introduction of sterile or genetically altered individuals into the wild population
- use of sterile insect technique
- involves tactics that cause the pest to contribute to the destruction of its own population

- **Male Sterile Technique**
  - sterile male insects are released to the population
  - sterile male insects compete with fertile males

Pests where Sterile Insect technique was used

- Screw worms (livestock pest)
- Fruit flies
- Mosquitoes

G. Behavioral Control

- involves tactics that affect the behavior of pests which result to the reduction of pest population

- **Chemical Attractants**
  - substances that cause insects to make oriented movement toward the source
  - e.g., pheromones

- **Repellents**
  - chemicals that cause insects to make oriented movements away from its source
  - e.g., Off lotion, *katol*

H. Legal or Regulatory Control

- all forms of legislations and regulations preventing entry, establishments and spread of a pest organism

Fundamental Objectives

- Prevent the entry and establishment of foreign plant and animal pests in a country or geographic area

- Eradicate/contain/suppress pests that have established in a limited area through legal means

I. Chemical Control Methods

- control based on substances that are toxic to the pests at target
- should be the last resort in integrated pest management (IPM) unless severe pest incidence occurred as insects may develop resistance

Pesticide

- any chemical substance used to control or kill pest
- pesticides should be registered under Fertilizer and Pesticide Authority (FPA)

Pesticide Principles

- toxicity is dose related
- pest populations are heterogenous and there is dynamic exchange of genes among local populations

Advantages of Pesticide Use

- fast curative action in preventing economic damage
- have a wide range of properties, uses and method of application to varied pest situation
- easy to access and simple to use

Disadvantages of Pesticide Use

- may cause pesticide resistance
- destruction of beneficial species
- outbreak of secondary pests
- chemical residue hazards
- environmental degradation
- increase in production cost

Pesticide label

– a written material or graphic design printed on the pesticide container
– required by law to provide the expiry date, a.i. mode of action and resistance management statement in the label

Pesticide Formulations

– mixture of active ingredient (a.i.) and inert ingredients

Purpose of formulations

- increase pesticide effectiveness
- improve safety features of pesticide
- enhance the handling qualities of pesticide

Spray Mix Terminologies

- **Solution**

– formulated product that dissolves in water

- **Suspension**

– a mixture of finely divided solid particles *dispersed in* a liquid.
– the solid particles do not dissolve in the liquid

- **Emulsion**

– a mixture that occurs when one liquid is dispersed (as droplets) in another liquid
– "milky appearance"

A	= Aerosol	PS	= Pellets
AF	= Aqueous flowable	RTU	= Ready-to-use
B	= Bait	S	= Solution
C	= Concentrate	SP	= Soluble powder (or soluble packet; see WSP)
D	= Dust	ULV	= Ultra-low volume
DF	= Dry flowables (see WDG)	W	= Wettable powder
E	= Emulsifiable concentrate	WDG	= Water-dispersible granules (see DF)
EC	= Emulsifiable concentrate	WP	= Wettable powder
F	= Flowable	WS	= Water soluble
G	= Granules	WSB	= Water-soluble bag (see WSP: water-soluble packet)
GL	= Gel	WSC	= Water-soluble concentrate
L	= Liquid	WSL	= Water-soluble liquid
LC	= Liquid concentrate	WSP	= Water-soluble powder (or water-soluble packet; see WSB)
LV	= Low volatile		
M	= Microencapsulated		
P	= Pellets		

List of abbreviations of common pesticide formulation

Major Types of Formulation & their Uses

- **Aqueous concentrates (AC)**

– active materials that readily dissolve in water but not in organic solvents
– usually creates true solutions which are homogenous mixtures of two or more substances

- **Emulsifiable concentrates (EC)**

– active materials are dissolved in small amounts of organic solvents
– emulsifying agents are added to the organic solvents carrying the active material such that if mixture is shaken with water it will break up into small droplets that will remain dispersed in water to form an emulsion

- **Wettable powders (WP)**

– if a.i. is not soluble in water or organic solvent, it is formulated as finely ground powder
– will form a suspension when mixed with water in the presence of a dispersing agent

- **Granules (G) or Pellets**

– the a.i. is combined with inert ingredients and/or carries formed into particles about the size of coarse sugar or pellets

- **Dusts (D)**

– usually contains 4-10% active ingredient and applied in a dry form

- **Fumigants**
  - formulated as dry solids or liquids which will liberate the toxic material in the form of gas or smoke upon mixture with another substance

- **Aerosols (A)**
  - the active ingredient is suspended in a pressurized container

- **Flowables (F)**
  - active material and diluent are ground to near colloidal dimensions, suspended in a small amount of liquid

- **ULV concentrates**
  - designed to be applied at very low volumes per hectare

Pesticide Classifications

a. Based on the Target Group of Pests

- **Insecticides** – insects
- **Fungicides** - fungal pathogens
- **Herbicides** – weeds
- **Nematicides** – nematodes
- **Molluscicide** – snails (mollusk)
- **Rodenticides** – rodents (rats and mice)
- **Acaricide** – mites
- **Avicide** - birds

b. Based on Hazards to Humans

Depiction				
Colour of lower triangle	Bright red	Bright yellow	Bright blue	Bright green
Toxicity class	Extremely toxic	Highly toxic	Moderately toxic	Slightly toxic
Oral LD_{50} value (mg/kg	<50	51-500	501-5000	>5000
Signal words (Upper half)	POISON (In red)	POISON (In red)	DANGER	CAUTION
Warning words (Outside the diamond)	Keep out of reach of children. If swallowed or symptoms of poisoning occur, call doctor.	Keep out of the reach of children.	Keep out of the reach of children.	---

c. Based on the Mobility of the a.i. in the plant

- Contact
- Systemic

d. Based on Range of Activity

- Broad spectrum or non-selective
- Selective

e. Based on the Chemical Grouping and Mode of Action

- **Mode of Action (MoA)**
  - the process by which pesticide kills or inhibit growth of a pest

- **Target site of action**
  - the specific location by which pesticide acted on the pest

Major Chemical Groupings:

- **Organochlorines**
  - **MoA:** opens Na^+ ion channels in neurons, causing to fire spontaneously
  - inhibits chloride flow in neurons
  - Example: DDT, Endrin, Endosulfan, Chlordane, Heptachlor, Mirex

- **Organophosphates**
  - **MoA:** disrupts acetylcholinesterase
  - leads to overstimulation of muscarinic and nicotinic receptors
  - nerve poisons
  - esters of phosphoric/ phosphorichloric acid
  - Example: Phosdrin, Malathion, Parathion

- **Carbamates**
  - **MoA:** similar action to organophosphate but more degradable
  - Example: Carbofuran, Aldicard, Furadan, Sevin

- **Pyrethroids**

– **MoA:** disrupt insects' nervous system; axonic excitotoxins

– from pyrethrum flowers; safe to operators; non- systemic

– Example: Cypermethrin, Bioremethrin

- **Insect growth regulators**

– **MoA:** juvenile hormones inhibit the molting process/ chitin synthesis of insects

– Inhibits chloride flow in neurons

– Example: Diflubenzuron, Phenoxycarb, Chlorfluazon, Methoprene

Insecticide Resistance

– ability of an insect species to tolerate or counteract the effects of an insecticide that would normally kill susceptible populations of the same insect species

– a heritable change in sensitivity of a pest population that is reflected in the repeated failure of a product to achieve control of the pest (IRAC, 2020)

Types of Insecticide Resistance

- **Physiological Resistance**

– insects are able to detoxify toxins due to presence of enzyme

- **Behavioral Resistance**

– insects are able to detect toxins and are able to hide and avoid the chemicals

Types of Insecticide Resistance (based on MoA of insecticides)

- **Cross Resistance**

– enables resistant insects to survive exposure to related insecticides (with the same MoA)

- **Multiple Resistance**

– resistance to insecticides with different mode of actions

Strategies for Resistance Management

- monitor pest population to know if it already necessary to use pesticide
- use different classes or groups of pesticide with different mode of action
- reduce or avoid use of pesticides and practice good area wide IPM program
- use of transgenic or resistant crop variety
- use an appropriate synergist to increase effectiveness without increasing the dosage of pesticide

UNIT VI: CALCULATIONS

Pesticide Calculations

– refer to the determination of the required amount of pesticide needed in an area

Common conversion factors

- 1 hectare (ha) = 10,000 square meters (m^2)
- 1 kilogram (kg) = 1,000 grams (g)
- 1 liter = 1,000 milliliters (ml)
- 1 tablespoon = 10 ml
- 1 ppm = 1mg/L, etc.
- 1 g = 1 ml
- 1kg = 1L

Recommended Rate Computation

Scenario 1: To calculate the spray volume (in liters per hectare), the following information are needed: size of sprayer (liters), area of the field (hectare) and the number of sprayer load.

Sample Problem 1:

Yami has a 16-L sprayer load capacity, and he applies 13 loads to a 0.5-hectare field. Calculate the spray volume (liters/ha) of Alexander in the field?

Solution: (16 liters (size of the sprayer load) x 13 load)/0.5 ha = 416 liters/ha

Sample Problem 2:

Makima has a 16-L sprayer load capacity and wishes to apply the pesticide at a rate of 150 liters/hectare in a 0.75-hectare field. How many sprayer loads are needed?

Solution: (150 liters/ha (desired spray volume) x 0.75 (area of the field))/16 L (size of the sprayer load)
= <u>7.03 or 7 sprayer loads</u>

Sample Problem 3:

Felix Kjellberg wishes to apply 400 liters of spray solution per hectare to a 0.75-hectare field using a 20-L sprayer load. The recommended spray concentration is 0.5% of the 45 EC herbicide. How many liters of the commercial pesticide formulation is needed for the said treatment of Felix in a corn field infested with ACB?

1. **Calculate the amount of spray volume needed for the treated area.**

   = Volume of spray solution applied (liters) x area to be treated (hectares)
   400 liters x 0.75 hectare = 300 liters

2. **Calculate the amount of commercial formulated product.**

   = (Spray volume required x Recommended concentration)/(% AI in the Formulation)
   = (300 liters x 0.005)/(0.45) = 3.33 liters

3. **Calculate the amount of commercial material per sprayer load.**

   = (Liters of commercial formulation x capacity of sprayer load (liters))/amount of spray required (liters)
   = (3.33 liters x 20-L)/300 liters = 0.222 kg.

Try to answer the following problems:

1. Shane Madej wishes to apply 320 liters of spray solution/ha to a 0.5 ha area. The recommended rate of the 50% wettable powder is 0.75 kg A.I./ha.

   How many kilograms of the commercial formulation is needed to treat the 0.5-ha field. What is the volume of spray needed for the treated area? How much materials are applied per sprayer load if Shane utilizes a sprayer load capacity of 20 liters?

2. Mhiema wishes to apply pesticide granules at a rate of 0.6 kg ai/ha to a 2-ha field. The granules contain 3% ai. How many kilograms of commercial formulation are needed to treat this area?

UNIT VII: NON-INSECT PESTS

<u>Mollusks Pests in the Philippines</u>

Golden Apple Snail
Pomacea canaliculata L.

Economic Importance

- golden kuhol as an important pest of rice and other aquatic plants
- 14-to-24-day old seedlings are more susceptible to golden kuhol snail attack
- beyond 6 weeks, seedlings are hardly eaten
- snails carry parasites of man and animals (hosts of internal fluke, lungworm and other parasites)

Management of Golden Apple Snail

- Chemical control (use of molluscicides)
- Mechanical control (wire screens to prevent field transfer)
- Biological control (use ducks and other BCA)
- Use of botanical extracts

Avian Pests in the Philippines

- rice-eating birds that chew the rice grains during the MILKY PHASE, or eat the entire grain once mature
- a damage indicator is the presence of milky-white substance covering the grains
- great loss in crop yield

- **Eurasian Tree Sparrow**
  Passer montanus
- significant pest to the food industry due to the risk of contamination from their droppings and damage done to damaged goods
- less than 6" long
- lives for 4-7 years, with 5 breeding seasons

Other avian pests:

- **Scaly-breasted Munia**
  Lonchura punctulata
- **Chestnut Manikin**
  Lonchura malacca
- **White-bellied Manikin**
  Lonchura leucogastra
- **Java Rice Sparrow**
  Lonchura oryzivora
- **Black-headed Munia**
  Lonchura atricapilla

Rodent Pests in the Philippines

Rodents

- characterized by pair of sharp front teeth (incisors) in both upper and lower jaws
- no canines
- a conspicuous gap between the front teeth and the molars
- incisors are strongly curved with a thick layer of enamel on only one side and grow continuously throughout life

Ecological and social importance

- **Pests**
- major competitor for food
- cause significant loss to crops
- prefers rice •cuts tillers and panicles
- pulls rice seedlings

- **Human Disease Carrier**
- Bubonic Plague (host of oriental rat fleas)
- Salmonellosis
- Leptospirosis
- Rat-bite fever
- Oriental Schistosomiasis

- **Social importance**
- experimental animals
- used for drug testing
- serves as food

Food and feeding behavior

- commensals have taste patterns similar to humans
- omnivorous, consuming food wastes
- adults eat 8-10% of their weight

Population Growth

- high reproductive rate
- young develop rapidly
- pregnancy period (19-21 days)
- give birth every three weeks
- young mature at about 6 weeks of age
- average litter size of 12
- a female can produce 36 young/rice season
- cropping seasons affect breeding and population size

Rodent Species in the Philippines

- **Oriental house rat**
  Rattus tanezumi

– Habitat: throughout the country; fields and storage
– Tail to body ratio: uniformly dark tail longer than head plus body
– Special characteristics: common rice pest; Medium sized averaging about 175 g
– Mammary formula: 2+3=10

- **Rice field rat**
  Rattus argentiventer

– Habitat: - Mindanao and Mindoro - fields
– Tail to body ratio: tail shorter than head plus body
– Special characteristics: tuft of orange hair near base of ear; Generally smaller than *R. tanezumi*
– Mammary formula: 3+3=12

- **Polynesian rat**
  Rattus exulans

– Habitat: - grasslands, houses, warehouses
– tail to body ratio: tail nearly as long as head plus body
– Special characteristics: agile climber; smaller than *R. tanezumi and R. argentiventer* than *R. tanezumi*
– Mammary formula: 2+2=8

- **Southeastern Asian house mouse**
  Mus musculus domesticus

– Habitat: - Houses and wood structures
– Tail to body ratio: tail length equal to longer than head plus body
– Special characteristics: common house mouse and important pest in urban areas; gnaws wood structures and feeds on grains; smaller than *R. exulans*; weighs 12 g

- **Norway rat/Common rat**
  Rattus norvegicus

– Habitat: - Found throughout the Philippines
– Tail to body ratio: Thick tail, shorter than head plus body; Long vibrissae on snout
– Special characteristics: Commensal with man; Classified urban pest in public health; food storage; structural damage; garbage disposal
– Mammary formula: 3+3=12

Rodent Management

a. Cultural Control

- clean cultivation
- habitat reduction
- synchronous planting

b. Physical/Mechanical Control

- digging burrows
- smoking and watering
- irrigation and plowing after harvest
- community trap barrier system

c. Biological control

- predators
- birds & mammals

d. Chemical control

- acute poison
- chronic poison/anticoagulants
- fumigants/toxic gas
- repellents

i. Acute poison

– highly toxic
– single dose killer
– kills within few hours
– zinc phosphide, barium carbonate, arsenious oxide
– baits with less the 2% zinc phosphide
– rats develop poison aversion of bait shyness

ii. Chronic poison/anticoagulants

- interfere with blood clotting mechanism
- rodents die due to internal bleeding
- slow acting bait this bait shyness does not develop
- warfarin, fumarin, calciferol
- saturation baiting and sustain baiting is necessary
- bait point needs to be replenished until feeding stopped

iii. Fumigants/toxic gas

- calcium cyanide, ethylene dichloride, carbon tetrachloride methyl bromide, aluminum phosphide
- effective only in airtight situations
- needs special equipment for application
- not suitable for field use
- repellents endrin as a rodent repellent to protect seeds

