COURSE CODE: CPT 507

COURSE TITLE: PLANT PROTECTION

NUMBER OF UNITS: 3 UNITS

COURSE DURATION: 3 HR/WK

COURSE DETAILS:

Course Coordinator: PROF O. A. ENIKUOMEHIN
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COURSE CONTENT:

Definition of terms; Disease, Pests, Symptoms. Characteristics and classification of insect pests, viruses, bacteria, fungi, nematodes. Important insect pest, mites, viruses, fungi, bacteria, nematodes of arable and permanent crops in the tropics. Principles and methods of insect pest, viruses, bacteria, fungi, nematode control and management.

COURSE REQUIREMENTS:

This is a compulsory course for all B. Agric students (500L) in the College of Plant Science and Crop Production (COLPLANT). Students are expected to participate in all the course activities and earn a minimum of 75% attendance to qualify to write the final examination.

READING LIST:

AGRIOS, G. N.PLANT PATHOLOGY BY (Elsevier Academic Press 2005)

MEHROTRA R. S. & SHOK AGGARWAL V. H. A. PLANT PATHOLOGY (Tata McGraw-Hill Publishing Co. 2003

Dropkin R.S, V. H. *Introduction to Plant Nematology* John Wiley & Sons, Inc. (1980)

Mai,W. F., and H. H. Lyon. *Pictorial Key to Genera of Plant-Parasitic Nematodes* Cornell University Press, (1975)

Adesiyan, S. O., Caveness, F. E., Adeniji, M. O., and B. Fawole. *Nematode Pests of Tropical Crops, Heinemann Educational Books* (19900

LECTURE NOTES

Definition of pests:
Pests are any form of plant or animal life that is injurious or potentially injurious

to man, his properties, etc, e.g insects, vertebrates, weeds, pathogens such as bacteria, fungi, viruses, rickettsia,

Categories of pests:

a . Key / major / main pests. These are insect pests that are found everywhere particular crops are grown. They are usually the target of insect pest control. They cause significant losses on the crops that they attack, e.g. *Clavigralla tomentosicollis* on cowpea.

b. Occasional pests: These species cause economic damage to crops only at certain times of the year, period, season or places. They do not occur regularly because they are regulated by certain ecological factors, e.g. *Sylepta derrogata*

c. Potential pests: These pests do not cause any serious economic loss although they possess the innate capacity to do so. They assume the position of a key pest only when certain ecological balance that regulate them are disrupted for instance with the use of insecticides, *Bathycoelia thalassima*

d. Migrant pests: The insects cause serious damage outside their local habitat. They move together in large numbers causing serious economic loss to the crops attack, e.g *Locusta migratoroides*

Development of Pest Situations

Certain situations cause pest development. These can be categorized into 3: (a) Ecosystem concentration and simplification (b) Transportation (c) Man's attiude and demands.

(a) Ecosystem concentration and simplification: in the course of human development, man has simplified the ecosystem. This has caused pest situations in several instances. Examples of such simplifications include the following

i. planting of monocrops

ii. storage of large quantities of grains in a closed environment

iii. planting of improved varieties

iv. fertilization of crops

v. weeding which invariably removes competition

vi. spraying of insecticides

b. Transportation: with the advent of fast means of transportation, a lot of insects have moved from their places of origin to new places causing serious damage in the absence of their natural enemies.

Man's attitude and demands: The demand for blemish-free produce or high grade produce has led to the labeling of many insects as pests even when they are not.

Pest damage Assessment

Insect pest damage assessment is done in order to apportion loss occasioned by particular insect pests and to know when to initiate control measures.

In most cases it is impracticable to count all the pest present in a field, therefore pest population may be estimated by samples.

Sampling: Pests are usually sampled so that their abundance can be predicted, losses attributable to them measured ad the damage they cause prevented.

Sampling may be direct wherein insects are counted directly on the plant parts (e.g. flea beetles on okra leaves); or indirect where insect populations are estimated via the damage they cause (e.g. stem borers).

Insect Damage: loss of plant parts or organ as a result of insect injury

There are 2 types of damage: direct damage and indirect damage.

Direct damage is when the harvestable part of a crop is affected (e.g. cowpea pod)

Indirect damage is when the non-harvestable portion of the crop is affected (e.g. maize leaf)

Types of insect damage

a. Biting and chewing insects

1. holing of leaves thereby reducing photosynthetic areas
2. boring of the stem causing reduction in plant vigour
3. scrapping of leaf surface causing burning of leaves

4. rasping of leaf edges
5. mining of leaves
6. cutting of roots
7. destruction of buds or growing points
8. flower abortion
9. premature fruit fall

b. Piercing and sucking insects

1. cause loss of vigour due to removal of sap (wilting)
2. sucking of sap from leaves or stems
3. staining or discolouring of seeds
4. transmission of diseases

Indirect effects of insect infestation

1. make crops much more difficult to cultivate
2. may make crops develop spreading habit which makes weeding and spraying difficult
3. contamination of produce thereby reducing quality and marketability
4. Transmission of diseases

Insect pest forecasting:

Accurate forecasting of pest attacks helps control programme to be effective. It depends on the established relationship among the following factors

1. stage of development of the crop
2. stage of the development of the pest
3. environmental factors

CHARACTERISTICS AND CLASSIFICATION OF INSECTS

Insects belong to the phylum Arthropoda and the Class Insecta.

