COURSE GUIDE

CRP 504
ADVANCED CROP PROTECTION

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ISBN: 978-058-887-1

INTRODUCTION

Advanced Crop Protection (CRP 504) is a three credit course for 500 level students of Bachelor of Science (BSc.) degree (Crop Production Programme). The course consists of five modules which deal with quarantine regulations and phyto-sanitary measures; fundamentals of plant resistance to diseases; principles and methods of disease management; principles, techniques and equipment for applying crop protection chemicals in the control of field and storage pests, diseases and weeds; equipment maintenance and repair; storage of pesticides.This course guide tells you briefly what the course is all about, and how you can work through its units.

COURSE ARRANGEMENT

The course consists of modules in units and a course guide. The course guide tells you briefly what the course is about, what course materials you will be using and how you can work with these materials. In addition, it advocates some general guidelines for the amount of time you are likely to spend on each unit of the course in order to complete it successfully. It gives you guidance in respect of your Tutor-Marked Assignment in the assignment file. There will be regular tutorial classes that are related to the course. It is advisable for you to attend these tutorial sessions. The course will prepare you for the challenges you will meet in the field of crop protection

COURSE AIMS

The course aims to provide you with an understanding of crop protection principles as regards insect pest and disease. These concepts encompass definitions of pest and their status as crop loss agents, damage and its varied nature, economic considerations in pest management. An understanding of the different management methods will also be discussed

COURSE OBJECTIVES

To achieve the aims set out, the course has a set of objectives. Each unit has specific objectives which are included at the beginning of the unit. You should read these objectives before you study the unit. You may wish to refer to them during your study to check on your progress. You should always look at the unit objectives after completion of each unit. By doing so, you would have followed the instructions in the unit. Below are the comprehensive objectives of the course as a whole. By meeting these objectives, you should have achieved the aims of the course as a whole. In addition to the aims above, this course sets to achieve some objectives.

Thus, after going through the course, you should be able to:

- Explain the concept of pest management and their population dynamics
- Identify and determine the damage status and threshold of a pest
- Understand the different management strategies available
- Explain how the disease pyramid influences disease spread
- Understand and deploy the concept of pest exclusion, eradication, resistance and prevention.
- Understand the concept of Integrated Pest Management (Insect and disease)

WORKING THROUGH THIS COURSE

To complete this course you are required to read the study units carefully and read other recommended materials. You will be required to answer some questions based on what you have read in the Content to reaffirm the key points. At the end of each module there are some Tutor- Marked Assignments (TMA) which you are expected to submit for Marking. The

TMA forms part of your continuous assignments. At the end of the course is a final examination.

THE COURSE MATERIALS

The main components of the course are:

1. The Course Guide
2. Study Units
3. References/Further Reading

TUTOR-MARKED ASSIGNMENTS (TMA)

There are tutor Marked assignments and self-assignment in each module. You would have to do the TMA as a revision of each module. This would help you to have broad view and better understanding of the subject. Your tutorial facilitator wouldinform you about the particular TMA you are to submit to him for Marking and recording. Make sure your assignment reaches your tutor before the deadline given in the presentation schedule and assignment file. If, for any reason, you cannot complete your work on schedule, contact your tutor before the assignment is due to discuss the possibility of an extension. Extensions will not be granted after the due date unless there are exceptional circumstances. You will be able to complete your assignment questions from the Contents contained in this course material and References/Further reading; however, it is desirable to search other References/Further reading, which will give you a broader view point and a deeper understanding of the subject.

FINAL EXAMINATION AND GRADING

The final examination for the course will be 2hrs duration and consist of six theoretical questions and you are expected to answer four questions. The total Marked for the final examination is 70 Marked. The examination will consist of questions, which reflect the tutor marked assignments that you might have previously encountered and other questions within the course covered areas. All areas of the course will be covered by the assignment. You are to use the time between finishing the last unit and sitting for the examination to revise the entire course. You might find it useful to review your Tutor Marked Assignments before the examination. The final examination covers information from all parts of the course.