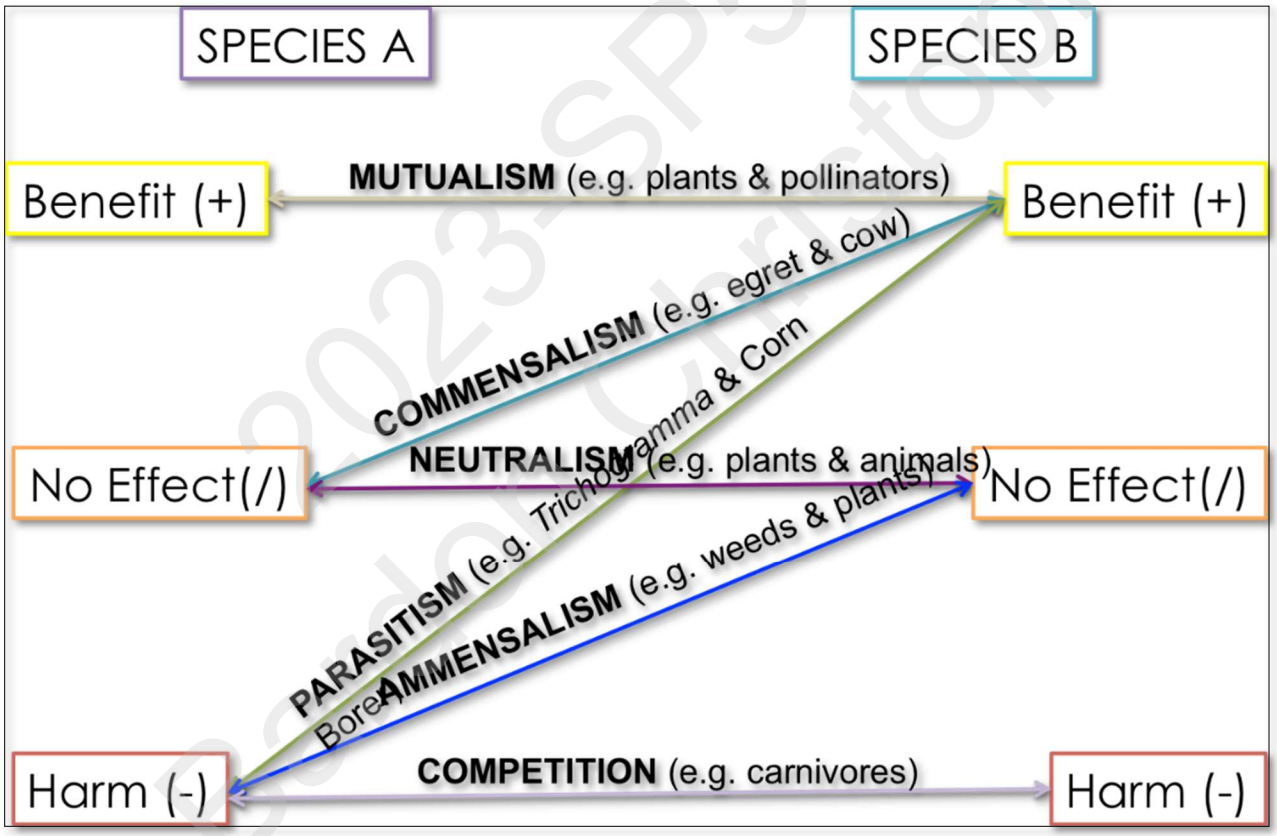


Diagram of ecological relationships between organisms.

List of Banned Pesticides in the Philippines

List of Banned Pesticides in the Philippines	
NAME OF CHEMICALS	**DETAILS OF RESTRICTION (Please refer to the following circulars and resolutions)**
1-Naphthylthiourea (ANTU)	Banned as per FPA Circular No. 04, Series of 1989.
2, 4, 5-T	Banned as per FPA Circular No. 04, Series of 1989.
Aldrin	Banned as per FPA Circular No. 4, Series of 1989 (Banned since 1989. There are alternatives to aldrin as prescribed by UNEP).
Azinphos Ethyl	Banned as per FPA Resolution No. 01, Series of 1993.
Chlordane	Banned as per FPA Resolution No. 01, Series of 1999.
Chlordimeform	Banned as per FPA Circular No. 04, Series of 1989.
Copper(II) Acetoaresenite (Paris Green)	Banned as per FPA Circular No. 04, Series of 1989.
DBCP	Banned as per FPA Circular No. 04, Series of 1989.
DDT	Banned as per FPA Board Resolution No. 04, Series of 2005.
Deltamethrin	Banned as per FPA Memorandum Circular No.1, Series of 2019. (Banning of the use of Deltamethrin in Banana)
Dieldrin	Banned as per FPA Circular No. 4, Series of 1989 (Banned since 1989. There are alternatives to dieldrin as prescribed by UNEP).
Elemental Phosphorus (White & Yellow)	Banned as per FPA Circular No. 04, Series of 1989.
Endosulfan	Banned as per FPA Board Resolution No. 01, Series of 2015.
Endrin	Banned as per FPA Circular No. 4, Series of 1989 (Banned since 1989. There are alternatives to endrin as prescribed by UNEP).
EPN	Banned as per FPA Circular No. 04, Series of 1989.
Ethylene Dibromide (EDB)	Banned as per FPA Circular No. 04, Series of 1989.
Fipronil	Banned as per FPA Memorandum Circular No.29, Series of 2018. (Banning of the use of Fipronil in Banana)
Gophacide	Banned as per FPA Circular No. 04, Series of 1989.
HCH/BHC	Banned as per FPA Circular No. 04, Series of 1989.
Heptachlor	Banned as per FPA Circular No. 4, Series of 1989 (Banned since 1989. There are alternatives to heptachlor as prescribed by UNEP).
Leptophos	Banned as per FPA Circular No. 04, Series of 1989.
Mercuric Fungicides	Banned as per FPA Circular No. 04, Series of 1989.
Nitrofen	Banned as per FPA Circular No. 04, Series of 1989.
Organotin Compounds	Banned as per FPA Resolution No. 01, Series of 1993.
Parathion-ethyl	Banned as per FPA Circular No. 04, Series of 1989.
Parathion-methyl	Banned as per FPA Resolution No. 01, Series of 1993.
2-Fluoroacetamide (1081)	Banned as per FPA Circular No. 04, Series of 1989.
Sodium Fluoroacetate	Banned as per FPA Circular No. 04, Series of 1989.
Strychnine	Banned as per FPA Circular No. 04, Series of 1989.
Thallium Sulfate	Banned as per FPA Circular No. 04, Series of 1989.
Toxaphene/ Camphechlor	Banned as per FPA Circular No. 4, Series of 1989 (Banned since 1989. There are alternatives to toxaphene as prescribed by UNEP).
Triphenyltin	Banned as per FPA Circular No. 04, Series of 1989.

Source: http://fpa.da.gov.ph/index.php/information-resources-momo/pesticide-regulatory-data

List of Restricted Pesticides in the Philippines

List of Restricted Pesticides in the Philippines		
NAME OF CHEMICALS	**DETAILS OF RESTRICTION (Please refer to the following circulars and resolutions)**	**IMPORTANT NOTES**
Pentachlorophenol (PCP)	Restricted as per FPA Circular No. 04 Series of 1989	*(Severely Restricted)* For use in wood treatment only by FPA Accredited wood treatments plants and institutions.
Aldicarb	Restricted as per FPA Circular No. 04 Series of 1989	Importation not allowed except in cases of emergency as determined by the authority.
Carbon Disulfide	Restricted as per FPA Circular No. 04 Series of 1989	Adequate time for aeration is required after treatment before commodities are processed into food or feed.
Carbon Tetrachloride	Restricted as per FPA Circular No. 04 Series of 1989	Adequate time for aeration is required after treatment before commodities are processed into food or feed.
Chlorobenzilate	Restricted as per FPA Circular No. 04 Series of 1989	Importation not allowed except in cases of emergency as determined by the authority.
Chloroform	Restricted as per FPA Circular No. 04 Series of 1989	Adequate time for aeration is required after treatment before commodities are processed into food or feed.
Entropop	Restricted as per FPA Circular No. 04 Series of 1989	For use in banana plantations only.
Ethyl formate	Restricted as per FPA Circular No. 04 Series of 1989	Adequate time for aeration is required after treatment before commodities are processed into food or feed.
HCN Generating Materials	Restricted as per FPA Circular No. 04 Series of 1989	Adequate time for aeration is required after treatment before commodities are processed into food or feed.
Inorganic Arsenicals (Arsenic Trioxide)	Restricted as per FPA Circular No. 04 Series of 1989	For use by FPA Accredited wood treatment and wood preserving plants only.
Lindane (Gamma-BHC)	Restricted as per FPA Circular No. 04 Series of 1989	The only allowed use to date is on pineapple plantations by soil pre-plant application.
Methidathion	Restricted as per FPA Circular No. 04 Series of 1989	For use in banana plantations only.
Methyl Bromide	Restricted as per FPA Circular No. 04 Series of 1989	Adequate time for aeration is required after treatment before commodities are processed into food or feed.
Monocrotophos	Restricted as per FPA Resolution No. 01, Series of 1993.	Allowed use is for beanfly control on legumes only.
Paraquat	Restricted as per FPA Circular No. 04 Series of 1989	Restricted for institutional Use Only. Approval of use will be based on strick compliance by the imported/end-user of the requirements act for its use.
Phenamiphos	Restricted as per FPA Circular No. 04 Series of 1989	For use in banana and pineapple plantations.
Phosphine Generating Compounds	Restricted as per FPA Circular No. 04 Series of 1989	Adequate time for aeration is required after treatment before commodities are processed into food or feed.

Source: http://fpa.da.gov.ph/index.php/information-resources-momo/pesticide-regulatory-data

PLANT PATHOLOGY

"pathos" = suffering; *"logos"* = to study

UNIT I: INTRODUCTION

Definition

Study of the organisms and of the environmental factors that cause disease in plants; of the mechanisms by which these factors induce disease in plants; and of the methods of preventing or controlling disease and reducing the damage it causes

Defined as a **SCIENCE** because it seeks to understand the NATURE of plant diseases

a. Disease characteristics
b. Agents, Host pathogen interaction
c. Disease development, and its Control measures

Defined as an **ART** because it is the application of knowledge gained from studying the nature of plant diseases (process where science is made useful)

d. Diagnosis and assessment
e. Forecasting and prevention
f. Pesticide application
g. Pest management

Ultimate Goal:
Control or manage plant diseases so that losses will be brought at minimum

Prominent Plant Diseases in World History

Late Blight Disease of Potato
(*Phytophthora infestans*)

- devastated Northeastern Europe as potato is its staple crop
- 1845 - observed in Belgium, Holland, England, and Ireland (25% losses incurred)
- 1846 - total crop failure in Ireland caused the Irish Famine

Coffee Rust in Ceylon (now Sri Lanka)
(*Hemilea vastatrix*)

- 1835 - British people planted 200 ha
- 1875 - booming economy (200,000 ha; 50M kg/ year)
- destroyed coffee plantations; tea was planted instead

Ergot of Rye
(*Claviceps purpurea*)

- from the french word "*argot*" meaning "spur"
- produces alkaloids including lsd (Lysergic Acid Diethylamidel, a well-known hallucinogenic drug
- caused abortion, tingling sensation, fever, gangrene, convulsions, halucinations
- 1722 – influenced the outcome of a war in Astrakhan, the army of Peter the Great of Russia (20,000 soldiers) died from consuming bread made from severely infected wheat

Bengal Famine
(*Helminthosporium oryzae*)

- Brown Spot of Rice
- Bangladesh; 50% yield loss for early maturing varieties; 75-90% yield loss for late maturing varieties

Prominent Plant Diseases in Philippine History

Cadang-cadang disease of coconut

- Caused by a viroid
- First observed in 1918; loss amounted to >$200M; killed 15M trees

Downey Mildew of Corn
(Peronosclerospora philippinensis)

- annual yield loss reached 95% amounting to p170m
- controlled by the seed treatment using Metalaxyl

Rice Tungro

- caused by a *Rice Tungro Bacilliform Virus* (RTBV) and *Rice Tungro Spherical Virus* (RTSV)
- affected 70,000 hectares in 1971
- losses of 1.22M canvas of rice valued at more than P30M

Coffee Rust
(Hemileaia vastatrix)

- destroyed Coffee Industry in Batangas

Citrus Decline
(Tylenchulus semipenetrans)

- wiped out Citrus plantations in Batangas

DISEASE	CAUSAL AGENT	HOST	IMPACT
Ergotism	*Claviceps purpurea*	*Triticum aetivum*	Sickness and disease in humans
Late Blight	*Phythopthora infestans*	Potato	Irish Famine
Coffee Rust	*Hemeleia vastatrix*	Coffee	Switch to Tea
Cadang-Cadang	*Cadang Cadang Viroid*	Coconut	200 M USD in losses
Rice Tungro	*Rice Tungro Bacilliform Virus Rice Tungro Spherical Virus*	Rice	1.22 M cavans lost, 30M php in losses
Downy Mildew	*Peronosclerospora philippinensis*	Corn	170 M Php losses annually

Threats Imposed by Plant Diseases

- endanger food supply
- reduce quantity and quality of plant produce
- cause financial losses
- limit the kinds of plants and industries in an area
- make some infected plants poisonous to humans
- increase cost of production due to control measures

Types of Crop Losses

- yield reduction
- postharvest losses
- quality reduction
- toxin contamination
- susceptibility/ predisposition of host attack
- increase in production cost and handling

UNIT II: HISTORICAL DEVELOPMENT OF PLANT PATHOLOGY

Pre-Scientific Period

- Fossil Records
- Ancient Writings
- **HOMER** - 1000 BC; mentioned therapeutic properties of **Sulfur** in plant diseases
- **BIBLE (stated)-** 750 BC; time of Joseph the dreamer- **Wheat Rust**;
  - **Egypt**- warm and windy **Mildews, Blasts, and Blights of Cereals**

Great Philosophers

- **DEMOCRITUS** - 470 bc, noted Plant Blights and described ways to control it
- **PLINY THE ELDER** - wrote about blights and rusts in *Historia naturalis*
- **THEOPHRASTUS** - 370-286 bc, Father of Botany

- first to make plants and plant diseases as subjects of systematic study
- wrote *The Nature of Plants* (morphology and anatomy of plants, descriptions of wild and cultivated plants, and *Reasons of Vegetable Growth*

- **GREEKS and HEBREWS** - 500-280 BC; diseases are punishments to sins due to bad weather and unfavorable conditions
- **ROMANS** - 320 bc-475 AD; held an annual festival called *Robigalia* in an attempt to please and pacify the Rust God, *Robigus*, so that he would not send the rusts to destroy their crops
- **Ergot of Rye and Wheat Epidemic in Europe** - also known as the *Holy Fire* or *St. Anthony's Fire* due to the initial burning sensation felt by the persons afflicted with Ergotism; believed as punishment of man's sins