Phylum: Arthropoda

- Their bodies and appendages are segmented externally
- Their appendages are modified for feeding
- They possess an exoskeleton i.e. cuticle covering that has chitin
- The body cavity is known as heamocoel instead of a coelom i.e. their body cavity is not entirely lined by mesoderm
- They have no cilia
- They possess a ventral nerve cord and a dorsal brain
- They have bilateral symmetry

Phylum Arthropoda is divided into three subphyla

a. Mandibulata: those with well developed mandibles for biting and chewing

b. Chelicerata: Those that utilize a pair appendage called ‘chelicerae near the oral opening

c. Trilobitomorpha: those known from fossils whose none of their appendages was modified for feeding

Characteristics of Class Insecta

- The head, thorax, and abdomen are distinct
- Head has a pair of antennae (except in Protura)
- The mouth parts are for chewing, sucking or lapping; it also has the salivary gland
- The thorax typically has two (2) pairs of wings variously modified, reduced or absent
- The digestive tract has a fore-gut, mid-gut and a hind gut
- They have a slender mid-dorsal heart and an anterior aorta. There are no blood capillaries or veins; blood bathes the organ within the body
- Respiration is by means of tracheae from paired spiracles on the sides of the thorax and abdomen directly to the tissues (except in some Protura and Collembola which are primitive insects
- Excretion is by means of malpighian tubules which are attached to the anterior end of the hind gut (except in Collembola)
- The brain is of fused ganglia. They have double ventral nerve cord with

segmented ganglia often concentrated anteriorly
- Sense organs usually include compound eyes. There are also chemoreceptors for smell and antennae
- Sexes are separate; development may be complete or incomplete
- They occur in all habitat

CLASSIFICATION OF INSECTS OF AGRICULTURAL IMPORTANCE

. Order Orthoptera:
- Possess chewing mouthparts
- Long legs
- Large compound eyes
- Pronotum of the thorax collar-like
- Wings present; flight is by the activity of the hind wings
- E.g. locusts, grasshoppers (*Zonozerus variegatus*)

Order Isoptera:
- They are social insects
- Similar wings
- Different castes
- E.g. *Amitermis evuncifer*

Order Hemiptera:
- True bugs
- Large compound eyes
- Mouth parts are for piercing and sucking
- Antennae often longer than the head
- E.g. *Clavigralla tomentosicollis*

Order Homoptera
- Large compound eyes
- Piercing and sucking mouth parts
- Antenna filiform or sentaceous
- E.g. *Aphis crassivora*

Order Lepidoptera
- Sucking mouthparts
- Wings are membraneous covered with overlapping scales
- Larva is called caterpillars and is the damaging stage
- E.g. *Busseola fusca*

Order Coleoptera:
- Beetles
- Chewing mouth parts
- Large compound eyes
- Thickened fore wings or elytra
- Larval stage is the destructive stage but many adults are also of economic importance
- E.g. *Callosobruchus maculatus*

IMPORTANT PESTS OF TROPICAL CROPS

Cassava

Casava green spider mite *Mononychelus tanajoa*
Cassava red spider mite *Oligonychelus gossypiella*
Cassava mealybug *Phenacoccus manihoti*
Whiteflies *Bemecia tabaci*
Elegant grasshopper *Zonocerus variegatus*

Maize

Stem borers: *Busseola fusca, Sesamia calamistis* and *Eldana sachharina*.
Zonocerus variegatus,
Heliothis zea
Sitophilus zeamais

Cowpea

Ootheca mutabilis
Aphis craccivora
Maruca vitratta
Clavigralla tomentosicollis
Rice
Aspavia armigera
Sesamia calamistis
Chilo spp
Diopsis thoracica
Yam
Heteroligus meles (yam beetle)
Zonocerus variegatus
Okra
Podagrica spp.
Sylepta derogata
Aphis gossypii
Disdercus superstitiosus
Tomato
Bemisia tabaci
Spodoptera littoralis
Sylepta derogata
Helicoverpa armigera
Cocoa
Sahlbergella singularis
Distantiella theobromae
Helopeltis spp
Bathycoela thalasina
Citrus
Phenacoccus citri
Dacus spp
Batrocera invadens
Ceratitis capitata
Cashew
Analeptis trifasciata
Helopeltis spp
Kola
Balanogastris kolae
Phosphorus spp

METHODS OF PEST CONTROL

Cultural control: Making crop environment not conducive for insect pest establishment. It is preventive and does not decimate already existing pest population. Examples of cultural control: intercropping, crop sanitation, crop rotation, close season, manuring, early planting, early harvesting, etc.

Biological control: The use of living organism to destroy, repel, replace and exsting pest population. This method is hinged on the fact that all organisms have their natural enemies. Biological control agents include: predators (e.g. lady birds), pathogens (e.g. *Bacillus thuringiensis*), parasites (e.g. nematodes) and parasitoids (*Gyranusoides tebygi*).

Chemical control: The use of natural or syntheic compounds to kill, repel, attract or decimate pest population. There are 2 major categories of insecticides: organic (which contains carbon atoms in their molecules) and inorganic (those that do not contain carbon in their molecules).

Legislative control: This is the enactment of laws to prevent entry, spread of pests into free areas. This cannot be undertaken by individuals but by the government.

Integrated pest management (IPM) is an integrated approach of crop management to solve ecological problems when applied in agriculture.

These methods are performed in three stages: *prevention*, *observation*, and *intervention*. It is an ecological approach with a main goal of significantly reducing or eliminating the use of pesticides while at the same time managing pest populations at an acceptable level. An IPM system is designed around six basic components: The US Environmental Protection Agency has a useful set of IPM principles.