MODULE 1 QUARANTINE REGULATIONS AND PHYTO-SANITARY MEASURES

MODULE 1: QUARANTINE REGULATIONS AND PHYTO-SANITARY MEASURES

Unit 1: Introduction

Contents

1.0 Plant Quarantine

'Plant Quarantine' refers to the holding of plants in isolation until they are believed to be healthy. Now, broader meaning of the plant quarantine covers all aspects of the regulation of the movement of living plants, living plant parts/plant products between politically defined territories or ecologically distinct parts of them. Intermediate quarantine and post entry quarantine are used respectively to denote the detention of plants in isolation for inspection during or after arrival at their final destination.

2.0 Importance

The entry of a single exotic insect or disease and its establishment in the new environment continues to cause great, national loss (table 1) till such time it is brought under effective control. In certain cases a country has to spend a few million rupees before success in controlling the introduced insect pest or disease is achieved.

Table1: Losses caused by introduced plant diseases

Disease	**Host**	**Country**	**Introduced from**	**Losses caused**
Canker	Citrus	U.S.A	Japan	$ 13 million; 19.5 million trees destroyed
Dutch elm	Elm	U.S.A.	Holland	$ 25 million -$ 50million
Powdery mildew	Grapevine	France	U.S.A	80% in wine production

Blue mould	Tobacco	Europe	U.K	$ 50 million
Downy mildew	Grapevine	France	U.S.A	$ 50 million

Despite every precaution of inspection, certification and treatment, it is not always possible to guarantee that a consignment is completely free from pathogens. In doubtful cases it is advisable to subject plants to a period of growth in isolation under strict supervision in the importing country (post-entry quarantine). The plants are grown at a quarantine station. When direct importation of plants to a country's own quarantine station is considered very dangerous, quarantine during transit from the country of origin (intermediate quarantine) may be required.

The international plant protection convention, the first effort towards international agreement on Plant Protection was made in 1914 under the auspices of the International Institute of Agriculture in Rome. This was followed by an International Convention of Plant Protection by over 50 member countries of the Institute in 1919 and certain Agreements regarding the issue and acceptance of phytosanitary certificates were finalized. The project received a setback due to Second World War and was later on revived by the FAO. In post-war period International action in Plant Protection and particularly in plant quarantine was encouraged by FAO with the establishment in 1951 of the International Plant Protection Convention. This agreement was constituted with the purpose of securing common and effective action to prevent the introduction and spread of pests and diseases of plants and plant products as to encourage Governments to take all steps necessary to implement its prevention.

3.0 Plant quarantine methods

Plant quarantine regulations are promulgated by the national and the state governments to prevent the introduction and spread of harmful pests and pathogens. Plant quarantine will be justified only when the pest has no natural means of spread and when they are based on biological considerations only, i.e., pest/pathogen introduction risks and the available safeguards.In general, risks are more with the introduction of vegetative propagules than with true seed. In case of true seed, risks are more with deep-seated infections than with the surface borne contamination of pests/pathogens. Again, risks are far greater with pathogens like viruses, downy mildews, smuts and many bacteria carried inside the seed without any external symptoms. When vegetative propagules are introduced, rooted plants, and other underground plant parts like rhizomes, suckers, runners, etc. carry higher risks than budwood, scions and un-rooted cuttings. In any case, bulk introductions are always risky as thorough examination and treatment in such cases is very difficult and planting area is far too large to prevent the establishment and spread of the introduced pest/disease.

There are number of plant quarantine methods which are used separately or collectively to prevent or retard the introduction and establishment of exotic pests and pathogens. The components of plant quarantine activities are:

3.1. Complete embargoes
It involves absolute prohibition or exclusion of specified plants and plant products from a country infected or infested with highly destructive pests or diseases that could be transmitted by the plant or plant products under consideration and against which no effective plant quarantine treatment can be applied or is not available for application.

3.2. Partial embargoes
Partial embargoes, applying when a pest or disease of quarantine importance to an importing country is known to occur only in well-defined area of the exporting country and an effectively operating internal plant quarantine service exists that is able to contain the pest or disease within this area.