Beginnings of Scientific Studies

- **Theory of Spontaneous Generation (Autogenetic Theory of Disease)**
  - **FRANZ UNGER**
  - "When plants are in the declining phase, the cellular constituents CALL FORTH NEW FORMS OF LIFE by vital force
  - **The pathogen is a result and not the cause of the disease**
  - Some beliefs in the origin of life:
    - Frogs are from mud in the ponds
    - Maggots are from decaying meat
    - Yeasts are from fermented grape juice
    - Rats are from piles of old clothing
- **Experiments to Disprove the Theory of Spontaneous Generation**
  - **REDI (1688)** - covered mouth of vessel containing meat with a screen; maggots develop only from eggs of flies and never in meat when flies were kept away
  - **SPALLANZANI (1777)** - bacteria did not develop in food materials that have been boiled for some time and sealed away from air; air is essential for spontaneous generation
  - **SCHULZE (1836)** - passed air through Sulfuric Acid; introduction of air did not induce development of bacteria
  - **SCHWANN (1837)** - passed air through hot tubes
  - **SCHRODER and DUSCH (1854) -** filtered air through sterile cotton

Germ Theory of Disease

- **LOUIS PASTEUR**
  - "All living things must come from pre-existing parents"
  - **"Microorganisms cause the disease and not the effect of the disease"**
- **PIER ANTONIO MICHELLI (1729)-** described many genera of fungi; believed that fungi arose from their own spores; used bunt infected wheat seeds
- **ROBERT HOOKE (1660)-** invented early compound microscope (double-lensed); examined thin slices of cork and called it "*cell*"; findings published in *Micrographia*
- **THOULLIER (1670)-** observed that Ergotism did not spread from one person to another but seemed to be associated with the consumption of contaminated grains
- **ANTOINE van LEEWUENHOEK (1683)-** first to describe bacteria from teeth scrapings and protozoans from pond water
- **TILLET (1755)-** noted that dust from smutted wheat mixed with healthy seeds resulted in smutted wheat plants; noted that he could reduce the number of smutted wheat plants produced by treating the smut-treated kernels with Copper Sulfate
- **PREVOST (1807)-** repeated Tillet's experiment and had the same results; observed and treated smut spores under the microscope

Etiological Period

- Microorganism were discussed to be associated with plant diseases
  - **NEEDHAM (1743)-** observed nematodes (*Anguina tritici*) in Wheat Kernels
  - **TARGIONI-TOZZET (1766) and FONTANA (1767)-** studied cereal ust and concluded that rust fungi is associated with the disease
  - **HEINRICH ANTON de BARY (1853)-** ***Father of Plant Pathology***, studied *Phytophtora infestans*, causal organism of Potato Late Blight; proved that stem rust of wheat (*Puccinia graminis* f.sp. *tritici*) needs an alternate host (Barberry; where fruiting bodies are formed) to complete its life cycle
  - **THOMAS JONATHAN BURILL (1978-1883)-** studied Apple and Pear Blight (*Erwinia amylovora*)
  - **MAYER (1886)-** found out that Tobacco Mosaic (*Tobacco Mosaic Virus*) can be reproduced by inoculating sap of diseased plant to a healthy plant
  - **IVANOWSKI (1892)-** demonstrated the filetrable nature of TMV
  - **BEIJERINCK (1898)-** coined the name "*Tobacco Mosaic Virus*"
  - **BAWDEN (1935)-** crystallized TMV
  - **DOI, TERENAKA, YORA, and ASUYAMA (1967)-** discovered the association of mycoplasma-like organisms (MLOs)/ Phytoplasmas in mulberry dwarf, potato witches' broom and aster yellows
  - **DAVIS, WHOELEY, WHITCOMB, ISHIYAMA, STEERE (1972)-** observed spiroplasmas associated with Corn Stunt Disease

Other Important Discoveries

- **PIERRE MARIE ALEXIS MILLARDET, ULYSSE GUYON (1882)-** discovered the Bordeaux Mixture, a fungicide made from Copper Sulfate + Lime, used to control the downy mildew of grapes
- **1960-** start of mycotoxin research due to the death of turkey poults in London, England (Turkey X Disease); caused by *Aspergillus flavus*

Plant Pathology in the Philippines

- **1910** – first course in Plant Pathology was taught as Botany 4 under the Agronomy Department
- **1914- Baker**- published *The Lower Fungi of the Philippines,* a review of Philippine Plant Diseases
- **1917-** Department of Plant Pathology was born and the course offered was Plant Pathology
- **1917- Otto Reinking**- first department head
- **1933- Gerardo Ocfemia**- Dean of Filipino Plant Pathologists; First Filipino Department Head
- **1885-1890- Batangas Coffee Rust** (*Hemileia vastatrix*)
- **1908- E.B. Copeland**- Coconut Bud Rot (*Phytophtora palmivora*)
- **1911- Robinson**- Corn Leaf Blight (*Helminthosporium maydis*)
- **1912- Baker**; **1920-1923-Weston**- Downy Mildew of Corn (*Peronosclerospora philippinensis*)
- **1920-1940 - G.O. Ocfemia**- Abaca Bunchy Top
- **1950-1960**- studies on the etiology and control of leaf and seedling diseases; development program in upgrading staff and physical facilities
- **1963 -** formation of Philippine Phytopathological Society
- **1970**- establishment of the Surveillance and Early Warning Systems by the Bureau of Plant Industry (BPI)
- **1978** - **Exconde et al**- controlled the Corn Downey Mildew by seed treatment using **Metalaxyl**
- **1983** - **Romulo Davide**- developed biocon *Paecilomyces lilacinus* against nematodes

UNIT III: CONCEPTS OF A PLANT DISEASE

Plant Disease

- "Physical malfunction caused by animate agents" (Whetzel, 1929)
- "Any deviation from normal growth or structure of plants that is efficiently pronounced and permanent to produce visible symptoms to impair quality or economic value." (Stakman & Harrar, 1957)
- A malfunctioning process caused by continuous irritation." (Horsfall & Dimond)
- "Any malfunctioning of host cells and tissues that results from continuous irritation by a pathogen or an environmental actor and leads to the development of symptoms

Classification

- rational grouping of plant diseases is helpful in the identification and subsequent of a particular disease

Affected plant organ

- root diseases, foliage diseases, fruit diseases

Symptom

- leaf spots, rusts, smuts, anthracnoses, mosaic, wilts, rots

Type of affected plant/host

- vegetable diseases, diseases of field crops, diseases of ornamentals

Type of pathogen

- *Infectious/Biotic*
  - Viral, Bacterial; caused by viroids, protozoa, parasitic flowering plants
- *Non-infectious/Biotic*
  - Extremely high temperatures, air pollution, pesticide toxicity

Common Terms

Pathogen - any agent (biotic or abiotic) that causes a disease. The term is generally used to refer to a living organism.

Host - a plant being attacked by a parasite. A food relationship with a parasite (pathogen) is implied

Suscept – a plant that is susceptible to a disease whether or not the pathogen is parasitic

Parasite - an organism which depends wholly or partly on another living organism for its food. Most parasites are pathogens.

Saprophyte - an organism that lives on dead organic or inorganic matter

Facultative Saprophyte - an organism which has the ability to become a saprophyte but is ordinarily a parasite

Facultative Parasite - an organism which has the ability to become a parasite but is ordinarily a saprophyte

Obligate Parasite - an organism that subsists only in living organisms and attacks only living tissues

Obligate Saprophyte – an organism that only subsists on and attacks dead tissue

Pathogenicity - capacity of a pathogen to cause disease

Pathogenesis - disease development in the plant

Virulence - quantitative amount of disease that an isolate of a given pathogen can cause in a given group of plants in terms of size or number of lesions

Aggressiveness - measures the rate of virulence expressed by a pathogenic isolate

Susceptibility - inability to overcome the effects of a pathogen; Opposite of resistance

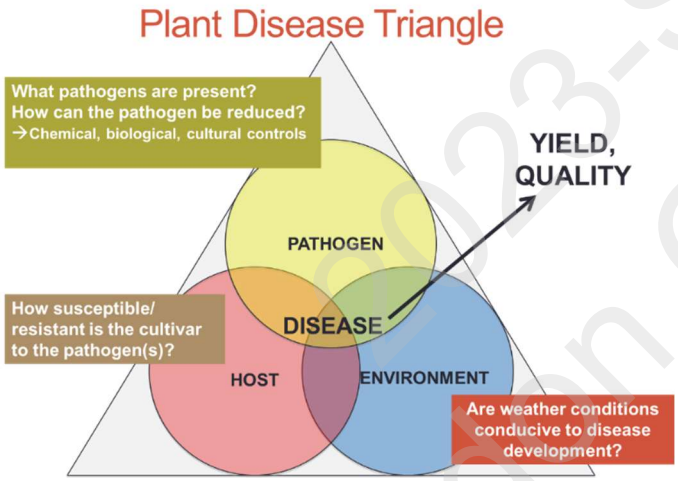
Disease resistance - inherent ability of an organism to overcome effects of a pathogen

Disease tolerance - ability of a plant to withstand the severe effects of the pathogen without experiencing a severe reduction in yield

Masked symptoms - symptoms not expressed due to unfavorable condition

Symptomless carrier - host that does not show symptoms irrespective of environment

Disease Triangle



Plant Disease Diagnosis

- Identification of specific plant disease through their characteristic symptoms and signs including other factors that may be related to the disease process

Signs vs. Symptoms

Symptom: Expression; **Sign**: Structures

Primary: Immediate and direct

Secondary: distant and uninvaded

Localized: Distinct; **Systemic**: Generalized

Histological: Internal

Morphological: Visible to naked eye

Macroscopic: can be seen by the unaided eye

Microscopic: seen under a microscope

Classification of Symptoms

Term	Keyword	Example
Plesionecrotic	Pre-necrotic "near dead"	Silvering, yellowing, wilting
Necrotic	Death of tissues	Spot, Blight, Canker, Die-back,
Hypoplastic	Developmental failure	Stunting, Chlorosis, Curling, Mosaic
Hyperplastic	Overdevelopment or enlargement	Gall formation, scab, fruit drop, greening
- **Hypertrophy** Increase in cell size - **Hyperplasia** Increase in cell number		

Symptom Terminologies

- **Abscission** – Early laying down of the abscission layer causing premature falling of leaves, fruits or flowers
- **Blast** – Sudden death of young buds, inflorescence or young fruits (Ex: *Pyricularia oryzae*- Rice Blast)
- **Blight** – Sudden and extensive death of tissue (Ex: Fire Blight of Apple)
- **Blotch** – Necrotic injury of epidermal cells seen as irregular, large spots in leaves or fruits
- **Canker** – a sunken necrotic area with cracked border (Ex: Nectria Canker)
- **Chlorosis** – yellowing caused by infection of a biotic factor such as a virus or mycoplasma

- **Curling** – abnormal bending of leaves caused by overgrowth on one side or localized growth in certain portions (Ex: Tomato Yellow Leaf Curl)
- **Damping off** – rotting of seedlings prior to emergence or rotting of seedling stems at an area just above the soil line (Ex: *Pythium* sp.- Damping Off of Seedlings)
- **Dieback** – drying of the leaves that happens from the tip of twigs (Papaya Dieback)
- **Etiolation** – yellowing of normally green tissues caused by inadequate light
- **Fasciation/Fasciculation** – clustering of roots, flowers, fruits, or twigs around a common focus
- **Gumming/Gummosis** – oozing out of viscid gum from wounds in bark
- **Leak** – host juices exude or leak out from soft-rotted portions
- **Mosaic** – the presence of variegated patterns of green and yellow shades with sharply defined borders (usually in leaves) (Ex: Tobacco Mosaic)
- **Mottling** – the variegation is less defined than mosaic and the boundaries of light and dark areas are more defused
- **Mummification** – the infected fruit is converted to a hard, dry, shriveled mummy
- **Phyllody** – metamorphosis of sepals, petals, stamens, or carpels into leaf-like structures
- **Pitting** – defined depressions or pits found in surfaces of fleshy organs that appear like pokes and holes
- **Rosetting** – shortening of shoot internodes and stems forming a foliage crowd in the shape of a rose/rosette
- **Rotting** – disintegration & decomposition of host tissue
- **Russeting** – suberization of epidermal tissues due to injury causing rough, brownish appearance of the skin
- **Sarcody** – abnormal swelling of the bark above wounds due to accumulation of food materials
- **Savoying** – cupping or pocketing of leaf parts due to underdevelopment of leaf veins or leaf margins
- **Scab** – overgrowth of epidermal and cortical tissue accompanied with rupture and suberization of cell walls causing slightly raised, rough, ulcer-like lesions.
- **Shothole** – perforated appearance of a leaf as the dead areas of local lesions drop out (Ex: *Colletotrichum gloeosporioides*; Mango Anthracnose)
- **Spot** – localized necrotic area that may be circular, angular, or irregularly shaped (Ex: Gray Leaf Spot of Tomato)
- **Streak/Stripe** – long, narrow, necrotic lesions on leaves or stems (Ex: *Helminthosporium* Stripe of Barley
- **Vein clearing** – leaf veins are translucent or pale, yet the rest of the leaf is normal in color
- **Virescence/Greening** – development of chlorophyll in tissues or organs where it is normally absent.

Categorization of Signs

Vegetative structures	**Absorption and nutrient storage**
Reproductive structures	Reproduction, multiplication and transfer of genetic material
Disease products	Gases and exudation products resulting from the disease

Sign Terminologies

- **Felt** – Densely woven mat of mycelium
- **Haustorium** – Absorbing organ of fungus that penetrates a host cell without penetrating the plasma membrane
- **Mycelium** – Mass of fungal threads or hyphae
- **Pathogen cells** – masses of bacterial cells
- **Plasmodium** – Naked mass of protoplasm
- **Rhizomorph** – cord-like strand of fungal hyphae
- **Sclerotium** – A hard, compact, resting body composed of fungal hyphae
- **Acervulus** – mat of hyphae, forming lesions with short, densely packed conidiophores
- **Apothecium** – Open, cuplike, ascus-containing fruiting body
- **Ascus** – sac-like structure containing ascospores formed as a result or karyogamy and meiosis
- **Basidium** – club-shaped structure on which basidiospores are produced as a result of karyogamy and meiosis
- **Cleistothecium** – closed ascus-containing fruiting body
- **Conidiophore** – specialized hyphal branch on which conidia are produced
- **Conk** – woody shell-like structure characteristic of many woody-rotting fungi
- **Mildew** – cobwebby or powdery growth usually on leaves
- **Mold** – Woolly of furry surface growth of mycelium
- **Mushroom (toadstool)** – Umbrella-shaped fruiting structure of many Basidiomycetes
- **Perithecium** – Fruiting body bearing asci in locules within a stroma
- **Pseudothecium** – Fruiting body bearing asci in locules within a stroma
- **Pycnidium** – Asexual, hollow fruiting body containing conidia
- **Seed-bearing plants** – higher plants that parasitize trees
- **Sorus** – mass or cluster of spores borne on short stalks
- **Sporangium** – enlarged tip of specialized hyphal branch in which sporangiospores are borne
- **Spore** – General name for a single to several-celled propagative unit in fungi and other lower plants
- **Sporodochium** – Cushion-shaped stroma covered with conidiophores
- **Stroma** – Compact mass of fungal hyphae on or within which fruiting structures are formed
- **Worms** – Generally nematodes which are microscopic, wormlike animals that can cause disease
- **Odor** – Characteristic smell associated with some host-pathogen interactions
- **Ooze** – Viscid mass made up of plant juices and often pathogen cells

Koch's Postulate of Pathogenicity

1. Association

- Pathogen or its signs must be found associated with the diseases in all the diseases plants examined

2. Isolation

- Pathogen must be isolated and grown in pure culture on nutrient media and its characteristics described
- Obligate parasites must be isolated and grown on a healthy but susceptible host plant, and its characteristics described

3. Inoculation

- Pathogen from the pure culture must be inoculated on healthy plants of the same species or variety on which the disease appears, and it must produce the same disease on the inoculated plants

4. Re-isolation

- Pathogen must be re-isolated from the inoculated plants and grown once more in pure- culture.
- Its characteristics must be exactly like those observed in Step 1 and 2