1. **Acceptable pest levels:** The emphasis is on *control*, not *eradication*. IPM holds that wiping out an entire pest population is often impossible, and the attempt can be econmically expensive, environmentally unsafe, and frequently unachievable. IPM programmes first work to establish acceptable pest levels, called action thresholds, and apply controls if those thresholds are crossed. These thresholds are pest and site specific, meaning that it may be acceptable at one site to have a weed such as white clover, but at another site it may not be acceptable. By allowing a pest population to survive at a reasonable threshold, selection pressure is reduced. This stops the pest gaining resistance to chemicals produced by the plant or applied to the crops. If many of the pests are killed then any that have resistance to the chemical will form the genetic basis of the future, more resistant, population. By not killing all the pests there are some un-resistant pests left that will dilute any resistant genes that appear.
2. **Preventive cultural practices:** Selecting varieties best for local growing conditions, and maintaining healthy crops, is the first line of defense, together with plant quarantine and 'cultural techniques' such as crop sanitation (*e.g.* removal of diseased plants to prevent spread of infection).
3. **Monitoring:** Regular observation is the cornerstone of IPM. Observation is broken into two steps, first; inspection and second; identification. Visual inspection, insect and spore traps, and other measurement methods and monitoring tools are used to monitor pest levels. Accurate pest identification is critical to a successful IPM program. Record-keeping is essential, as is a thorough knowledge of the behavior and reproductive cycles of target pests. Since insects are cold-blooded, their physical development is dependent on the temperature of their environment. Many insects have had their development cycles modeled in terms of degree days. Monitor the degree days of an environment to determine when is the optimal time for a specific insect's outbreak.
4. **Mechanical controls:** Should a pest reach an unacceptable level, mechanical methods are the first options to consider. They include simple hand-picking, erecting insect barriers, using traps, vacuuming, and tillage to disrupt breeding.
5. **Biological controls:** Natural biological processes and materials can provide control, with minimal environmental impact, and often at low cost. The main focus here is on promoting beneficial insects that eat target pests. Biological insecticides, derived from naturally occurring microorganisms (*e.g.*: *Bt*, entomopathogenic fungi and entomopathogenic nematodes), also fit in this category.
6. **Responsible Pesticide Use:** Synthetic pesticides are generally only used as required and often only at specific times in a pests life cycle. Many of the newer pesticide groups are derived from plants or naturally occurring substances (*e.g.*: nicotine, pyrethrum and insect juvenile hormone analogues), but the toxophore or active component may be altered to provide increased biological activity or stability. Further 'biology-based' or 'ecological' techniques are under evaluation

What are viruses?

Viruses are very small (submicroscopic) infectious particles (virions) composed of a protein coat
and a nucleic acid core.
They carry genetic information encoded in their nucleic acid, which typically specifies two or more proteins. Translation of the genome (to produce proteins) or transcription and replication
(to produce more nucleic acid) takes place within the host cell and uses some of the host's biochemical "machinery".
Viruses do not capture or store free energy and are not functionally active outside their host.
They are therefore parasites (and usually pathogens) but are not usually regarded as genuine microorganisms.
Most viruses are restricted to a particular type of host. Some infect bacteria, and are known as bacteriophages,
whereas others are known that infect algae, protozoa, fungi (mycoviruses), invertebrates, vertebrates or vascular plants.
However, some viruses that are transmitted between vertebrate or plant hosts by feeding insects
(vectors) can replicate within both their host and their vector.
Viroids, are infectious RNA molecules that cause diseases in various plants. Their genomes are
much smaller than those of viruses (up to 400 nucleotides of circular single-stranded RNA) and
do not code for any proteins.
DEFINITION: A **virus** is a subcellular, submicroscopic, infectious obligate parasite composted
of nucleic acid within a protein coat that uses the host cellular machinery to replicate itself.

Why are viruses important?

Viruses cause many diseases of international importance. Viruses also cause many important plant diseases and are responsible for huge losses in crop production and quality in all parts of
the world.
Infected plants may show a range of symptoms depending on the disease but often there is leaf
yellowing (either of the whole leaf or in a pattern of stripes or blotches), leaf distortion (e.g.

curling) and/or other growth distortions (e.g. stunting of the whole plant, abnormalities in flower
or fruit formation).
Virtually all plants that humans grow for food, feed, and fiber are affected by at least one virus.
It is the viruses of cultivated crops that have been most studied because of the financial implications of the losses they incur. However, it is also important to recognise that many “wild”
plants are also hosts to viruses.
Although plant viruses do not have an immediate impact on humans to the extent that human viruses do, the damage they do to food supplies has a significant indirect effect.

II Properties/characteristics of viruses

- Do not divide or multiply on their own.
- Reproduce by inducing the host cell to form more virus.
- Do not consist of cells and therefore have no organelles.
- Cannot penetrate cells on their own - enter through wounds or vectors
- Are not self-motile - depend upon various types of vectors for transmission.

- The virus nucleic acid is encapsidated by a protein. The protein surrounding the nucleic acid is referred to as the coat protein or capsid which is formed by protein subunits.
- The majority of plant viruses are made up of RNA. At least 80 viruses contain DNA.
- 60-95% of the virus is made of protein and the remaining 5-40% is nucleic acid.
- The RNA or DNA is what carries the genetic information.

How are viruses classified?

Within each group, many different characteristics are used to classify the viruses into **families,** *(Virus families represent groupings of genera of viruses that share common characteristics and are distinct from the member viruses of other families. Virus families are designated by names with the suffix -viridae. Most of the families of viruses have distinct virion morphology, genome structure, and/or strategies of replication, indicating phylogenetic independence or great phylogenetic separation.),*
genera, *(Virus genera represent groupings of species of viruses that share common characteristics and are distinct from the member viruses of other genera. Virus genera are designated by terms with the suffix -virus.)*

and species, *(in 1991, the ICTV accepted the definition of a virus species proposed by van Regenmortel (1990), as follows: "A virus species is defined as a polythetic class of viruses that constitutes a replicating lineage and occupies a particular ecological niche.").*
Typically, a combination of characters are used and some of the most important are:

- Particle morphology: the shape and size of particles as seen under the electron microscope.