3.3. Inspection and treatment at point of origin
It involves the inspection and treatment of a given commodity when it originates from a country where pest/disease of quarantine importance to importing country is known to occur.

3.4. Inspection and certification at point of origin
It involves pre-shipment inspection by the importing country in cooperation with exporting country and certification in accordance with quarantine requirements of importing country.

3.5. Inspection at the point of entry
It involves inspection of plant material immediately upon arrival at the prescribed port of entry and if necessary subject to treatment before the same related.

3.6. Utilization of post entry plant quarantine facilities
It involves growing of introduced plant propagating material under isolated or confined conditions.

3.7. Certification
Phytosanitary or health certificate is a certificate which should accompany a plant or plant material or seed which is to be moved from one place to another place. This certificate indicates or certifies that the material under transit is free from pests or diseases.

Unit 2:Pest detection techniques

Contents

1.0 Introduction

Success or failure of plant quarantine measures would depend, to a great extent, on the ability of plant quarantine officials to detect pests and pathogens that may be associated with the introduced planting material. For quarantine purposes, techniques should be sensitive enough to detect even trace infections. This is particularly important in case of pests/pathogens with very high multiplication rate like certain pycnidial fungi, downy mildews, bacteria and also viruses when the insect vectors are efficient.

A wide variety of pests and pathogens (insects, mites, nematodes, fungi, bacteria, viruses, viroids, spiroplasma, etc.) and weeds are the objects for quarantine consideration. Similarly, planting material also may be introduced in a variety of forms, i.e., true seed, corms, bulbs, rhizomes, suckers, runners, budwood, scions, cuttings and rooted plants. Therefore, detection techniques would vary depending on the type of material, the host species and the type of pests/pathogens involved. Many a times, more than one technique would have to be used.

2.0 Detection Techniques

Detection techniques may broadly be classified into two groups:
(a) generalized tests which would reveal a wide range of pests/pathogens; and
(b) specialized or specific tests which are used to detect specific pests/pathogens.

2.1 Generalized tests

A very widely used method is the inspection of dry seed with the naked eye or under the low power of microscope. This method would reveal a wide range of free moving insects, their eggs and larval stages, mites on or with the seed, weeds, soil, infected/infested plant debris, fungal fructifications like sclerotia, smut and bunt balls, nematode galls, discoloured or deformed seeds mixed with seed; oospore or bacterial crusts, acervuli, pycnidia, sclerotia and even free spores of rusts, smuts and many other fungi on the seed surface. Examination of dry seed under UV or NUV light may reveal infections of certain fungi and bacteria through emission of fluorescence of different colours. Examination of seed washings may reveal surface contamination by rusts, smuts, downy mildews and a large number of other fungi.

Most commonly used incubation methods for the detection of fungi are the common moist blotter and agar tests wherein seeds are incubated on these media for a specific length of time (generally about a week) at a suitable temperature under alternating light and dark cycles. These two media reveal a wide range of internally seed-borne fungal and some bacterial

pathogens in a wide variety of crops. Seedling symptom test and the grow-out test are quite versatile and reveal the symptoms produced by any category of plant pathogens including fungi, bacteria and viruses. Grow out test is the simplest of the tests extensively used for the detection of viruses. However, some viruses may be carried symptomlessly in the plant and, therefore, it should be used in combination with other tests like indexing on indicator test plants and serology.

2.2 Specialized tests

2.2.1 Insects

X-ray radiography has been used very successfully all over the world for the detection of hidden infestation (with no apparent sign of infestation on the seed surface) of insects, particularly seed infesting chalcids and bruchids. Seed transparency test (boiling the seeds in lactophenol to make them transparent) may also be used for the detection of hidden infestation and extraction of the insects for identification. X-ray radiography is also very effective in salvaging infested seed lots.

2.2.2 Nematodes

For the detection of seed-borne nematodes, seeds are soaked in water for about 24 hours. This makes the nematodes active, which then come out of the seed into the water, or the seeds may be teased out with the help of forceps and a needle and examined for detection of nematodes under a stereo microscope. In rooted plants, the accompanying soil and plant debris may similarly be soaked in water and nematodes may be extracted for identification using nematological sieves or tissue paper.