UNIT IV: BIOTIC AGENTS OF PLANT DISEASE

– Agents that cause infectious diseases of plants

– Include the viruses, viroids, bacteria, mollicutes, fungi, nematodes, parasitic flowering plants, insects, protozoa, and few other minor parasites

A. Bacteria

Characteristics:

- Rod-shaped
- Aerobic
- Flagellated
- Gram negative
- Non-spore forming

Exceptions:

- ***Streptomyces* spp.**
  - Filamentous like a mold but their biochemical and physiological properties like bacteria
- ***Corynebacterium***
  - Gram positive
  - Clostridia
  - Anaerobic and spore-forming

Distinctive characteristics

- **Plasmids**
  - Extracellular, closed, circular genetic components
  - Self-replicating, can be integrated into bacterial chromosome
  - Carry elements for:
    - drug resistance
    - phage resistance
    - UV resistance Survival in secondary habitats
    - pathogenesis

Shapes

- Spherical (cocci)
- Rod-shaped (bacilli)
- Spiral-shaped (spirilla)

Flagellation

- Monotrichous (one flagellum)
- Lophotrichous (2 or more flagella at one side/ pole)
- Amphitrichous (flagella on both sides)
- Peritrichous (flagella on all surfaces)

Genera of plant pathogenic bacteria

- **Old Genera (before 1980)**
  - *Agrobacterium*
  - *Pseudomonas*
  - *Erwinia*
  - *Xanthomonas*
  - *Corynebacteria* (now invalid)
- **New Genera (after 1980)**
  - *Acidovorax*
  - *Burkholderia*
  - *Ralstonia*
  - *Pseudomonas*
- **From *Erwinia***
  - *Brenneria*
  - *Enterobacter*
  - *Pantoea*
  - *Pectobacterium*
  - *Erwinia*

- **From *Corynebacteria***
  - *Anthrobacter*
  - *Clavibacter*
  - *Cutobacterium*
  - *Leifsonia*
  - *Rathayibacter*
  - *Rhodococcus*

- **From other genera**
  - *Acetobacter*
  - *Agrobacterium*
  - *Bacillus*
  - *Clostridium*
  - *Gluconobacter*
  - *Nocardia*
  - *Rhizobacter*
  - *Sphingomonas*
  - *Serratia*
  - *Spiroplasma*
  - *Streptomyces*
  - *Xylella*
  - *Xylopilus*

Common symptoms

- **Leaf spot** – bacteria in sub stomatal cavities and parenchyma cells of leaves causing localized lesions
- **Soft rot** – bacteria produce hydrolytic enzymes that degrade the middle lamella and cell walls of the host resulting to soft, slimy, watery decay
- **Blight** – General necrosis due to rapid growth and advance of bacteria
- **Gall** – Due to hypertrophy and hyperplasia of meristematic and parenchymatous tissues
- **Canker** – Phloem and parenchyma tissues become sunken, dry up and die
- **Wilting** – A result of vascular disorders, bacteria multiply and block normal water flow

Mode of reproduction and Bacterial classification

- **Binary fission**
  - Traditional methods of characterization to group bacteria into genera
    - **Morphological** - size, shape, flagella
    - **Cultural** - growth characteristics in media
    - **Biochemical** - reactions in substrates (catalase, urease, oxidase)
    - **Physiological** – Carbon and Nitrogen Requirements
    - **Pathological** - pathogenicity to plants
  - **Molecular Techniques**
    - DNA Base Comparison
    - DNA-DNA Homology- for bacterial species identification
    - DNA-rRNA Homology detect similarities between families
    - Restriction Fragment Length Polymorphism - for strain identification

Gene transfer

- *Transformation* - change in cell through uptake and expression of additional genetic material
- *Transduction* - transfer of genetic material from one bacterium to another by means of a bacteriophage
- *Conjugation* – transfer of genetic material from a donor cell to a recipient cell through direct cell to cell contact

Control

- **Cultural**
  - Sanitation to reduce inoculum
  - Crop rotation for pathogens with limited host range
  - Proper irrigation and drainage to control moisture levels

- **Seed treatment**
  - Seed soaking in weak acid solution/ sodium hypochlorite
- **Antibiotics**
  - Streptomycin, Oxytetracycline
  - resistance as disadvantage

Example of Diseases

- *Xanthomonas campestris pv. vesicatoria*
  Leaf spot of tomato
- *Xanthomonas axonopodis pv. dieffenbachiae*
  Bacterial blight of anthurium
- *Xanthomonas oryzae pv. oryzae*
  Bacterial leaf blight of Rice
- *Pectobacterium carotovorum subsp. carotovorum*
  Soft rot of vegetables
- *Psedomonas syringae pv. tabaci*
  Tobacco wildfire
- *Agrobacterium tumefaciens*
  Crown gall of roses

B. Mollicutes

Characteristics

- Prokaryotic
- No cell walls
- With 9-12 nm thick unit plasma membrane
- Contain both RNA & DNA
- Pathogenic on plants, arthropods, and man
- *Pleomorphic* – sensitive to osmotic change
- Resistant to penicillin but sensitive to tetracycline and chloramphenicol

Pathogenic species

- **Phytoplasmas**
  - Formerly called MLOs or mycoplasma-like organisms
  - Generally found in the phloem
  - Generally spherical or ovoid
  - May appear mucoid or filamentous
  - Nutritionally fastidious
  - Very difficult to culture in artificial media
  - Reproduce by budding and by binary transverse fission of cells
- **Spiroplasmas**
  - Helical or spiral-shaped during certain phases of growth
  - Relatively easy to grow
  - Require sterol for growth
  - Larger than phytoplasmas

Common symptoms and transmission

- Blocks translocation in the phloem
- Interferes with plants' hormonal balance

Common symptoms

- Yellowing
- Virescence
- Stunting
- Phyllody
- Production of axillary shoots and adventitious roots

Transmission

- **Insect vectors**
  - Insects acquire mollicutes via the phloem sieve tubes
  - 10-45 days incubation period from acquisition feeding
- **Mechanical**

Control

- Use of resistant cultivars or hybrids
- Proper control of insect vectors
- Use of mollicute-free planting materials
- Eradication of alternative hosts (i.e., Weeds)
- Use of tetracycline as antibiotic
- Sanitation and pruning

Examples of diseases caused

- **Lethal yellowing of coconut trees**
  - A Phytoplasma that causes death of flowers and leaves, kills the trees in less than 6 months
- **Citrus stubborn disease**
  - A Spiroplasma that affects leaves, fruits, and stems by stunting, die-back, bunchy growth of twigs, mottling, and leaf chlorosis
- **Corn stunt**
  - A Spiroplasma causing leaf chlorosis, stunting, and bunchy top appearance (Doi, 1967)
  - observed the association of mollicutes with aster yellows, mulberry dwarf and potato witches' broom

C. Fungi

Characteristics

- Form a mycelium
- Cell walls contain chitin and glucan
- No chloroplast
- Heterotrophic
- Penetration and entry:
  - uses an Appressorium to attach to the host

Nutrition

- Derive food from organic matter
- Haustoria: structure used to take food needed for its growth

Reproduction

- By spores, which are small seed-like structures that germinate and produce threadlike filaments through the plant's natural opening like the stomates, hydathodes, and lenticels

Survival

- Through spores o mycelia in decaying materials

Plant pathogenic species

1. **Phylum Chytridiomycota** – has motile cells (zoospores with posterior flagellum)
   a. **Order Chytridiomycetes**
   - *Physoderma maydis*
     Brown spot of Corn
   - *Synchytrium psopocarpi*
     Orange gall of Winged Bean
   - *Olpidium brassicae*
     Root disease of crucifers
2. **Phylum Zygomycota** – have asexual spores in sporangia; produce Zygospores
   a. **Order *Mucorales***
   - *Rhizopus nigricans; R. stolonifera*
     Soft rot of fruits and vegetables
   - *Choanephora cucurbitarum*
     Fruit rot

   b. **Order *Glomales* (mycorrhiza)**
3. **Phylum Basidiomycota** – club and mushroom fungi; produce Basidiospores
   a. Order *Ustilaginales* – Smut fungi
   - *Ustilago maydis* – Corn Smut
   - *Urocystis cepulae* – Onion smut

   b. Order *Uredinales* – Obligate rust fungi
   - *Puccinia graminis f.sp. tritici*
     attacks wheat only
   - *Puccinia graminis f..sp. hordei*
     attacks barley only
   - *Uromyces phaseoli* – Bean Rust
   - *Hemileia vastatrix* – Coffee rust
   - *Puccinia polysora* – Peanut rust

Fruiting Structures	Spore Forms
Basidium	Basidiospores (n)
Spermagonium	Spermatia (n)
Aecium	Aeciospores (n+n)
Uredinium	Uredospores (n+n)
Telium	Teliospores (2n)

a. Order *Agaricales* – Mushrooms

- Basidium without crosswalls
- Produce radiating gills/ lamellae
- Many are mycorrhizal fungi
  - *Armillaria* - cause root rot of trees
  - *Crinipellis* - witches' broom of cacao
  - *Masmius* - fairy ring disease of turfgrasses
  - *Pleurotus* - white rot on logs
  - *Pholiota* - brown wood rot of deciduous forest trees

b. Order Aphyllophorales – Bracket Fungi

- *Athelia*- root and stem rot of many plants
- *Chondrostereum*- silver leaf disease of trees
- *Corticium*- red thread disease of turf grasses
- *Ganoderma*- root and basal stem rot of trees
- *Polyporus*- heart rot of living trees and rot of dead trees

4. **Phylum Ascomycota** – Sac fungi; produce ascospores within an ascus

a. Class *Archiascomycetes*

b. Class *Saccharomycetes*

c. Class *Pyrenomycetes*

Claviceps purpurea - Ergot of Rye

Magnaporthe grisea – Rice blast

d. Class *Plectomycetes*

e. Class *Loculoascomycetes*

Mycosphaerella fijiensis – Black sigatoka leafspot of Banana

f. Class *Discomycetes*

- **Teleomorph** – sexual/perfect stage
- **Anamorph** – asexual/imperfect stage

g. Class *Deuteromycetes* or Imperfect Fungi

5. Imperfect stage or Phylum Ascomycota

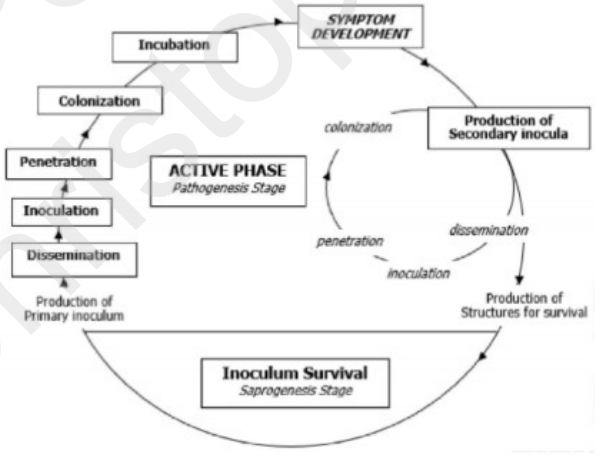
- **Hypomycetes**
  - Produce conidia on conidiophores

    Alternaria; Bipolaris – leaf spot
- **Coelomycetes**
  - Produce acervuli or pycnidia

    Diplodia – fruit rots
- **Mycelia sterilia**
  - No asexual or sexual spores

    Rhizoctonia – Rot of leaves, stems, roots

    Sclerotium – Seed, root, stem rot



Control

- **Kinds of fungicide:**
  - **Protective fungicide**
    - as foliage and fruit sprays or dusts to keep disease-causing fungi from penetrating plants
    - *Zineb*
  - **Eradicant fungicide**
    - Kills or inhibits fungi after they have penetrated the plants
    - *Mercury Chloride*
  - **Protective and eradicant fungicide**
    - Controls foliage and fruit diseases, as seed treatment
    - *Captan*

- **Systemic and curative fungicide**
  - Absorbed by roots and distributed within the plants to control certain diseases; applied to seeds or soil
  - *Benlate, Apron 35*

D. Virus

Characteristics:

- obligate parasites
- ultramicroscopic

Structure:

- Most plant pathogenic viruses have single stranded RNA genomes

Types:

- **Bacteriophages:**
  - Viruses that attack bacteria
- **Satellite Virus:**
  - Viruses that must be associated with an autonomous virus before it can cause infection
- **Shapes:**
  - Isometric
  - Spherical
  - Rigid
  - Filamentous
    - Flexous and long
  - Geminate
  - twinned isometric particles
  - Baciliform
    - short, round-ended rods

Classification and Detection

- **Transmission studies using indicator hosts:**
  - Electron microscopy
  - Serological tests (ELISA)
  - Symptomatology & host range
  - Physical properties
- **Thermal inactivation point (TIP)**
  - Lowest temperature by which the virus is inactivated
- **Virus longevity in vitro**
- **Dilution end point (DEP)**
  - Dilution of a virus that can still cause infection

Common Symptoms

1. Mosaic
2. Ring spot
3. Vein clearing
4. Color breaking
5. Stunting
6. Chlorosis
7. Leaf Curling
8. Excessive branching (Witches' broom)

Mode of Transmission

1. Infected planting materials (pollen, seeds)
2. Grafting
3. Mechanical
4. Vectors

- **Nematodes**
  - Soil inhabiting ectoparasitic nematodes
  - Genera *Longidorus, Paralongidorus, Xiphinema* can transmit several polyhedral- shaped virus known as *Nepovirus* (Grape-fanleaf, Tobacco ringspot etc.)
  - Genera *Trichodorus & Paratrichodorus* are able to transmit 2 rod-shaped *Tobravirus*, *Tobacco rattle virus* and *Pea early browning virus*
- **Soil-borne fungi**
  - Root-infecting fungal-like organisms
  - Plasmodiophoromycetes: *Polymyxa, Spongospora*
  - Chytridiomycete: *Olpidium*

- **Mites**
  - Family Eriophyidae
    - can transmit Wheat Streak Mosaic and several Rymoviruses affecting cereals

- **Insects**
  - **Non-Persistent (Stylet-borne)**
    - Transmit virus within seconds or minutes after acquisition then losses the ability to transmit it (Ex: Vector are some aphids)
  - **Semi-Persistent(Foregut-borne)**
    - Virus can stay in the foregut of the insect for several days
  - **Persistent**
    - Transmits the virus after a latent period has elapsed after acquisition; vector is capable of transmission for days
    - ***Circulative*** - replicate only in plants but passes through the gut into the hemolymph and then the salivary glands
    - ***Propagative*** - replicate both in plants and vectors

Control

1. Preventive Measures
   - Quarantine
   - Certification
   - Virus-free planting materials
2. Eradication
3. Protection
4. Cross protection
5. Genetic Engineering
6. Early detection

Examples of Diseases

- *Tobacco mosaic virus*
- *Cucumber mosaic virus*
- *Tomato Leaf Curl*
- *Tungro virus*

E. Viroids

Characteristics:

- Stable "naked (no protein coat)" RNA that infects plants
- Smaller than viruses
- Closely associated with nuclei of infected cells especially the chromatin

Classification and detection

- **Particle morphology**
  - Particle size
  - Viroid shape
- **Genome properties**
  - Genome nature
  - Number of genes
  - Translation strategy
- **Biological properties**
  - Type of host
  - Mode of transmission
- **Serological properties**
  - Relatedness of proteins
  - Antigen – Antibody relations

Common symptoms

- Yellowing of leaves
- Stunting
- Rolling and twisting of leaves
- Mottling and chlorosis
- Vertical breaking of bark

Mode of transmission

- **Infected sap**
  - Contaminated tools and hands
  - Chewing insects
- **Vegetative propagules**