1) Particle morphology:

- Rigid rod particles : i.e. Tobacco mosaic virus
- Flexuous or filamentous particle i.e. Potato virus X
- Isometric, spherical or polyhedral particles: Cucumber mosaic virus

Geminated particles: i.e. Tobacco yellow dwarf virus

- Bacilliform: i.e. Broccoli necrotic yellow virus
- Genome properties: this includes the number of genome components and the translation strategy. Where genome sequences have been determined, the relatedness of different sequences is often an important factor in discriminating between species.

The highest level of virus classification recognises six major groups, based on the nature of the genome:

- (+) ssRNA : i. e. Tobacco mosaic virus.
- (-) ssRNA: i. e. Tomato spotted wilt virus.
- dsRNA: i. e. Wound tumor virus
- ssDNA: i.e. Beet curly top virus

1b) Genome segments

i. monopartite (genome in one segment)

ii. bipartite (genome divided in two segments)

iii. multipartite (genome divided in three or more segments)

- Single-stranded DNA (ssDNA): there are two families of plant viruses in this group and both of these have small circular genome components, often with two or more segments.
- Reverse-transcribing viruses: these have dsDNA or ssRNA genomes and their replication

includes the synthesis of DNA from RNA by the enzyme reverse transcriptase; many integrate into their host genomes. The group includes the retroviruses, of which Human immunodeficiency virus (HIV), the cause of AIDS, is a member. There is a single family
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of plant viruses in this group and this is characterised by a single component of circular dsDNA, the replication of which is *via* an RNA intermediate.

- Double-stranded RNA (dsRNA): some plant viruses and many of the mycoviruses are included in this group.
- Negative sense single-stranded RNA (ssRNA-): in this group, some or all of the genes are translated into protein from an RNA strand complementary to that of the genome (as packaged in the virus particle). There are some plant viruses in this group and it also includes the viruses that cause measles, influenza and rabies.
- Positive sense single-stranded RNA (ssRNA+): the majority of plant viruses are included in this group. It also includes the SARS coronavirus and many other viruses that cause respiratory diseases (including the "common cold"), and the causal agents of polio and foot-and-mouth disease.
- Biological properties: this may include the type of host and also the mode of transmission.

natural host range
mode of transmission in nature
vector relationships
geographic distribution
pathogenicity, association with disease
tissue tropisms, pathology, histopathology

- Serological properties: the relatedness (or otherwise) of the virion protein(s).

Antigenic Properties

serologic relationships, especially as obtained in reference centers

1. Diseases of field crops

2. Diseases of cereal crops (e.g. diseases of wheat, rice, millet, maize, sorghum etc)
3. Diseases of sugar crops (e.g. diseases of sugarcane, sugar beet etc)
4. Diseases of oil seed crops (e.g. diseases of sunflower, soybean, sesame etc)
5. Diseases of fiber crops (e.g. diseases of cotton)
6. Diseases of pulses (e.g. diseases of gram, lentil, mung been etc)
7. Diseases of fodder (e.g. diseases of lucern, berseam, millet, maize, sorghum etc)

1. Diseases of horticultural crops

a. Diseases of vegetables (e.g. diseases of summer/winter vegetable crops, i.e. diseases of chilies, tomatoes, cucurbits etc)
b. Diseases of fruit crops (e.g. diseases of summer/winter vegetable crops, i.e. diseases of mango, banana, citrus etc)
c. Diseases of ornamentals (e.g. diseases of flowers i.e. rose etc)

Fibre plants
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COTTON

Cotton leaf curl is recorded as most destructive diseases

COTTON LEAF CURL VIRUS (CLCV)

This disease is also called leaf crinkle. A virus causing leaf curl of cotton was first recorded in Nigeria (1912), Sudan (1924), Tanzania (1926), Philippine (1959). It is quite difficult to present accurate estimates of the losses due to cotton leaf curl disease, because the losses vary from year to year and from one area to the other. Sometimes the cotton fields have been found to show as much as 100 percent damage.

PATHOGEN: The disease causing virus belongs to Gemini group, sometimes refer as Gossypium virus 1. Cotton leaf curl virus

DISTRIBUTION: Africa, Nigeria, Sudan, Tanzania, Philippine and Pakistan.
HOST RANGE: More than 30 different crop, weed and ornamental plants are reported as hosts.
SERIOUSNESS: Cotton, lady's finger, tomato, chili, cucurbit (especially water melon), beans,
sunflower, sesame, soybean, cow peas, egg plant (brinjal),
TRANSMISSION: The disease transmitted by feeding of the white fly, Bemissia tabacci within
6.5 hours. The virus is not transmitted by sap, seed or soil.
SYMPTOMS: Upward and downward curling of leaves accompanied by small and main vein
thickening **(SVT & MVT)** on leaves, pronounced on underside. If a diseased leaf is viewed from
beneath against the light, thickened vein found darker green and opaque than normal. In extreme
but not in frequent cases, formation of cup shaped or leaf laminar (veins) outgrowth called
"enation" appears on the back or underside of the leaf. The newly produced leaves are small,
excessively crinkled and curled at the edge. Primary stem often tends to grow taller than normal.
The internodes being elongated and irregularly curved but sometimes the whole plant is stunted.
The flowers checked in growth and become abortive. Bolls remained small in size and failed to
open. All parts of badly hit plants are very brittle and ready broken.
CONTROL: Cultivation of resistant varieties is only safe measure. Crop rotation with non host
crop. Proper use of irrigation and fertilizers. Potassium fertilizer improves the disease resistant
power in plants. Vector, white fly must be controlled. All alternate hosts (including weeds) must
be eradicated before, during and after cotton crop. Deep plowing with short duration in fallow
lands help to control weed hosts. The disease **(CLCV)** is not seed transmitted but use of healthy
seed, acid delinting and chemical seed treatment is recommended as preventive measure. Use of
proper cotton production technology is economical and most effective for management of all
diseases (including this).