2.2.3 Fungi, bacteria and viruses

Serological tests are very effective for the detection and identification of viruses and bacterial pathogens and are being used in various plant quarantine stations with great success. Phage-plague technique is still more sensitive for bacterial pathogens as even strains of bacteria can be identified. Indicator test plants are also very helpful as they may reveal pathogenic races within a species of a fungus, bacterium and specific strains within a virus.Modifications of the generalized incubation tests (agar and blotter tests) have also been used for the detection of specific plant pathogens. Deep-freezing blotter test and 2,4-D blotter test are very efficient for detection of black-leg pathogen (*Phoma lingam*) in crucifer crops. Potato-dextrose-oxgall agar is useful for the detection of *Septorianodorum* in wheat.

In the case of vegetative propagules, laboratory methods may suffice for the detection of insects and mites, nematodes, majority of fungi and certain bacteria. However, for the detection of systemic fungal pathogens, bacteria, viruses, viroids, isolation growing for a season or a year or more in quarantine glass-houses/net-houses is required. Availability of glass-houses/net-houses in large number is an expensive proposition, but the quarantine safeguards afforded by them to any country are worth that expenditure.

Unit 3: Decontamination Procedures for infested/infected material

Contents

1.0 Introduction

Once a pest, pathogen or a weed has been detected in the introduced planting material, quarantine officials must make all efforts to disinfect/decontaminate the material and make it available for further exploitation in the country without undue delay. Such an effort on the part of quarantine officials would help to restore a positive image to plant quarantine. However, it may be kept in mind that treatments, which only reduce the inoculum, may be acceptable for general agricultural practices, but they are not acceptable in plant quarantine. For quarantine purposes, tolerances are zero and, therefore, no residual inoculum of exotic pests/pathogens must remain. Fool-proof eradicative treatments are required to be employed before release of the planting material from quarantine.

2.0 Treatment Options

2.1 Fumigation

Fumigation of the material under atmospheric or under reduced pressure has been found acceptable as a quarantine treatment against insects and mites. Fumigants like methyl bromide, HCN, phosphine and EDCT (ethylene dichloride + carbon tetrachloride mixture) are commonly used.

2.2 Heat treatment

Hot water treatment or hot air treatment are also used in quarantine for eradication of insects, mites, nematodes, fungi, bacteria and viruses. The basic principle involved is that treatment temperature should be sufficiently high to kill the associated pest/pathogen but not the host. However, in most cases, margin of safety is very narrow and, therefore, the temperature should be very accurately controlled. Some recommended hot water treatments are:

1. Nematodes: Flower bulbs, 44° C for 240 min; chrysanthemum, 48° C for 25 min; potato tubers, 45° C for 5 min;
2. Insects and mites: Narcissus bulbs, 44° C for 180 min; strawberry runners, 46° C for 10 min;
3. Viruses: Grape vine, 45° C for 120-180 min; sugarcane setts, 50° C for 120 min.; potato tubers, 50° C for 17 min;
4. Fungi: Celery seed, 50° C for 25 min; wheat seed, 52-54° C for 10 min;

Reports of eradication of *Phomabetae* in sugarbeet seed by hot water treatment at 50° C for

30 min have been made. Hot water seed treatment has also been reported to eradicate certain bacterial pathogens like black-rot pathogen (*Xanthomonascampestrispv. campestris*) in crucifer seeds at 50° C for 30 min; bacterial blight of cluster bean (*X. campestrispv. cyamopsidis*) at 56° C for 10 min; and bacterial blight of sesame (*X. campestrispv. sesami*) at 52° C for 10 min.

2.3 Chemical treatments

Chemicals may be applied as dust, slurry, spray or as dip. It should be ensured that dosage of chemical should be enough to eradicate the inoculum but should not kill the host and the chemical should not be hazardous to personnel handling the treated seed. Treatment should be given on arrival and only after ascertaining the health status of the material. The choice of the chemical and dosage to be used should be made depending upon the pest/pathogen involved. Seeds treated at origin are not only difficult to examine but are hazardous to inspect also. Heavily treated seed, which makes inspection difficult, should be denied entry.