Control

- Thorough disinfection of tools used
- Viroid-free seedlings
- Early detection

Viroids are resistant to heat, so hot water treatment is not applicable

Examples of diseases

- Cadang-cadang disease of coconut
- Chrysanthemum stunt disease
- Potato spindle tuber
- Chrysanthemum chlorotic mottle
- Citrus exocortis

F. Nematodes

Characteristics

- Thread-like, cylindrical, elongated in shape
- Unsegmented
- Saprophagous
- Predaceous
- Plant parasitic
- Feed on all forms of plant life, some feed on fungi and bacteria
- Mostly obligate parasites

Parts of the outer tube of nematodes

- **Cuticle**
  - semipermeable outermost covering of the nematode body
  - made up of protein (keratin and collagen)
  - shed off at molting to allow growth
- **Epidermis**
  - thin layer which functions mainly for secretion of new cuticle during molting
- **Muscles**
  - allow movement by alternate contractions and relaxations of dorsal and ventral muscles

Parts of Inner Tube of Nematodes

- the digestive system of the nematode
- from the mouth opening to the anus (for females) or cloaca (for males)

Stylet

- protrusible structure in the mouth
- distinguishes plant parasitic from free-living nematodes
- for puncturing plant cells and withdrawing their contents

Three types of stylet

- **Stomatostylet**
  - with distinct cone, shaft, and knobs; hollow
  - Ex: Order Tylenchida
- **Odontostylet**
  - Hollow spear
  - Ex: Order Dorylaimida; *Xiphinema, Longidorus, Paralongidorus*
- **Onchiostylet**
  - Bent, solid needle-like stylet
  - Ex: Order Triplonchida; *Trichodorus, Paratrichodorus*

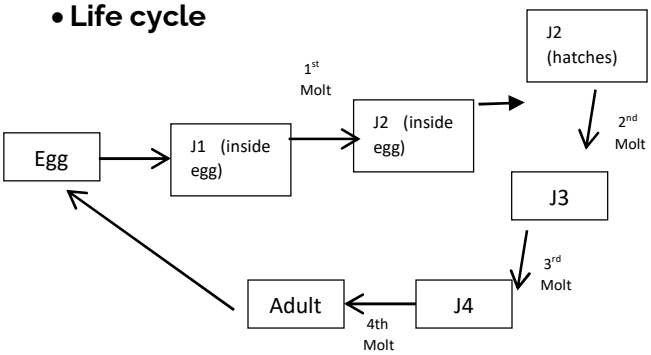
Phytonematology

– study of nematodes that parasitize plants

- *Turbatrix aceli* (Wheat gall nematode)
  - first plant parasitic nematode described
- *Caenorhabditis elegans*
  - model organism for genetic and physiological studies

Biology

- **Life cycle**



- **Reproductive stage**
  - Amphimixis
    - males are needed
- **Parthenogenesis**
  - only females are produced, and offspring are clones of the female
- **Sex reversal**
  - observed in juvenile stage during unfavorable condition

Survival strategy

- **Dormancy** – lowered metabolism

  Types

  - **Diapause** - state of arrested development which persist until specific requirements for development are satisfied even if favorable conditions return
  - **Quiescence** - spontaneous reversible response to unpredictable unfavorable conditions

STATE	ADVERSE COND'N
Cryobiosis	Low Temperature
Thermobiosis	High Temperature
Anoxybiosis	Lack of Oxygen
Osmobiosis	High Osmotic Pressure
Anhydrobiosis	Dehydration

- **Egg stage** – the ***survival stage*** of nematode
  - Survival strategies
    - **Egg Sac/ Gelatinous Matrix** - *Meloidogyne* spp
    - **Cysts** - *Globodera* spp.
    - **Coiling/ Clamping** - *Ditylenchus*, *Anguina*

Groups Classifications

- **According to *feeding position***
  - **Ectoparasites**
    - Feed from the outside
    - Only the stylet enters the plant
    - Do not enter the roots
    - Feed mainly on root hairs and tips
  - **Semiendoparasites**
    - Feed by burying the front part of the body into the host cells while posterior portion is outside the host
  - **Endoparasites**
    - The entire nematode body enters the plant cells while it feeds
- **According to *movement* while feeding**
  - **Migratory**
    - Move from one part of the plant to another
    - Move from the plant to the soil and back
  - **Sedentary**
    - Attach and burrow themselves to the roots
- **Examples of combining two classifications**
  1. **Migratory Ectoparasite**
     - *Longidorus*
     - *Xiphinema*
     - *Trichodorus*
     - *Paratrichodorus*
  2. **Sedentary Ectoparasite**
     - *Criconemoides*
     - *Hemicyclophora*
  3. **Semi-Ecto, Semi-Endo**
     - *Tylenchulus*
     - *Rotylenchulus*
  4. **Sedentary Endoparasite**
     - *Meloidogyne*
     - *Globodera*
     - *Naccobus*
     - *Hirschmaniella*

Sampling Theories

- **Spatial Distribution**
  - Distribution within the field is generally patchy due to their small size and slow movement
- **Vertical Distribution**
  - Dispersal of nematodes in a soil profile

- **Temporal/Seasonal Distribution**
  - Influenced by climatic patten & availability

Nematode density is highest during near harvest stage of crop

Extraction techniques

- **Motility Dependent/ Active Methods:**
  - Extract slender and active stages of nematodes
    a. Baermann funnel
    b. H_2O incubation Method
- **Motility Independent/ Passive Methods**:
  - Extracts even slow moving nematodes
    a. Wet-Sieving Method
    b. Elutriation Method
    c. Centrifugal Floatation

Examples of diseases caused

- ***Radopholus similis***
  - Spreading decline of citrus
  - Toppling disease of banana
  - Yellow dwarf disease of black pepper
- ***Meloidogyne incognita***
  - Root knot
- ***Tylenchulus semipenetrans***
  - Slow decline of citrus
- ***Radinaphelencus cocophilus***
  - Red ring disease of coconut
- ***Apelenchoides besseyi***
  - Ufra disease of rice
- ***Hirschmaniella oryzae***
  - Rice root knot

G. Fastidious Vascular Bacteria (Rickettsia-like organisms – RLO)

History

- 1972
  - **Phloem limited bacteria**
    - **Clover Club Leaf disease** – Clover and periwinkle plant
    - **Greening disease** – Citrus plants
- **1973**
  - **Xylem limited bacteria**
    - *Xyllela fastidiosa*
      - **Pierce's disease** – Grapes
      - **Alfalfa dwarf** – Alfalfa

Characteristics

- **Fastidious** - Cannot be grown in simple culture media in the absence of host cells
  - Generally rod-shaped
  - Measures 0.2 to 0.5 µm in length
  - Bounded by a cell membrane and a cell wall
  - No flagella
  - Undulated/ rippled cell structure
  - Nearly all RLOs are gram negative
  - Sensitive to the ff:
    - Tetracycline
    - Penicillin
    - High temperature

Plant pathogenic species

- **Xylem-limited bacteria**
  - Several are placed in the genus Xylella
  - Can be grown in culture in complex nutrient media but growth is slow, and colonies produced are tiny (1-2 mm)
  - All are gram negative except the ff:
  - *Leifsonia xlyi*
    - Sugarcane ratoon stunting (*Leifsonia xyli* subsp. *xyli*)
    - Bermuda grass stunting (*Leifsonia xyli* subsp. *cynodontis*)
- **Phloem-limited bacteria**
  - None has been grown in culture

Diseases caused

- Fastidious xylem-limited Gram-negative bacteria: (caused by forms of *Xylella fastidiosa*)
  - Pierce's disease of grapes
  - Citrus variegation chlorosis
  - Phony peach disease
  - Almond leaf scorch
  - Plum leaf scald
- Fastidious xylem-limited Gram-positive bacteria:
  - Ratoon stunting disease of sugarcane – caused by *Clavibacter xyli* subsp. *xyli*
  - Fastidious phloem-limited bacteria – cause of important citrus greening disease and minor diseases of clover and periwinkle

H. Plant Pathogenic Protists

History

- Previously considered as fungi due to their cell wall structure
- Reclassified as protozoa-like or fungi-like

Characteristics

- **Protozoa like protists**
  - Unicellular
  - Plasmodial
  - Very simple multicell
  - Phagotrophic (engulfs food)
- **Fungal-like protists**
  - Have mycelia and conidia
  - Cell walls are made up of cellulose and glucan

Plant Pathogenic species

- **Protozoa-like protists**
  - Phylum Myxomycota (slime molds)
  - Phylum Plasmodiophoromycota (endoparasitic slime molds)
  - Flagellate protozoa (sieve tubes)
- **Fungal-like protists**
  - Pythiaceae – Damping-off
  - Peronosporaceae- Downy mildews
  - Albuginaceae – White rust

Examples of Diseases caused

- **Protozoa-like protists**
  - *Mucilago, Fuligo, Physarum*
  - *Plasmodiophora brassicae* (Clubroot of crucifers)
  - *Spongospora subterranean* (Powdery scab of potato)
  - *Phytomonas leptovasorum* (Phloem necrosis of coffee)
- **Fungal-like protists**
  - Pythium
  - *Phytophthora infestans* (Potato Late Blight)

I. Parasitic Higher Plants

- **Hemiparasites**
  – contains chlorophyll but without roots
  i.e. Witchweed; True Mistletoe; Leafy Mistletoe*; Loranthus Isp*
- **True parasite**
  – Have little or no chlorophyll and no roots
  i.e. Dodder, Broomrapes, *Aeginetia indica*

UNIT V: ABIOTIC AGENTS OF PLANT DISEASE

- Non-Living
- Not contagious/ infectious
- Knowledge of environmental factors before and during disease occurrence necessary for correct diagnosis

Types of Abiotic Stress

Physical factors

Freezing injury	T ° below 0 °C	Ice crystals form within or between cells
Chilling injury	Low T °; slightly above freezing (below 12.5 °C)	Pitted and water-soaked symptoms
Sunscald	Prolonged exposure to high T °	Light colored and blistered tissue
Heat necrosis	Potato growing in light soils; hot and dry condition	Yellow or brown discoloration in the vascular system

Air pollutants

Ozone (O_3)	Released NO^2 combines with O^2 in the sunlight > O_3	Most destructive Air Pollutant Stippling, Mottling, Leaf Chlorosis, Premature Defoliation, Stunting
Peroxyacyl Nitrates (PANS)	Gasoline vapors/ Incompletely burned gasoline + O_3+ NO > PANS	Plasmolyze spongy mesophyll cells and lower epidermal cells Bronzing, Silvering, Glazing in lower leaf
Nitrogen Oxides (NO_2)	Combustion of coals, gasoline, natural gas, and fuel	Bleaching and bronzing of plants plus brown and white lesion along leaf margins
Chlorine (Cl^2) and Hydrogen Chloride (HCl)	-	Bleaching, Interveinal necrosis, scorched leaf margins, premature dropping of leaves
Ethylene (CH_2CH_2)	-	Premature senescence, etiolation, stunting, flower drop, sepal necrosis, leaf malformation
Particulate Matter	Dusts	Necrotic lesions in covered areas, leaves fall off

Stress caused by Mineral Deficiencies

Macroelements: CHONNaPKMgS
Microelements: FeCuZnMoBClMnNi

Stress caused by improper Agricultural Practices

- **Unfavorable Soil pH** - controlled by adding lime to increase pH level
- **Lack of or excess moisture** - zoospores present with excess moisture, causing it to swim from plan to plant to attack crucifers
- **Improper use of pesticides**

How to prevent Abiotic Stress/ Injuries

- Avoid the factor
- Protect the plants
- Supply the factor
- Good crop management

UNIT VI: VARIABILITY IN PLANT PATHOGENS

Biotype

Population of life forms that is identical in all inheritable traits

Pathovar

A strain or group of strains at infra subspecies level, with identical or similar characteristics based on pathogenicity, symptoms, or signs and host range

Pathogenic Race

Based on the ability to attack different genera of crop plants

Disease Cycle

- Sequence of events that lead to, and involved in disease production
- Activities of pathogen away from and in the host
- DIFFERENT from the LIFE CYCLE of pathogen
- Continuous process

Types of Disease Cycle

Monocyclic

- One disease cycle in one cropping season or one year
- FAST build-up in *Rate of Inoculum*
- 50-100% increase in *Rate of Disease*
- Cause epidemics
- Ex: Late blight of Potato, Grain Rusts, Rice Blast, Leaf Spot of Mungbean, Viruses with Insect Vectors

Polycyclic

- Repeating disease cycle in one cropping season or one year
- SLOW build-up in *Rate of Inoculum*
- SLOW increase in *Rate of Disease*
- Ex: Soil borne diseases (Bacterial/ Fusarial Wilt, Rusts of Trees, Smuts)

Stages of the Disease Cycle

SAPROGENESIS phase

- Survival Phase
- WEAKEST link in the disease cycle
- Pathogen population at LOWEST
- TARGET of most control strategies

Mechanisms of Pathogen Survival

Formation of specialized structures

- Nematode cysts, teliospores, oospores, sclerotial bodies, cleistothecia, zygospores

Dormancy

- Rest period interrupting development
- Long enough for the pathogen to resume parasitic activity
- Synchronized with renewed host activity

Fungistasis

- Control mechanis, which restricts the germination of fungal propagules deposited in the soil

Survival in hosts or vectors

- Quiescent vegetative condition in host tissues
- Can also be in ALTERNATE HOST(S)

Survival as saprophytes

- Degrade and make use of a wide range of organic matter

PATHOGENIC phase

- Dissemination
- Inoculation
- Penetration
- Infection
- Colonization
- Incubation
- Symptom Development
- Production of 2° inoculum

Inoculation

- Contact of pathogen with the host
- Deposition of the INOCULUM into an INFECTION COURT
- "**Inoculum**" any part of the pathogen that can initiate a disease
  - Fungi: Spores/ Conidia, Mycelial Fragments, Sclerotial Bodies
  - Nematodes: Eggs, Larvae, Adults
  - Phanerogams: seeds
  - Bacterial Cells, Phytoplasma Cells, Protozoan Cells
  - Virus and Viroid particles

Penetration (Ingress)

- Entrance of pathogens into the host (via wounds or natural openings)
- **PASSIVE**: pathogens play no active part (vectors carry the pathogen into the plant cells)
- **ACTIVE**: pathogen plays an active role through flagellar movement, spore germination, appressorium, and penetration pegs
- *Avenues for Penetration*
  - Natural Openings: Stomata, Lenticels, Hydathodes, Nectarthodes
  - Wounds: Mechanical Wounds

Infection

- Occurs when the pathogen has become ESTABLISHED in the plant tissues after penetration and obtain nutrients from the hosts
- Penetration alone doesn't imply successful infection
- **LATENT INFECTION**: state in which the host is infected with the pathogen but does not show any symptoms
  Ex: Anthracnose (*Colletotrichum gloeosporioides*)

Colonization (Invasion)

- Growth/multiplication or movement of the pathogen in or through host tissues
- Pathogens produce chemicals like enzymes, toxins, hormones, and other pathogenicity related factors
- Example:
  - Fungi: produce mycelia and spores
    - INTERCELLULAR INVASION: hyphae are in BETWEEN cells; spores and hyphae in Xylem Vessels
    - INTRACELLULAR INVASION: hyphae punctured and inside host cell
  - Bacteria: multiplication of more bacterial cells
  - Virus: multiplication of virus particles (Always intracellular)

Mechanisms of Pathogenicity

- Interference with the uptake of water and inorganic elements from the soil
- Interference with translocation of organic compounds
- Reduction of plants' photosynthetic capacity
- Increased transpiration
- Changes in the growth of the suscept

Gene for Gene Theory (Flor, 1971)

For every gene conferring resistance in the host, there is a corresponding gene conferring avirulence to the pathogen