CEREALS

RICE: *Oryza sativa*
Pathogen: Rice yellow mottle virus (RYMV)
Is the most economically important viruses of rice.
Host Range: can affect irrigated low land and up land susceptible varieties.
Symptoms; chlorotic mottling and streaking on leaves. Intensity of symptoms vary with resistance level of variety.
Damage: delayed flowering and yield loss with deformation of panicles. Loss can exceed 95%.
Distribution: Africa
Control; Plant resistant varieties.
SUGARCANE
Mosaic, grassy shoot and chlorotic streaks are considered major viral diseases of sugarcane.
MOSAIC
PATHOGEN: Sugarcane mosaic virus (SMV).
DISTRIBUTION: Wherever sugarcane is grown.

HOST RANGE: The disease causing virus has a wide range and infects a large number of grasses.
TRANSMISSION: Aphids, Mechanical, and is seedborne in corn.
PERPETUATION: Grasses and infected sugarcane crop.
SYMPTOMS: Newly leaves are unrolled from spindle. Irregular oval or oblong, pale green blotches of various sizes occur on leaves, with various widths. Stunted shoots, twisted and distorted leaves in some cultivars. Mottling of stem, causing death of tissue and cankered areas
in other cultivars may also occur.
CONTROL: Rogue out infected plants.

MAIZE AND SORGHUM

STREAK DISEASE has been reported as viral disease but has not importance with reference to
damaging the crop.

DISTRIBUTION: Asia and Africa.
HOST RANGE: Maize and sorghum.
TRANSMISSION: Through leafhoppers (not seed or sap).
SYMPTOMS: Initially, circular, colorless spots occur on lowest exposed portions of young leaves. Spots are scattered at first but later on become closer. Narrow, broken, chlorotic stripes
occur along veins. The stripes may coalesce to form wider stripes.
CONTROL: Sow resistant varieties.

LEGUMES

BEAN CROPS

MOSAIC is considered as major threat to almost all **BEAN CROPS.**
PATHOGEN: Bean yellow mosaic (BYM) and Common bean mosaic (CBM).
DISTRIBUTION: Generally wherever field beansare grown.
TRANSMISSION: Yellow mosaic is transmitted through aphids only but common mosaic is seedborne, may also transmit through aphids, pollens and by mechanical mean.
SYMPTOMS: Differences between symptoms may vary greatly between plants. However, in
both diseases, the general symptoms include dwarfing, excessive branching or bunches, leaf cupping and typical symptoms of mosaic.
CONTROL: Disease free seed is suggested for common mosaic. Resistant varieties or rouging
of infected plants are best way against both diseases.

GROUNDNUT

ROSETTE is alone important viral disease of groundnut.
PATHOGEN: Groundnut rosette virus (GRV).
DISTRIBUTION: Africa, Java and Pakistan.
TRANSMISSION: Mechanically.
SYMPTOMS: An overall stunting of plants with typical rosette or clumped appearance is common symptom. Affected plants have flattened growth at the top portions associated with

leafy growth and malformed buds. Young leaflets become faint in colour followed by chlorosis.
Chlorotic and mottled leaf, and blossom and pod formation is reduced. Early infection causes small, sessile flowers that do not open.
CONTROL: Sow resistant varieties. Diseased plants should be uprooted and destroyed.

SESAME

LEAF CURL is recorded as problematic disease.
TRANSMISSION: White fly, Bemissia spp. is the main vector in nature, and graft transmission
is reported successful for producing the disease.

SYMPTOMS: Diseased leaves are markedly reduced in size, become slightly thick and brittle and dark green in colour. Affected plants are stunted and bear scanty capsules having poor seed setting. Early infection may result in severe reduction in yield.
CONTROL: Diseased plants and weeds must be collected and destroyed. The vector white fly may be controlled.

Horticultural crops

TOMATO

LEAF CURL is considered as secondarily important viral disease of the tomato crop that may also cause considerable loss in quality and quantity of produce.
PATHOGEN: Tomato yellow leaf curl virus
TRANSMISSION: White fly, Bemissia tabacci.
SYMPTOMS: Dwarfing, twisting and curling of leaves, mottle vein clearing, excessive branching, stunting of plants and partial or complete sterility.
CONTROL: Planting resistant varieties.

CHILI

SYMPTOMS: Curling of leaves, accompanied by thickening and swelling of veins. Clusters of leaves with reduced size. The whole plant assumes bushy appearance with stunted growth. Fewer flowers and fruit, but if are formed, are much reduced in size and are curled.
CONTROL: Planting resistant varieties.

LADY'S FINGER (BHINDI OR OKRA)

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YELLOW VEIN MOSAIC is considered very important disease.
PATHOGEN: Hibiscus or Bhindi yellow vein mosaic virus.
TRANSMISSION: White fly, Bemissia tabacci.
SYMPTOMS: Vein clearing, vein chlorosis, yellow veins enclosing green patches of the leaf. Veins are thickened on lower surface of the leaf. Fruits are develop malformed and reduced in size, mostly are yellow, small, tough and fibrous.
CONTROL: Planting resistant varieties. Eradication or rouging of infected plants and weeds.

CUCUMBER (CUCURBIT)

MOSAIC is recorded as major problem in almost all members of cucurbit.
PATHOGEN: Cucumber mosaic virus (CMV).
DISTRIBUTION: World wide.
HOST RANGE: Wide range of hosts than any other virus.
SERIOUSNESS: Cucurbit, peppers, spinach, tomatoes, beets, beans, banana, crucifers, lilies, zinnia and many weeds.
TRANSMISSION: Sap and several insects. Mostly 6 spp. of aphids, including Myzus persicae and Aphis gossypii. Not through seed in cucumber but is in some hosts.
PERPETUATION: Through weeds, flowers and crop plants.
SYMPTOMS: Cotyledons turn yellow and wilt. Young leaves become mottled, distorted, wrinkled and their edges begin to curl downward forming rosette like clump. The plants appear dwarfed, leaves become half to their normal size. Few runners, flowers and fruits. Older leaves develop chlorotic and necrotic areas that cover entire leaf and killed leaves hang down or fall off.