2.4 Tissue culture

Tissue culture as a safeguard in quarantine has been advocated. This method reduces the pest/pathogen introduction risk in two ways:

(i) the size of the consignment is very much reduced since the introductions are represented by meristem tips, excised buds or embryos, and

(ii) (ii) the aseptic plantlet system has built-in pest/pathogen detection capability. All insects, mites, nematodes and most fungi can be eliminated.

Symptoms on young seedlings, and growth of the organisms on the agar medium, if any, may be visible through the transparent culture tubes, and these could be discarded. Tissue culture in combination with thermotherapy and chemotherapy is an excellent safeguard from quarantine angle. However, certain systemically infecting pathogens like rusts, downy mildews, bacteria, viruses, and viroids, may still get transported. Therefore, as an additional safeguard, the tissue culture material could be passed through post-entry quarantine isolation growing and indexed/tested for the suspected pathogens. Indeed, tissue culture technology provides an exciting prospect for large scale exchange of genetic stocks with very little pest/pathogen introduction risk.

3.0 Examination of pest/pathogen risk in plant introduction

Analysis of pest risk in plant introduction is essential to decide as to whether a particular planting material could be permitted entry or not. Such risk analysis provides sound biological basis to decide quarantine policies. The attitude towards 'entry status' of a material may be liberal or conservative depending on the risks involved in its introduction. If risks are low, quarantine would be liberal in permitting the entry. However, if risks are very high, the material may be denied entry. Whether an introduced pest could establish, spread and become serious, depends on three factors viz.

(i) availability of susceptible host in abundance;

(ii) ability of the introduced pest/pathogen to multiply and spread rapidly; and

(iii)availability of favourable environmental conditions.

Agricultural practices and the pest/pathogen management strategies in the country of introduction are also important. However, the host-pathogen-environment interactions are very complex and it is not always easy to understand them. As such, many a times, our predictions about risks involved and quarantine importance of a pest may go wrong.

Organisms of quarantine importance are the exotic pests/pathogens, which are considered to pose serious threat to agriculture and environment of a country or region, and include races and biotypes of indigenous pests and pathogens. Any pest risk analysis should take into account the benefits that are likely to accrue from the introduction of the planting material concerned and also the costs of quarantine inspection, treatment including detention in the post-entry quarantine facility and the cost of eradication, should an exotic pest gets established. Pest risk analysis should also consider factors, such as availability of trained personnel, efficacious detection techniques, treatments at the point of entry quarantine, knowledge about the life cycle of the pest, existence of races and strains, world distribution, modes of transmission, factors favouring establishment and spread of pests/pathogens, availability of safeguards (necessary manpower resources, chemicals and equipment to contain and eradicate the pests), and adequacy of the survey and surveillance programme.

Unit 4: International/regional cooperation

Content

1.0 Introduction

Plant quarantine, while being national in execution, is international in character. Therefore, international/regional cooperation is very necessary for achieving the objectives since plant genetic resources are a world resource meant for the welfare of the human race as a whole. Cooperation on the following lines would greatly help in safe exchange of germplasm materials.

1.1Consortium of plant quarantine stations: It is an excellent concept fashioned to facilitate the exchange of genetic stocks and scientific information at international/regional level. Any material passing through a plant quarantine station will have very low pest/pathogen risk. The material so generated should be exchanged with other plant quarantine stations promptly, before it is distributed locally and gets contaminated with local pests/pathogens. Several quarantine stations working independently may be processing the same material (same crop or even same variety) at each station. Under the proposed consortium concept, different quarantine stations would undertake the processing of different materials (several accessions of the same crop or a group of crops at each station) and then share the material. This would avoid duplication of efforts, reduce costs of processing and more material would be available with adequate quarantine safeguards. In the same spirit, scientific information (detection techniques, treatments, distribution of pests/pathogens) and antisera for sero-diagnosis of viruses and bacteria could be shared by quarantine stations of different countries.