-	Avr	avr
R	-	+
r	+	+

+ : Compatible reaction; Disease will occur
- : Incompatible reaction; No disease

Epidemiology

- Study of Disease Development in plant population
  - **Epidemics** - increase in disease incidence within the plant population with time
  - **Epiphytotics** - epidemics of plant disease
  - **Endemic Disease** - disease that is native or indigenous
  - **Exotic Disease** - Disease which is introduced from some area
  - **Pandemic Disease** - disease of worldwide or widespread occurrence throughout a continent

Dissemination of inocula

- **By <u>wind</u>**
  - Airborne pathogens take off, fly into the air, and deposit in any area of the plant
- **By <u>rain</u>**
  - Fungal spores and bacterial cells are carried by rain splashes
- **By <u>insects</u>**
  - Plant to plant via insects through injury
- **By <u>seed and planting materials</u>**
- **By <u>man</u>**
  - carry through agricultural mechanics and products

Factors affecting epidemic development

- **Host factors**
  - Levels of genetic resistance or susceptibility of the host
  - Degree of uniformity of host plants
  - Type of crop
  - Age of host plants
- **Pathogen factors**
  - Levels of virulence
  - Quantity of inoculum near host
  - Ecology of the pathogen
  - Mode of spread of the pathogen
- **Environmental factors**
  - Moisture
  - Temperature
  - Human factors
  - Site selection and preparation
  - Selection of propagative materials
  - Cultural practices
  - Disease control measures
  - Introduction of new pathogens

UNIT VII: METHODS OF PLANT DISEASE CONTROL

<u>Four General Principles</u>

1. **Exclusion**
   - **Quarantine**
     – regulatory actions to prevent the introduction or dispersal of non-native organism (exotic diseases), legal methods
   - *Inspection and seed certification*
   - *Use of pathogen-free propagating materials*
2. **Eradication**
   - Elimination of pathogens established within the plant or in an area

   Methods:
   - Cultural rouging, crop rotation
   - Biological use of Natural enemies
   - Chemical Fumigants, Fungicides
   - Physical Heat Treatment, Irradiation, Drying
3. **Protection**
   - Prevention of infection through the ff:
     - Chemical barrier
     - Biological control
     - Manipulation of environment
   - Putting a chemical barrier between the pathogen and the host:
     - Before inoculation
     - Prevent spore germination
     - Kill germinating spores
4. **Resistance/immunization methods**
   - Modifying certain physiological or physical features of the host so that it can repel infection
     - **Selection**
     - **Gene pyramiding**
       - incorporation of several resistance genes in one host variety
     - **Multiline varieties**
       - Mixture of several lines with agronomic characteristics but with different genes for resistance

BIOTECHNOLOGY AND PHILIPPINE QUARANTINE SYSTEM

OVERVIEW OF THE PLANT QUARANTINE SYSTEM (PQS): ROLES AND MANDATES

Biotechnology Regulations In The Philippines

The Philippines is the first ASEAN country to develop a functional biotech regulatory system with the issuance of Executive Order No. 430 in 1990 which constitutes the National Committee on Biosafety of the Philippines (NCBP). NCBP is mandated to formulate, review, and amend national policy on biosafety and formulate guidelines on the conduct of activities on genetic engineering.

On July 16, 2001, President Gloria Macapagal-Arroyo issued the Policy Statement on Modern Biotechnology which promotes the safe and responsible use of modern biotechnology and its products.

In 2002, the Department of Agriculture issued DA Administrative Order No. 8, series of 2002 which provides guidelines for the importation and release into the environment of Plants and Plant Products Derived from the Use of Modern Biotechnology and since then, the biotechnology regulations have been continuously evolving.

To continuously ensure the safe and responsible use of products of modern biotechnology, the Philippines has issued the DOST-DA-DENR-DOH-DILG Joint Department Circular (JDC) No.1, series of 2021 which mandates several national government agencies to oversee the implementation of the said Circular.

Role Of National Government Agencies

The five (5) national government agencies shall have the following roles and functions under the JDC.

1. **Department of Science and Technology**
   - Take the lead in ensuring that the best available science is utilized and applied in making biosafety decisions
   - Lead in evaluating and monitoring contained use of regulated articles
2. **Department of Agriculture**
   - Address biosafety issues related to the country's agricultural productivity and food security
   - Lead in the evaluation and monitoring of regulated articles
3. **Department of Environment and Natural Resources**
   - Ensure that the applicable environmental assessments are undertaken, and potential impacts identified
   - Lead in evaluating and monitoring regulated articles intended for bioremediation, the improvement of forest genetic resources and wildlife genetic resources
4. **Department of Health**
   - Assess the health impacts of GM applications
   - Lead in evaluating and monitoring processed food derived from or containing GMOs

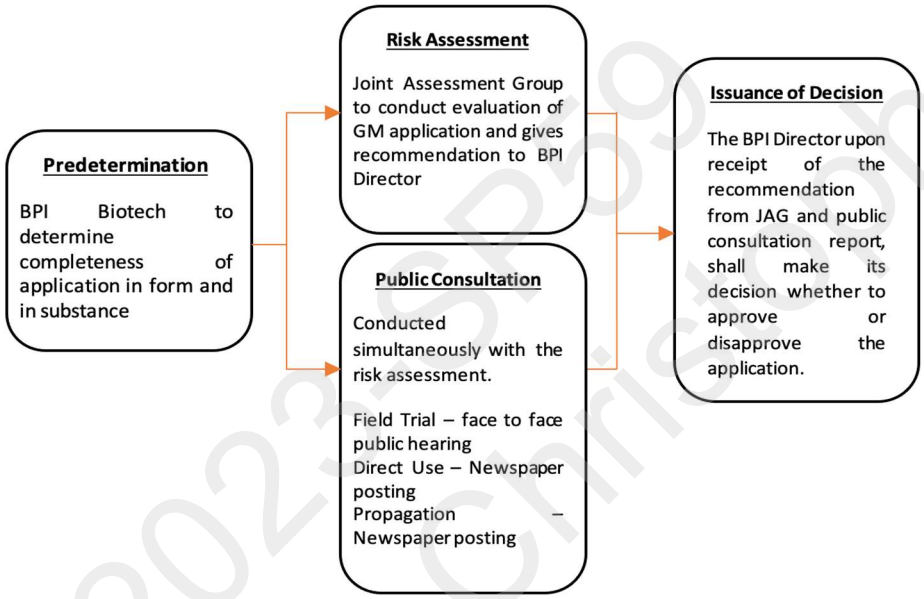
5. **Department of the Interior and Local Government**

- Oversee the conduct of public consultations as required under the Local Government Code

Procedure For The Issuance Of Biosafety Permit (*In A Nutshell*)

A Biosafety Permit is a document issued by BPI which certifies that a particular GM application has satisfactorily passed biosafety risk assessment. The BPI Director is the issuing authority of Biosafety Permit.

Under the **JDC No.1, s2021**, issuance of permit is around 35-40 (working?) days which is compliant with the Republic Act No. 11032 "Ease of Doing Business and Efficient Government Service Delivery Act of 2018." Figure below illustrates the procedure for the issuance of a biosafety permit.



Procedure for the issuance of Biosafety Permit (in a nutshell)

Predetermination

The Biotech Office of the BPI is mandated to perform determination of the completeness of the submitted GM crop application in form and substance.

The BPI Biotech staff has 3 days upon acceptance of the application to determine if all required documents are submitted. If found complete, the applications shall be endorsed to DA, DENR, DOH, and DOST Biosafety Committees for review.

Conduct of Risk Assessment

In accordance with the JDC No.1, s2021, the risk assessment shall be carried out in a scientifically sound and transparent manner based on available scientific and technical information.

The risk assessment of GM crop applications is conducted by the Joint Assessment Group which is composed of qualified representatives from the Biosafety Committees of DA, DENR, DOH, and DOST. The JAG is mandated to do the evaluation of

the GM crop applications for field trial, direct use, and commercial propagation to determine if they will pose greater risk to human and animal health and the environment compared to its conventional counterpart.

The JAG makes recommendations to the BPI Director based on the result of the risk assessment. The risk assessment is conducted simultaneously with the public consultation.

Public Consultation

Decisions taken under the JDC No.1, s2021 shall be arrived at in a transparent and participatory manner. Public consultation aims to gather comments of the stakeholder and the general public, and an opportunity for the public to participate in a responsible and accountable manner in biosafety decision-making processes. The BPI has the responsibility to make all applications publicly available by posting on the relevant websites.

The process of public consultation varies depending on the type of biosafety permit application.

- Public Consultation for Field Trial
  The applicant shall post a Public Information Sheet (PIS) in conspicuous places within the vicinity of the city/municipality and barangay where the field trial will be conducted. The PIS contains information in the proposal including the objective, potential risk and benefits of the GM crop application.

  The applicant shall also conduct face-to-face public hearing to gather the comments of the stakeholder and concerned individuals/groups in the area. The applicant shall submit a) a report summarizing all comments raised during the public hearing and how these were addressed by the applicant, and b) resolution of the City/Municipal Sanggunian regarding the proposal.

- Public Consultation for Direct Use and Commercial Propagation
  The applicant shall publish a copy of the PIS for direct use and commercial propagation in one newspaper of general circulation (i.e., Manila Bulletin, Malaya Business Insight, etc.). The approved PIS shall also be published in the official website of the applicant and the official website of the BPI.

Issuance of Decision

The Director of the Bureau of Plant Industry shall make a decision to approve or disapprove the application within five (5) working days upon receipt of the recommendation document from the JAG, based on the following considerations:

1. Compliance with administrative procedure and requirements;
2. Recommendation of the Joint Assessment Group;
3. Issues and concerns raised during the public participation period; and
4. Applicant's response to the issues and concerns raised during the public consultation

Once approved, Biosafety Permit for the intended purpose shall be issued. Biosafety Permit for Direct Use and Commercial Propagation shall remain valid unless revoked for any reasons set forth under the Circular. On the other hand, a Biosafety permit for field trial is valid only for two (2) years.

Biosafety Permit lists all the conditions the permit holder has to comply with.

Compliance with the conditions of the biosafety permit for field trial, commercial propagation, or direct use shall be monitored by the BPI, with the assistance of other agencies.

Types of biosafety Permit Issued

The applicant may file an application for the issuance of Biosafety Permit for direct use, field trial, or commercial propagation.

1. Application for Biosafety Permit for Direct Use

   Applicant may apply for Biosafety Permit for Direct Use of imported or domestically developed GM crop to be used for food, feed, or for processing

2. Application for Biosafety Permit for Field Trial

   Applicant may apply for the issuance of Biosafety Permit for Field Trial either for the following purposes:

   a. generate the data requirements for biosafety evaluation which include agronomic performance under different environmental conditions, effect on target and non-target organisms, and other relevant data
   b. check that the regulated article does not pose greater risk to human health and the environment as compared to its conventional counterpart
   c. choose which line/variety to advance to commercial propagation
   d. other purpose set or proposed by the applicant

3. Application for Biosafety Permit for Commercial Propagation

   Applicant applies for Biosafety Permit for Commercial Propagation to allow the commercial planting of the approved GM crop.

Petition for Reconsideration

An aggrieved party may file a request for the reconsideration of the decision of the BPI Director with the DA Secretary within fifteen (15) working days from the announcement of the decision.

Approved GM Applications With Valid Biosafety Permit

As of June 2022, there are 93 valid biosafety permits issued for cotton, soybean, rice, alfalfa, corn, sugar beet, canola, potato, and eggplant for direct use as food and feed, or for processing.

Furthermore, 14 biosafety permits for commercial propagation were issued for corn and rice.

Insect Resistance Management and its significance

(Taken from Chapter 2 of the Manual on Insect and Weed Resistance Management Data Collection for Post Commercial Monitoring of Biotech Corn in the Philippines)

1. What is insect resistance, IRM, concept of refuge and other components of IRM?

Bt corn has proven to be an important technology to help corn growers control damaging target lepidopteran insect pests and produce higher yields and better-quality grain.

In the Philippines, *Bt* corn had been planted in commercial fields starting 2003 with a steady rate of increase in adoption. The key information on insect resistance, IRM, refuge and other components of IRM are defined and explained in memorandum circulars issued by Department Agriculture such as MC No. 17 series of 2003, MC No. 08 series of 2005, MC No. 01 series of 2006, MC No. 04 series of 2007, MC No. 03 series of 2012 and MC No. 02 series of 2014.

Insect resistance

Insect resistance may be defined as "a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the recommendation for that pest species".

Insect Resistance Management (IRM)

IRM refers to the deployment of a combination of strategies designed to reduce the risk of the target insect (ACB) developing resistance to the *Bt* corn plant. The combined high dose/refuge strategy is an integral part of IRM system prescribed for *Bt* corn in the country and provides the condition by which the number of resistant individuals is maintained at a very low level. The high dose guarantees not less than 99% mortality of ACB, while the refuge serves as source of Bt-susceptible insects that can mate with rare resistant individuals that may emerge from Bt corn. The high dose plus refuge strategy keeps the rare status of the resistant individuals in the field.

Concept of refuge

Refuge are crops such as non-*Bt* corn hybrids (herbicide-tolerant corn, conventional corn hybrid), open pollinated corn varieties, and alternate host (crops and weeds) that are present in the area and surrounding environment of the target insect pest of *Bt* corn. It serves as a habitat for susceptible insects that can potentially mate with resistant individuals that might have evolved in *Bt* corn, thereby diluting the resistant population. Planting of a refuge crop is required to help preserve the effectiveness of *Bt* corn technology. Follow period and crop rotation also provide a temporal refuge for susceptible insects.

In the implementation of IRM for *Bt* corn in the Philippines, structured refuge is required through 90:10 bag-in-a-bag (BIB) mode of deployment for corn with single *Bt* insecticidal proteins, and 95:5 BIB or 95:5 seed blend for *Bt* corn with pyramided Bt insecticidal proteins targeting ACB. In the case of 90:10 BIB, the Technology Developers packed separately the 90% of *Bt* corn seeds and 10% refuge or non-Bt corn seeds (herbicide-tolerant corn) in a bag and put the two bags in one bag. In the same manner, the packing of 95:5 BIB is done by packing separately the 95% *Bt* corn seeds and 5% non-Bt corn seeds (herbicide tolerant corn) in a bag and put the two bags in one bag. However, the 95:5 seed blend for *Bt* corn with pyramided *Bt* insecticidal proteins is packed by mixing the 95% *Bt* corn seeds and 5% non-Bt corn seeds (herbicide-tolerant corn), and put in one bag

The bagging of biotech corn seeds are good for one hectare weighing 18kg per bag (16.2 kg *Bt* corn and 1.8 kg herbicide-tolerant corn as refuge seeds for 90:10 BIB; and 17.1 kg *Bt* corn and 0.9 kg herbicide-tolerant corn as refuge seeds for 95:5 BIB), and good for one half hectare weighing 9kg per bag (8.1 kg *Bt* corn and 0.9 kg herbicide-tolerant corn as refuge seeds for 90:10 BIB; and 8.55 kg *Bt* corn and 0.045 kg herbicide-tolerant corn as refuge seeds for 95:5 BIB)

Other component of IRM

The best way for growers to preserve the benefits and insect protection of *Bt* technology is to incorporate Integrated Pest Management (IPM) practices. This can be done by following recommended IPM practices, including cultural and biological control tactics, and appropriate use of pest thresholds and sampling. Farm monitoring and reporting of unexpected damage on *Bt* corn will be done by all companies deploying Biotech corn technology

2. What are the corn events with Bt resistant trait approved for propagation in the Philippines?

There are three (3) single *Bt* corn events (MON810, Bt11 and TC1507), one (1) pyramided *Bt* corn event (MON89034), and four (4) stacked trait events (MON810xNK603, Bt11xGA21, MON89034xNK603, and TC1507xMON810xNK603) approved for propagation in the Philippines. In 2014, the Technology Developers and its licensee only commercialized the 4 stacked trait events with *Bt* and herbicide-tolerance such as MON810xNK603, Bt11xGA21, MON89034xNK603, and TC1507xMON810xNK603. The specific hybrids are listed in Table 1. MON810 was the first Bt corn event approved for propagation in the Philippines, which contains the Cry1Ab gene conferring resistance to ACB. Bt11 contains CryAb & pat genes conferring resistance to ACB and phosphinothricin herbicide. TC1507 contains Cry1F and pat genes conferring resistance to ACB and tolerance to glofosinate-ammonium herbicide. MON89034 is a pyramided *Bt* corn trait event containing Cry1A.105 & Cry2Ab conferring resistance to ACB, cutworm and earworm

3. What are the recommended planting designs of refuge for single and pyramided stacked traits of *Bt* corn?

In order to maximize the effectiveness of the refuge, it is recommended that structured refuge shall be followed for 90:10 BIB mode of deployment for corn with single *Bt* insecticidal proteins, and 95:5 BIB or 95:5 seed blend for *Bt* corn with pyramided *Bt* insecticidal proteins targeting ACB (Fig1A-D).