Fruit shows pale green or white areas intermingled with dark green, raised areas. Often form rough, wartlike projections, cause distortion, are somewhat misshapen but have smooth gray white colour with some irregular green areas. Often have bitter taste and upon picking become
soft and soggy.

CONTROL: Resistant varieties. Use of disease free seedlings. Elimination of alternate hosts (including weeds). Control of insect vectors.

PAPAYA

LEAF CURL is important viral disease of papaya.

DISTRIBUTION: Where papaya is grown.

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TRANSMISSION: White fly, Bemissia tabacci.

SYMPTOMS: Almost all the leaves of the plant are reduced in size and show malformation and
sever curling, crinkling and distortion. The margins of the leaves are curved or rolled downward
and or inward. Vein clearing and thickening also take place. The leaves become brittle and growth of the plant is arrested. Sometimes, plants become partially or completely sterile depending on growth stage and severity of the disease. If the fruits are formed, these are disfigured and mummified.

CONTROL: Planting resistant varieties. Eradication of diseased plants.

Root and tuber crops

Cassava,

Disease: African cassava mosaic disease

Pathogen; ACMV, EACMV

Symptoms, mosaic, leaf distortions

Vector: whiteflies. *B. tabaci*

Distribution: East, Africa, SSA.

Control, plant resistant varieties.

Yam:

Yam mosaic virus.

Symptoms, yellowing of leaves, retarted growth, small yam tubers

Trans, aphids

Control, control vectors

Tree crops:

Cocao *Theobroma cacao*

Cocoa is one of the most important economic species of plants in many west African countries,
particularly Ghana, Nigeria, Cote'l Voire and seria leone. The most important disease is the swollen shoot disease.

Pathogen: *Cocoa swollen shoot virus*. About 20 strains of the virus is known in Nigeria.

The vectors are mealybugs, *Pseudococcus njalensis*

Symptoms: red veins on newly formed leaves that later turn yellow in colour (vein clearing).
Unusual swellings on stems and roots of affected plants. Infected pods are brownish and small in
size. The disease reduces growth in affected plants and may lead to plant death.

Control: remove infected trees i.e cut down and burn. Spray to kill vectors. Ensure virus free stock for planting.

Nematology Section

SYNOPSIS

• Characteristics & classification of PPN intropics

• Important PPN of arable and permanentcrops in the tropics
• Principles and methods of nematodecontrol and management

INTRODUCTION
• Food and economic crises
• Climate change and global agriculture
• Nigerian Agriculture and the economy
• Covers 94m ha, 91m ha arable, < 30%under cultivation

INTRODUCTION
• Some fundamental questions
– Resource endowment a blessing?
– Have we been able to feed ourselves?
– Why the dwindling agricultural production statistics
– Why food problems? (social, climate, biotic, political)
– How long will it take to be self sufficient in foodproduction?
– What are the solutions?
– What role does nematodes play in limiting food production?

What are nematodes & where do they live?
• nematodes are worm-like organisms (animals) which can be found in the soil, salt and fresh water, plant and animal parts.
– Animal parasites nematodes (Helminths)
• Egs. Intestinal worm (*Ascaris lumbricoides*)
• The guinea worm (*Dracunculus medinensis*)
• The eye worm (*Onchocerca vulvulus*)
• *Wucheria malayi* responsible for Elephanthiasis
• The heart worm (*Dirofilaria spp*.)

What are nematodes & where do they live?
• Nematodes (those in the soil, fresh water, salt water, and plant parts)

They consist of the following groups:
– Free-living nematodes (saprophytes)
– Predaceous nematodes
– Entomogenous/entomophagus nematodes, and
– Plant-Parasitic nematodes.
Nematode Types
• **Free-Living nematodes**
(a. k. a. Saprophytic nematodes)
– Feed on decaying matter as well as their products in the soil
– Constitute no threat to crop plants
Eg Rabditida

Nematode Types
• **Predaceous nematodes**
– Prey or predate other microorganism such as bacteria, fungi and even nematodes.
– Microbivorous nematodes or microbial-feeding nematodes.

• fungivores or fungivorous nematodes (e.g. Anguinidae, Aphelenchidae, Tylencholaimidae)
• bacterivores or bacterivorous nematodes (e. g. Alaimidae, Plectidae, Leptolaimidae, Rhabditidae)
– Play vital roles in food web (nutrient recycling) as secondary decomposers
– Beneficial to agriculture especially organic agriculture.

Nematode Types
• **Entomogenous nematodes**
– The entomogenous group consists of nematodes that parasitize insects.
– Useful tool in biological control of insects (e.g. *Zonocerus variegatus*) by *Mermis* spp. of nematode.
• **Plant-Parasitic groups**
– Phytonematodes
– They are thread-like, non-segmented, microscopic, styletbearing organisms which inhabit the rhizosphere of plants
• Interacts with the plants
• Leading to reduction in growth and economic yield.