1.2. Establishment of central seed health testing laboratories: At present, thousands of seed samples of a variety of crops are being exchanged by different countries for breeding purposes and for conducting multilocation international trials. This has exposed many countries, particularly the developing ones, to the hazards of serious and new seed borne pests/pathogens. Sometimes, the volume of material may be so large that it is not physically possible for a quarantine service to process it with any degree of surety during the time at its disposal before the planting date. In many countries, seed health testing facilities may not be in existence or they may be inadequate. The concept of establishing a few central seed health testing laboratories well equipped with required facilities and trained personnel has been proposed. These may be coordinated with regional genebanks or international centres, but should be independent of the organisation for which they are working. Such an arrangement would lower pest risk to a considerable extent and avoid duplication of efforts, thus reducing

costs of processing. Plant quarantine services of different countries will have faith in such laboratories and will accept their certification.

1.3. Third country intermediate quarantine: The concept of third country quarantine is another example where international cooperation could play an important role in safe transfer of plant genetic resources. This is particularly helpful for transferring high risk tropical/sub-tropical plant genera from one country to another. The material could be grown, tested/indexed for hazardous plant pests and pathogens in a temperate country without much risk because either the possible hosts are not present there or the environment is unfavourable for their establishment. Some centres which have been providing third country quarantine facilities for transferring genetic resources include Sub-tropical Horticulture Research Station, Miami, USA for cocoa, coffee, rubber and tea; University of Reading, UK for groundnut; and Institute Nazionale Per Piante de Legno, Torino, Italy for cassava.

1.4. Biogeographical regions: The eight biogeographical regions proposed for effective quarantine are separated by natural barriers like sea, high mountains and deserts, making pest/pathogen dissemination extremely difficult so long as the exchange of genetic resources is judiciously regulated. Accordingly, all countries in such a region must have common quarantine regulations since the larger the land mass covered by the same set of regulations, the greater is the protection afforded to the agriculture of the region.

2.0 General considerations

To sustain the tempo of accelerated agricultural growth, it is necessary that valuable plant genetic resources continue to flow. At the same time, it is also important that exotic pests, pathogens and weeds do not gain entry while introducing exotic germplasm or other planting material. This could be achieved through effective implementation of plant quarantine measures. Plant quarantine can be effective only if it is based on sound scientific considerations. Pest/pathogen introduction risk only should be the guiding principle of our national quarantine policy. The following general suggestions to users of germplasm are made in this regard:

1. Bulk imports of planting materials should be discouraged as far as possible because the pest/pathogen introduction risk increases in proportion to the quantity of material. It is so because thorough examination and treatment of bulk consignments is difficult and the area under cultivation becomes too large for effective monitoring of the crops. If it becomes absolutely essential to import propagating material in bulk, it should be imported from seed companies/agencies reputed to produce seed/planting material under strict phytosanitary conditions.

2. Bulk imports for consumption should be de-vitalized making them unfit for planting and these should be processed immediately on arrival under supervision of quarantine officials.

3. All imports, whether for consumption or planting for commercial or for research purposes, should be done under 'Import Permit' only, and all conditions mentioned in the permit should be strictly followed.

4. All the plant material being brought by travelling passengers must be handed over to the plant quarantine officials for inspection at the international airports/seaports, where separate 'Plant Quarantine Counters' should be established urgently.