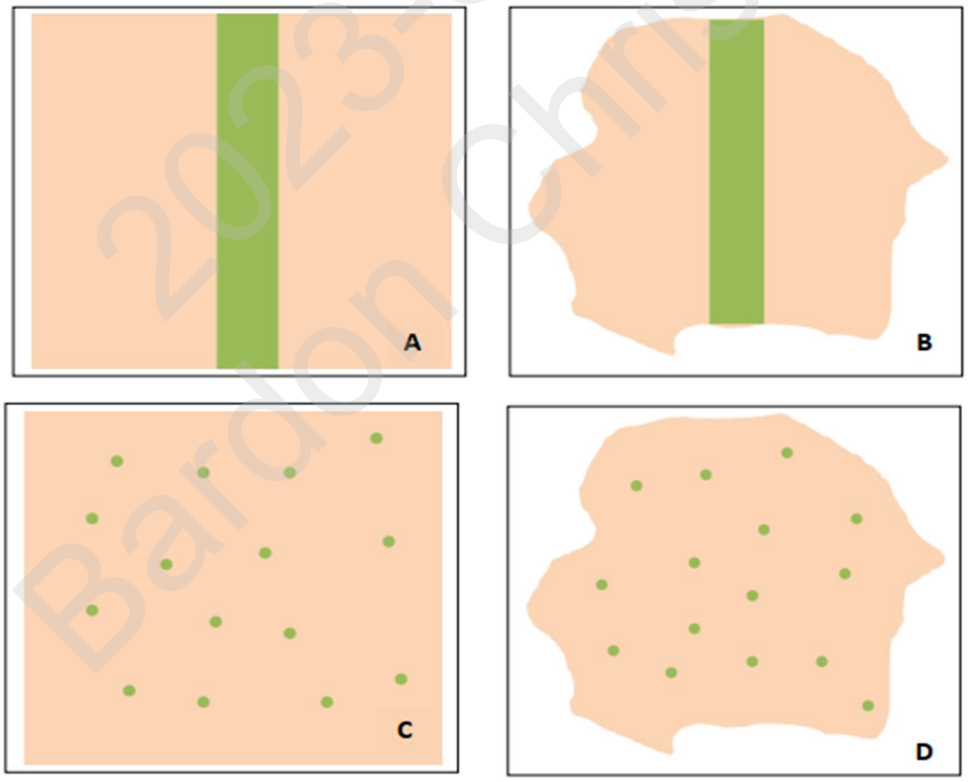


Fig. 1.A-B. Recommended planting designs for the 90:10 BIB for corn with single Bt insecticidal proteins and 95:5 BIB for corn with pyramided Bt insecticidal proteins; C-D. Probability of refuge seed distribution in 95:5 seed blend for Bt corn with pyramided Bt insecticidal proteins

Figure from: Green Manual, BPI.

In the case of 90:10 BIB and 95:5 BIB, the refuge seeds shall be planted at the center of the corn field. To facilitate better planting operation, it is suggested to plant first the half of the *Bt* corn seeds, followed by the refuge seeds at the center, and the remaining *Bt* corn seeds for half or one hectare bagging of Biotech corn seeds.

The 95:5 seed blend *Bt* corn with pyramided *Bt* insecticidal proteins targeting Lepidopteran insect pests are packed at 9 kg for half hectare or 18kg for one hectare and can readily planted in the corn field. The 5% refuge seeds are randomly distributed in the bag; hence the refuge seeds will be randomly planted in the corn field.

Plant Breeding Innovations And Mc No. 8 S2022

The Science of PBIs

Plant breeding innovation (PBI) is a term used to describe the ever-changing and evolving techniques and practices which could develop the current methods of plant breeding. This involves using new methods of genetic manipulation and molecular biology. Some examples are the use of CRISPR-Cas9, TALENS, and Zinc Finger Endonucleases (ZFNs) used to cut a specific portion of the DNA strand in order to insert, substitute, or delete a desired fragment of the gene.

One famous example is CRISPR/Cas which is a form of bacterial immunity which creates a repair mechanism in plant DNA by creating double stranded breaks, with possible outcomes of creating mutations which alters gene expression.

Methods of Generating PBIs

1.Oligonucleotide directed mutagenesis (ODM)
2. Cisgenesis/intragenesis
3. RNA-dependent DNA methylation
4.Grafting on GM material
5. Reverse breeding
6.Agro-infiltration
7. Site-directed nucleases
8. Synthetic Genomics

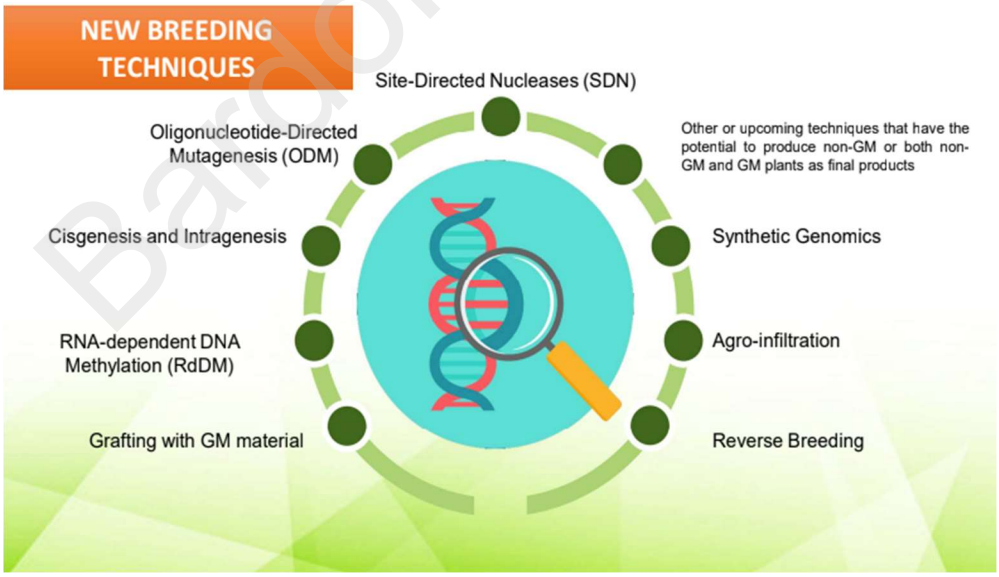


Photo from: ISAAA, 2023

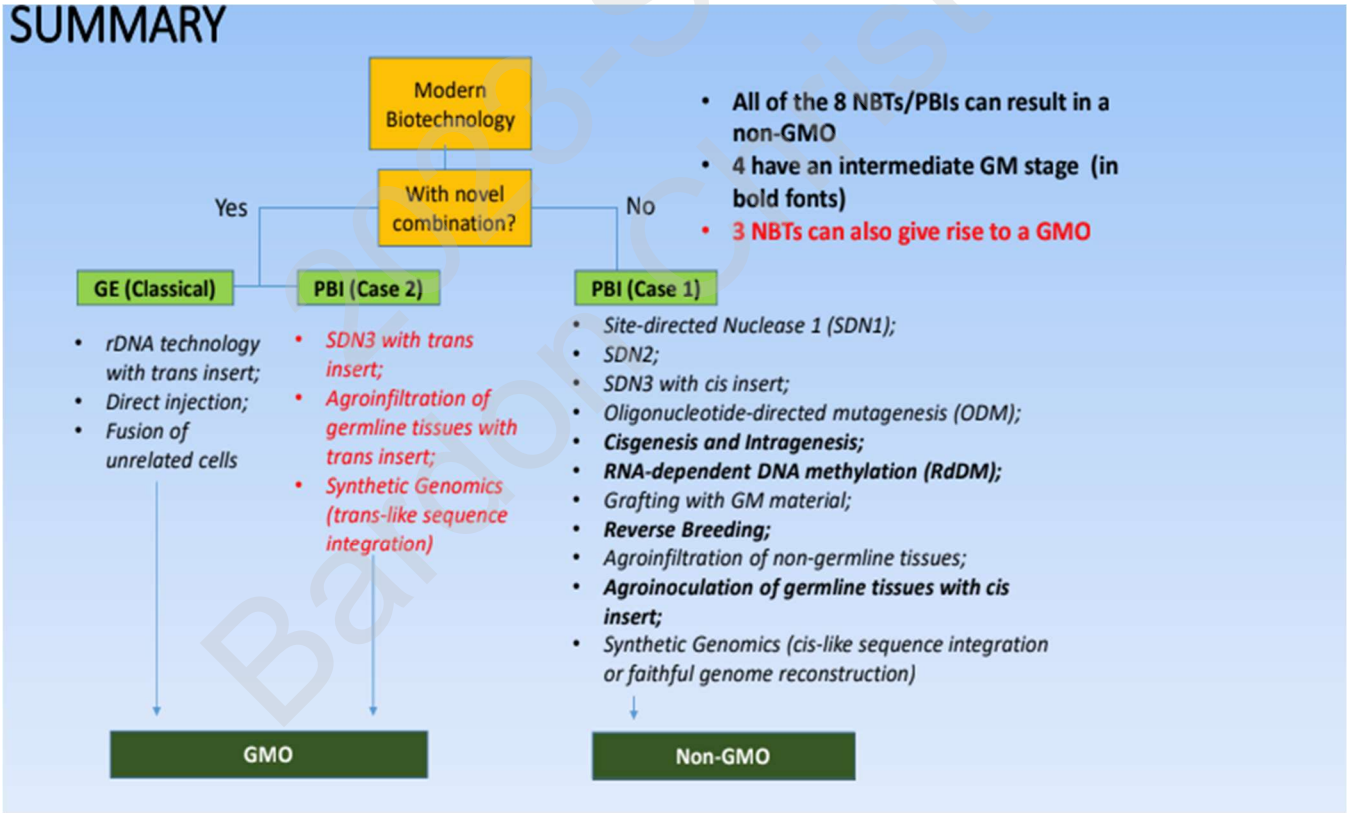
Policy On Plant Breeding Innovations

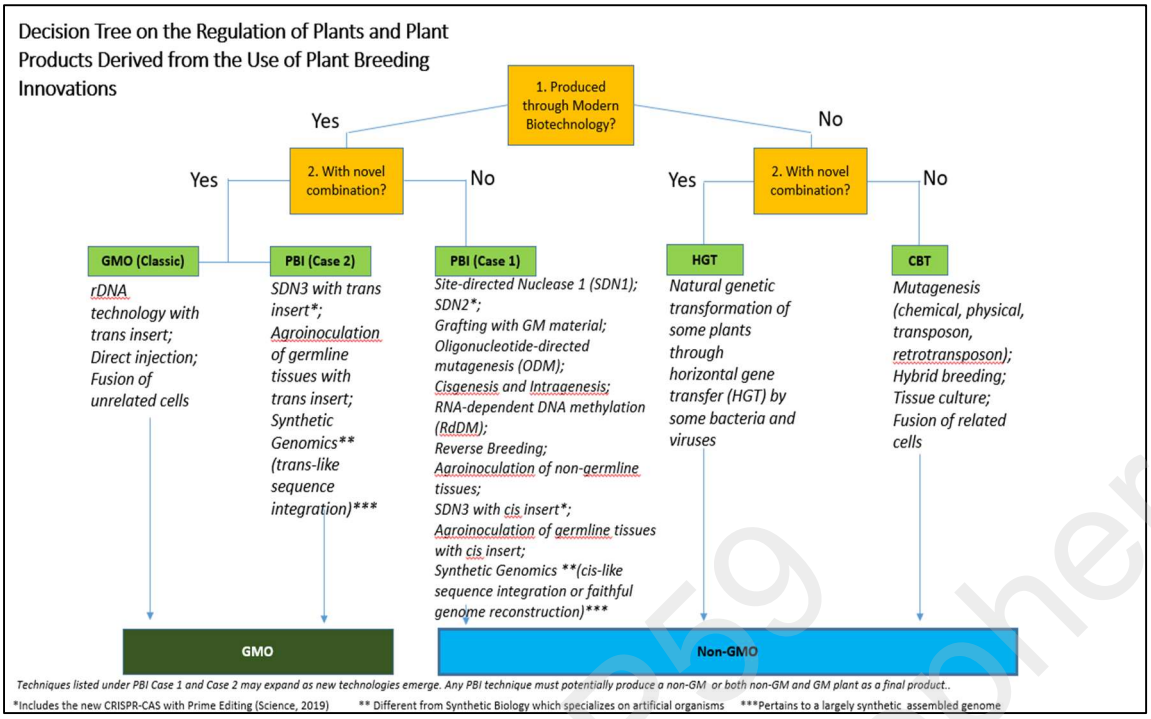
NCBP Resolution no. 001, series of 2020 and DA Memo Circular no. 08, series of 2022: The Regulation of PBI Products

The governing policy for the determination whether the products of PBIs fall within the scope of JDC No. 1 s2021 is the MC No. 8 s2022 *"RULES AND PROCEDURE TO EVALUATE AND DETERMINE WHEN PRODUCTS OF PLANT BREEDING INNOVATIONS (PBIs) ARE COVERED UNDER THE DOST-DA-DENR-DOH-DILG JOINT DEPARTMENT CIRCULAR No.1, SERIES OF 2021 (JDC1, s2021) BASED ON THE NCBP RESOLUTION NO. 1, SERIES OF 2020 ".* This policy contains the procedures and conditions on how to evaluate and determine the regulatory status of products of PBIs, on the basis that whether it contains or not a foreign genetic material. This is based on the NCBP Resolution No. 001 s2020 "*THE REGULATION OF PLANT AND PLANT PRODUCTS DERIVED FROM THE USE OF PLANT BREEDING INNOVATIONS (PBIs) OR NEW PLANT BREEDING TECHNIQUES (NBTs)"*

Decision Tree For The Determination Of PBI Products (Summarized)

The basis on whether products of PBIs will fall under the scope of GM regulations or not depends on several criteria. Below is the decision tree used by the regulators in the determination.





Decision Tree from: Dr. Reynante Ordonio, PhilRice

EXAMPLES OF PRODUCTS OF PBIs

(ISAAA, 2021)

Listed below are some examples of gene-edited plants, animals, and plant products which has enhanced performance and characteristic traits.