Some important data
• 500,000 nematodes spp. have been predicted
– 15,000 spp. Described & classified
– 2,200 spp. are plant parasitic (10 or 15%)
• 95 to 98% RKN {Mi (52%), Mj (31%), Ma(7%)}
• Others 2 to 5 %
– 12,800 spp. non parasitic (85 %)
• 485,000 spp. yet to be described
Some vernacular/common names of nematodes

Common Name Scientific Name
Root knot or gall nematode *Meloidogyne* spp.
Root Lesion nematode *Pratylenchus* spp.
Cyst nematode *Heterodera* & *Globodera* spp.
Dagger nematode *Xiphinema* spp.
Burrowing nematode *Radopholus similis*
Stem nematode *Ditylenchus* spp.
Banana root lesion nematode *Pratylenchus coffeae*
Citrus nematode *Tylenchulus semipenetrans*
Pin nematodes *Paratylenchus* spp.
Yam nematodes *Scutellonema bradys*

Red ring nematode *Rhadinaphelenchus cocophilus*
Rice white tip nematode *Aphelenchus besseyi*
Ring nematode *Criconemoides* spp.
Cob’s spiral nematode *Helicotylenchus multicinctus*
Bulb nematode *Ditylenchus dipsaci*

Characteristics of PPN
• Sytlet (protrusible, hard, sharp,spear

shaped structure on the cephalic region)
– Function to:
• Rupture egg shell during hatching
• Puncture and penetrate plant cell during infection
• Suck cell content during feeding
– May or may not possess stylet knob
• Stomatostylet (Order:Tylenchida)
• Odontostylet (Order: Dorylaimida)

Characteristics of PPN
• **Morphology and anatomy** (external and internal structures)
– Size 0.25 to 0.30mm long and 0.05mm wide
– Mostly cylindrical in shape, tapering at the two ends
– Usually filiform but female in some loose worm shape
Egs. *Meloidogyne*, *Heterodera*,*Globodera*
_ Complex organisational structure like higher animals
• Feeding and digestive organs
• Reproductive organs, sexes separate
• Circulatory system
• Excretory system
• No respiratory organs because exchange of gases is directly from the atmosphere

• **Morphology and anatomy (Cont'd)**
– Body plan is simple
• Triploblastic (three layered skin)
• Cuticle (moults 4 times as the nematode grows)
Colourless and transparent
– Annulated
– Smooth
– Serpentine movement
– Hollow body (Pseudocoelumate)
– Tube within tubes
– Alimentary canal runs from stylet to anus
– Oesophagus (Pharynx) links stylet with intestine for food movement

• **Morphology and anatomy (Cont'd)**
– Sex organs (gonads) are also & threadlike
– Female gonad
• Ovary (Eggs develop from germ cell in the ovary)
• uterus (Fertilisation of eggs take place here)
• vulva (vagina) (Copulation)
– Male gonad
• Testes (Sperms are produced here)
• Spicule (sperms are deposited via spicule into the vagina via vulva)

• **Morphology and anatomy (Cont'd)**
– **Life cycle and reproduction**
– Six stages (egg, J1, J2, J3, J4, Adult)

– Moults (4 times)
– Egg production potentials 250 to 25,000/generation or cycle
– A cycle is 28 to 30 days in tropics
– Polycyclic nematode diseases of plants
– Reproduction is by:
• amphimixis (male + female) the most common
• Parthenogenesis (male not involved)
• Hermaphrodism (both sexes present in an individual)

Classification of plant parasitic nematodes
• Why classify?
– Knowing each nematode enhances the understanding of its biology and control
– Approaches in classification are changing
– Integration of morphology and molecular approaches (DNA sequencing)
• Taxonomy = Science of classification

What is Classification?
• Theory and practice by which kinds of nematodes are delimited to avoid chaotic accumulation of species (the basic entity)
• Principles of classification
– Morphology
– Anatomy
– Physiology
– Ecology
– Genetics
– Biogeography

Classification system
• De Ley (2002) Developed new classification system based on:
– Molecular Biology
– Morphological analysis
• Pictorial and non pictorial identification keys
• The key uses all kinds of characters
• Taxonomic characters (stylet etc)

Classification and Identification
• Classification = Ordering of nematodes into groups on the basis of their relationship
• Identification = the assignment of unidentified nematodes into the correct taxon once classification has been established
– Micro taxonomy (fewer characters are used)
– Macro taxonomy (many characters are involved)
Example:
• Kingdom: Animalia
– Phylum: Nematoda
• Order: Tylenchida
– Family: *Meloidogynideae*
» Genus: *Meloidogyne*
» Species: *Meloidogyne incognita*

Host reaction to nematodes/factors

- **Nematode crop interactions**

– Resistant
– Tolerant
– Susceptible
– Hypersusceptible

- **Environmental factors**

– Temperature
– Soil
– Microbes

- **Host nutrition**

Nematode-plant interactions

- **Crop damage by nematodes**

– Physical injury
– Enzymatic/Physiological/Chemical Changes

GENERAL NEMATODE DISEASE SYMPTOMS

- Above ground.

- Chlorosis (depigmentation i.e yelowing of foliage)
- Necrosis (complete drying & death of plant cell/tissue)
- Stunting (reduction in growth due to shortened internodes)
- Patchiness (crop failures, staggered growth)
- Inter-veinal chlorosis (strpping of green tissues between veins which turns yellow while the veins remain greenish)

GENERAL NEMATODE DISEASE SYMPTOMS

- Above ground.

- Snapping
- Toppling
- Dieback – progressive necrosis of branch terminals particularly of trees and other plants
- Sudden death

GENERAL NEMATODE DISEASE SYMPTOMS

- Below ground.

- Root knot – pronounced localised swelling of root tissue resulting from hypertrophy and hyperplasia incited by nematode feeding activities.
- Lesion – an injury, wound, or morbid change in plant structure (a localised spot of infected tissue)
- Necrosis – Death of cells surrounded by living tissue, especially en mass.

Nematode-plant interactions

• **Crop loss**
– Economic threshold level
– Crop loss assessment
• Direct (Experimentation & surveys)
• Indirect (Literature review, expert testimony)

Important nematodes of crops
• **Nematode basis**
• **Crop basis**
– **Legumes** eg. Cowpea, Soybean, Groundnut, (Protein)
• Soybean (40%) } RKN disease caused by *Meloidogyne* spp.
• Cowpea (25%)
– **Tuber Crops** (CHO) Yam, cassava, sweet potato, carrot
• Dry rot of yam caused by *Scutellonema bradys*
• RKN disease caused by Mi
• Root lesion disease caused by *Pratylenchus* spp.