Enhances blood pressure lowering

Gene inactivation of *eIF4E2* gene: 3 lines exhibited resistance to pepper veinal mottle virus –Ca31, partially to strain 1C but susceptible to PVY: France

Powdery mildew resistant wheat without growth penalties, at CAS, Tamlo-32 does not have yield penalty compared to its predecessor: China

Intentional genomic alteration(IGA)
Slick hair coat = mutation in cattle to better regulate their internal body temperature with an increased capacity for sweating.
USDA announced the low risk determination for the marketing of products derived from GnEd beef cattle

A typical horned dairy cow (left) and a genome-edited cow without horns (right) that contains a DNA sequence found in hornless cattle. *(Photo courtesy of Alison L. Van Eenennaam, Department of Animal Science at University of California, Davis.)*

Source: ISAAA. 2021. Breaking Barriers with Breeding: A Primer on New Breeding Innovations for Food security. ISAAA Brief No. 56. ISAAA: Ithaca, NY.

Sea bream with myostatin protein knocked –out increased growth rate

Puffer fish with disrupted leptin gene gained appetite and weight

BASIC CONCEPTS OF BIOTECHNOLOGY

What is biotechnology?

Biotechnology is defined as any biology-based technology which uses organisms or their parts to make or modify products, or improve microorganisms, plants, & animals

What is modern biotechnology?

refers to biotechnological techniques for the manipulation of genetic material and the fusion of cells beyond normal breeding barriers.

Genetic Engineering or Recombinant DNA Technology

refers to the set of techniques for recombining genes from different sources in vitro and transferring this recombinant DNA into a cell where it may be expressed.

Requirements of Recombinant DNA Technology:

1. Gene/Gene source
2. Enzymes
3. Vector
4. Method to introduce the recombinant DNA to the host cell
5. Host cell
6. Selection systems

What is Genetically Modified Organism or GMO?

Genetically Modified Organism (GMO) refers to any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology.

Genetically Modified (GM) Plants

Traits incorporated in Transgenic Crops/ Biotech Crops:

1. Insect resistance
2. Herbicide tolerance
3. Abiotic Stress
4. Modified product quality
5. Disease resistance
6. Altered growth yield
7. Pollination control system

GMOs in the Philippines

The Philippines is the first country to plant a biotech crop in Southeast Asia in 2003 after *Bt* Corn was approved for commercial planting in 2002. In 2021, Golden Rice was given a biosafety permit for commercial propagation, while *Bt* Eggplant was given a biosafety permit for direct use as food, feed, or for processing. In 2022, High Iron and Zinc Rice received its biosafety permit for field trial, while *Bt* Eggplant received its biosafety permit for commercial propagation.

A total of 266,257.50 hectares were planted with Bt Corn (herbicide tolerant and insect resistant) nationwide, during the wet season of 2021. This indicates a high crop adoption of Bt Corn in the Philippines during the previous planting season.

Plant Quarantine Regulations

What is Plant Quarantine?

- defined as a legal preventive measure against introduction of exotic pests harmful to agricultural, horticultural and forestry industries.
- all activities designed to prevent the introduction and/or spread of quarantine pests or to ensure their official control [FAO, 1990; revised FAO, 1995].

National Plant Quarantine Services Division

- regulatory arm of the Philippine Department of Agriculture
- BPI serves as a National Plant Protection Organization (NPPO)
- PD No. 1433 "Plant Quarantine Decree of 1978",
- strengthened by adequate laws, regulations, resources and facilities to monitor and control the movement of plant pests

GOVERNING LAW

Philippine Plant Quarantine is being enforced by the Bureau of Plant Industry-National Plant Quarantine Services Division by virtue of PRESIDENTIAL DECREE 1433, as amended otherwise known as the Plant Quarantine Law of 1978, as amended.

Mandate:

- prevent the entry of foreign pests into the country
- prevent spread of pests already existing in the country and;
- comply with international standards (describes the principles of PQ in relation to int'l trade)

International Quarantine

- import and export of plants, planting materials and plant products

Issuance of:

- Phytosanitary Certificate
- SPS Import Clearance

Domestic Plant Quarantine

- focuses on the restriction on the movement of infected and/or infested plants and plant parts/products
- prevent further spread of indigenous quarantine pests and introduced pests to a known Pest Free Area

Plant Quarantine Functions

- Promulgation and Enforcement of Plant Quarantine Rules and Regulations
- Bilateral discussions / negotiations
- (Market Access)
- Conduct Plant Pest Risk Analysis (PRA)
- Conduct Laboratory Analysis
- Commodity Inspection and treatment
- Post Entry Quarantine
- Accreditation of Importers, Exporters, Farmers/Growers, Treatment Facilities and Treatment Providers
- Pest Survey
- Establishment of Pest Free Area (PFA)
- Other relevant functions to achieve its mandate (e.g., formulate rules, guidelines, orders, etc.)

Main Functions:

- Inspection of imported agricultural commodities to prevent entry of exotic pests
- Inspection of agricultural commodities intended for export to comply with the requirements of the importing country
- Detection of introduced exotic pests for containment or control by adopting domestic regulations
- Undertaking post entry quarantine inspection for identified planting materials
- Conducting the Pest Risk Analysis (PRA) to identify phytosanitary requirements for the importation of plants/planting materials

Bases/Sources of PQ Rules and Regulations

- ISPM's set by IPPC
- Bilateral / Multilateral Agreements
- Pest Occurrence / outbreak
- Incursion of exotic pests
- Biosafety concerns on GM crops
- PRA Results
- New Technologies

Post-Entry Quarantine

- to get the plant propagating materials guaranteed to be free from plant pests not known to occur in the country

- Post entry monitoring on the occurrence of pests associated with imported plants and planting materials [and monitoring of genetically modified (GM) crops

If an unidentified organism is found:

- control and contain a consignment
- further inspection of a consignment to determine level or proportion of infestation or infection, testing, quarantine,
- prohibit the movement of a consignment,
- destruction of a consignment,
- treatment (chemical and/or physical), and,
- return to origin

Presidential Decrees, Administrative Orders, Memorandum Orders etc.

Act No. 3027	An Act to Protect Agricultural Industries of the Philippine Islands from Injurious Plant Pests and Diseases Existing in Foreign Countries and Further to Regulate the Domestic Movement of Plant Material in Order to Minimize the Injury from Pests and Diseases Already Introduced	March 8, 1922
Presidential Decree No. 1433	Promulgating the Plant Quarantine Law of 1978, Thereby Revising and Consolidating Existing Plant Quarantine Laws to Further Improve and Strengthen the Plant Quarantine Service of the Bureau of Plant Industry	June 10, 1978
Administrative Order No. 1-B, Series of 1955	(Revised) Regulations Governing the Zonification of Abaca Areas, Actual and Potential, and Prescribing Certain Restrictions and Other Measures for the Control of *Abaca Mosaic Disease*	May 16, 1955
Administrative Order No. 14, Series of 1950	Regulations Governing the Inter-Provincial Quarantine on All Plants of the Genus *Musa*, in Order to Prevent the Spread of *Abaca Diseases known as Bunchy-Top* Including *Heart Rot*, *Mosaic*, *Wilt (Vascular Disease)* and *Bacterial Leaf Streak*	1950
BPI Special Quarantine Administrative Order No. 01, Series of 2012	*Declaring Panama Disease of Bananas (Fusarium Wilt) caused by Fusarium oxysporum f. sp. cubense, a Dangerous and Injurious Banana and Abaca Disease;* Providing its Control and Placing Under Quarantine All the Provinces where the Disease Already Exists to Prevent Further Spread from Infected Areas to Non-Infected Areas	February 15, 2012

- **Fusarium wilt in banana** (also known as Panama disease) is caused by a soil-borne fungal pathogen *Fusarium oxysporum f. sp. cubense* (Foc) that invades the roots and then the vascular of the plant resulting to wilt and dieback.
- **Tropical Race 4 (TR4)** is one of only six strains of *F. oxysporum f.sp. cubense* (Foc) that attack Cavendish bananas.

DA BPI Special Quarantine Order No. 01, Series of 2015	*Declaring Cassava Witches Broom (CWB) a Dangerous Disease of Cassava,* Providing for Its Control and Placing Under Quarantine the Province of Bukidnon where the Disease Exists	June 05, 2015
Administrative Order No. 02, Series of 1969	*Declaring the "Leaf Mottling Virus" Diseases a Dangerous Disease of Citrus:* Providing Its Control and Placing Under Quarantine All the Provinces where the Disease Already Exists	June 13, 1969
BPI Special Quarantine Order No. 01, Series of 2013	Rules and Regulations on the Movement, Transfer, and Carrying of Citrus Plants and Planting Materials Nationwide and Providing for Regulatory Measures to *Prevent the Spread of Probable Strains of Insect Borne and Bud Transmissible Diseases Thereby Allowing the Revival of Citrus Industry in Suitable Areas*	February 06, 2013
Administrative Order No. 06, Series of 1949	Declaring the *Coconut "Cadang-Cadang" of the Bicol Type a Dangerous Disease;* Providing for its Control, and Placing Under Quarantine All the Provinces Where the Disease Already Exists	March 11, 1959
BPI Special Quarantine Order No. D-1, Series of 1982	Declaring *Socorro Wilt of Coconut as Dangerous and Injurious Coconut Disease and Likewise Declaring the Island of Mindoro and Other Places Where the Same may be Found to Exist, Under Quarantine* to Prevent its Spread from Infested Areas to Non-infested Areas	May 26, 1982
BPI Special Quarantine Order No. I-2, Series of 1982	Regulations Prohibiting, Except for Certain Purposes and Under Certain Conditions, the Importation of Coconut (Cocos Nucifera Linn.) and Other Palms and/or Parts thereof from Areas Infested with the *Lethal Yellowing Disease of Coconut*	May 26, 1982
BPI Special Quarantine Order No. 02, Series of 2005	Quarantine Measures to Prevent the Introduction and Spread of *Chlorotic Ringspot Virus of Oil Palm*	August 22, 2005

BPI Special Quarantine Order No. I-1, Series of 1982	Regulating the Importation of Mango Plants *(Mangifera* spp.) and Parts thereof from Places, Areas and Countries Infested with *Mango Malformation or Bunchy-Top, Woody-Gall and Scaly Bark (Cuarteado),* Diseases of Mango in Order to Prevent their Introduction into the Philippines	May 26, 1982
BPI Special Quarantine Administrative Order No. 16, Series of 1989	Regulations Governing Inter-Provincial/Regional Movements of All Plants Species Belonging to Papaya (*Carica papaya*) in Order *to Prevent the Spread of Papaya Ring Spot Virus Disease (PRSV) to Non-infected Areas;* Providing Measures for the Destruction of All Infected Papaya Plants and Plant Pest Thereof	March 01, 1989
BPI Quarantine Administrative Order No. 14, Series of 1988	Declaring the *Potato Golden Cyst Nematode (Globodera rostochiensis* Woll.*) a Dangerous Pest and Placing Under Quarantine All Areas in the Philippines* where They are Found and Known to Exist	1988
Administrative Order No. 13, Series of 1949	Regulating the *Importation of Rubber Plants and Parts Thereof such as Seeds, Rubber Stumps, Budsticks, etc. from Central America in Order to Prevent the Introduction into the Philippine Islands of a Disease Known as Dothidella ulei,* Except for Certain Purposes and Under Certain Conditions	August 13, 1949
DA Administrative Order No. 03, Series of 2013	Regulating the Importation of Rubber (*Hevea* sp.) Plants and Parts Thereof Such As Seeds, Stumps, Budsticks, Etc., from South American Leaf Blight (SALB) Endemic Countries in Order to *Prevent the Introduction into the Philippines, the South American Leaf Blight of Rubber, a Disease Caused by Mycrocyclus ulei syn, Dothidella ulei,* Except for Certain Purposes and Under Certain Conditions	January 31, 2013

Inspection

• Inspection of consignments of plants (including planting materials) and plant products moving in international trade is an essential tool for management of pest risks and is the most frequently used phytosanitary procedure worldwide for import and export to determine if pests are present and/or the compliance with phytosanitary import requirements.

• Inspection also plays a vital role in the domestic transport of plants and plant products, particularly with plants and planting materials to ensure that regulated pests (regulated non-quarantine pests) will not be likely to spread in the country.

(Quarantine) Treatments

Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalization (ISPM 5).

Commonly used phytosanitary treatments in the Philippines prior to Export of Plants and Plant Products:

- Pesticide treatment (dressing/coating, spraying, dipping)

- Vapor Heat Treatment

- Hot Water Treatment

- (Dry) Heat Treatment

- Fumigation (methyl bromide, phosphine)

Most of the contents of the **Biotechnology and Philippine Quarantine System portion** is from the BPI Biotechnology Office as part of their training material. No contents can be used for other purposes aside from as a review material for URC students (Cea, 2023).

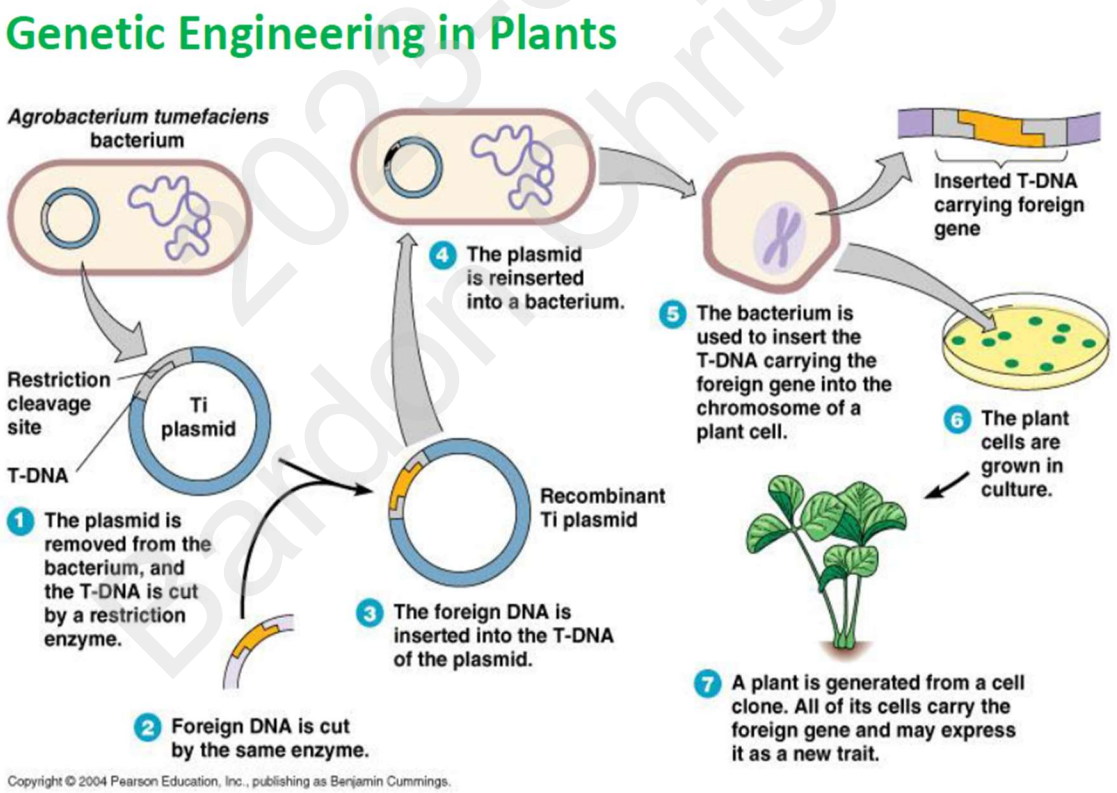


Photo from: Google images

TOP Five BIOTECH Crops

AdobeStock

Soybean
91.9 M ha.

https://www.britannica.com/plant/corn-plant

Corn
60.9 M ha.

https://www.the-sustainable-fashion-collective.com/

Cotton
25.7 M ha.

https://www.newfoodmagazine.com/

Canola
10.1 M ha.

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Alfalfa
1.3 M ha.

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