Important nematodes of crops
– **Plantation crops**
• Toppling disease of Plantain caused by *Radopholus similis*
– **Cereals**
• **Maize**
– Root lesion disease of Maize caused by *Pratylenchus safeansi*
– RKN disease caused by Mi
• **Rice**
• White tip disease caused by *Aphelenchoides besseyi*
• RKN disease caused by Mi

Important nematodes of crops
– **Cocoa**
• RKN disease caused by Meloidogyne incognita
• Die back caused by Mi (progressive necrosis of branches while the trunk is alive)
• Sudden death caused by Mi (Green leaves turn yellow, brown and finally dry up but remain hanging even after the death of the plant)

NEMATODE POPULATION AND DISEASEMANAGEMENT

Principles of nematode management
• **Avoidance -** Avoidance of the pest/pathogeninvolves selection of geographical areas with low/zero initial inoculum (pl. inocula)
• **Eradication -** deals with elimination of pest/pathogen from the crop or the area after establishment
• **Exclusion -** is a principle aimed at preventing the spread of pest/disease
• **Protection - i**s aimed at killing the pest/pathogen before it invade the crop
• **Resistance -** is genetic or innate ability to prevent, reduce or tolerate pest/disease organism
• **Therapy/treatment –** application of treatment to diseased plants

Methods of nematode management
• Cultural
• Physical
• Chemical
• Biological
• Host-Plant resistance
• Integrated nematode management
• Organic protection system, and
• Biotechnology

Cultural Method

• Any agronomic practice adopted consciously or unconsciously by farmers to improve crop yields. Although, its effectiveness on nematodes may be difficult to verify, there are evidence that cultural practices can also achieve good crop protection against nematodes. Examples include:

1. **Nematode-free planting materials**. Infested or infected seeds and plant materials, such as tubers, rootstocks, cutting and grafts, can infect an entire crop. Using healthy and clean seeds or planting materials is the best starting point in nematode management.

2. Selection of good site (reasonably free of inoculum) is a good strategy of nematode management

3. **Ploughing the fields and burning stubble.** This method produces good seedbeds or plant beds. Turning the soil exposes nematode larva and eggs

4. **Planting susceptible trap crops.** Trap crops such as celosia can encourage penetration of nematodes but must be destroyed before the adults emerge in order to avoid egg laying.

5**. Intercropping.** The planting of different crops or varieties within the same area diversifies the available habitat and may inhibit the expansion of nematode **especially if resistant varieties are included.**

6.Crop rotation. Varying the annual crop in the same field from year to year interrupts the specific relationship between nematodes and host plants and can prevent the spread the target nematode. For example: (i) cereals can be alternated with beans or groundnuts, sweet potatoes with cotton and cassava. (ii) Another example of crop rotation is growing maize or sorghum for one or two seasons and planting vegetables or a root crop in the third season.

NB: Crop rotation can be an effective measure against nematodes if the rotation cycle is sufficiently long and **resistant host is included**

7. **Plant nutrition-** Well-balanced fertilizer application results in healthy plants. Organic fertilizer, which improves the physical and microbial properties of soils, is better than inorganic fertilizers.

8. **Farm/Tool sanitation/hygiene**. Sanitation in storage areas, farmyards and fields is also a principal means of preventing nemaodes. They aim at reducing initial inocula.

Physical/Mechanical Method

1. Roguing: Some nematode infected plants can be physically collected and then destroyed in areas where labour is cheap.

2. The use of mechanical implements for weeding is growing. Removal of weed removes some important alternate host hence protect high-value or small-area crops from nematode pests.

3. Physical barriers – screenhouse benches, concreted floors and /or raised platforms

4. **Flooding** is an effective way of reducing nematode population in lowland rice field.

Chemical Method

• Synthetic nematicides are routinely used to control nematodes

• Quick action- The major advantage is that synthetic pesticides are quick in action. However, they have been found to have the potential to harm humans, livestock and wildlife. They can pollute the environment and destroy beneficial organisms and there is also growing concern about the increasing resistance of pests to pesticides.
• To optimize the timing and efficacy of nematicides against target nematodes and to minimize the potential detrimental effects on beneficial species, other non-target organisms and the natural
environment, it is important to know their general mode of action.

Mode of action
1 Contact nematicides which kill the nematode in contact with it.
2 Systemic nematicides move through the plant's vascular system. They are absorbed by the nematodes that feed on the leaves, stems, fruits or roots of treated plants.

Biological Control
• Use of natural enemies/other organisms to control nematodes:
(i) *Trichoderma* spp.
(ii) *Dactylella* spp.
(iii) *Mycorryhza*

Host-Plant Resistance
• Resistant varieties are one of the important components of nematode management and can easily be combined with other control methods.
• In the field, however, crop resistance to nematodes can eventually break down.
• Therefore, plant resistance breeding programmes continuously select new varieties to replace older ones.

Nature of resistance:
1. Horizontal resistance is polygenic resistance
2. Vertical resistance is monogenic resistance

Biotechnology
• Biotechnology is the application of molecular biology in agriculture, environment and health.
• This implies improvement of the genetic traits of the cell (of plant, animal, bacterium or fungus) by exploiting recombinant deoxyribonucleic acid (DNA) and other molecular technologies inorder to develop improved methods and modified organisms.
• Biotechnology has already yielded nematode-resistant, plants in developed agriculture.

Organic approach
• Organic nematode management (OPM) describes a system that would mimic and optimise natural processes and products (holistic).
• Encourages growth and diversity of soil fauna and flora with beneficial and/or antagonistic effects on nematode pests.
• OPM is not IPM Integrated Nematode Management
• INM attempts to combine 2 or more methods of nematode managements