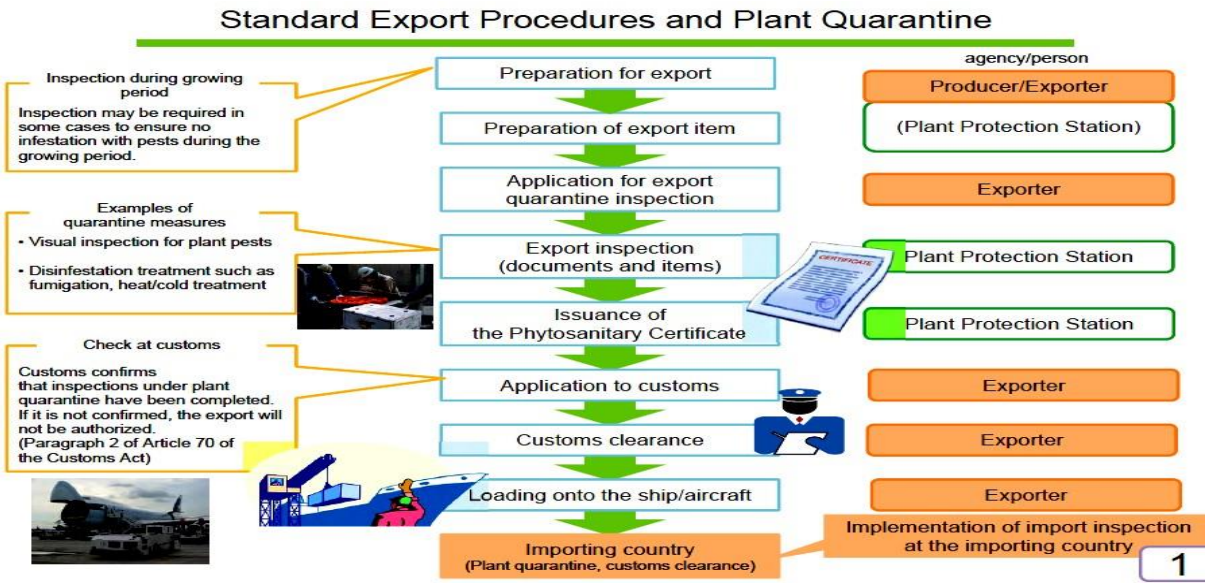
5. At the international post-offices, all the mail should be passed through some kind of detection or scanning system as is done at the time of security check, and intercepted plant materials should be passed on to the plant quarantine officials for inspection. In fact, a plant quarantine official should be posted at each of the international post-offices to coordinate the interception of planting materials and their despatch to plant quarantine service for inspection before release.

6. In case of germplasm, repeat introductions should be avoided as the pest risk increases with repeat introduction of germplasm material into the country.

7. Domestic quarantine is as important as the international quarantine and, therefore, planting material should be moved from one state to another or from one place within a state to another under strict phytosanitary conditions.

8. Effective linkages/cooperation should be established among various organisations/agencies involved in the import of plant material for effective plant quarantine implementation and smooth flow of material.

9. Periodic workshops/meetings at national level involving concerned departments may be held to discuss common problems and impediments so as to help the national crop improvement programme.



Tutor Marked Assignments

1. Define the term "plant Quarantine" stating its importance in agriculture.
2. List five (5) quarantine methods and discuss any three (3)
3. What is a Phytosanitary Certificate?
4. Describe the generalized methods of pest detection in agricultural produce.
5. Describe the specialized methods of detection of insects and viruses in agricultural produce.
6. How is heat treatment used in decontaminating sugar cane setts from viruses?
7. Discuss the importance of international collaborations in establishing effective quarantine.
8. What are three general considerations for ensuring safety in transfer of plant genetic resources across boarders?

Further reading

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MODULE 2 FUNDAMENTALS OF PLANT RESISTANCE TO DISEASES

Unit 1: Introduction

Contents
1.0 Introduction

1.0 Introduction

In nature organisms are classified as producers, greenplants, consumers (organisms exploiting other organisms),and decomposers (organisms using dead organisms). Greenplants, including our crops, are used by a multitude ofconsumers of almost every kind, from various types ofherbivores (mammals, snails, and insects) to typical parasites(insects, mites, fungi, bacteria). In order to survive greenplants developed a broad range of defence mechanisms toward off most of these consumers. These defence mechanismsare principally based on avoidance, resistance or tolerance.Avoidance operates before parasitic contact between host andparasite is established and decreases the frequency ofincidence. After parasitic contact has been established thehost may resist the parasite by decreasing its growth, ortolerate its presence by suffering relatively little damage.Avoidance is mainly active against animal parasitesand includes such diverse mechanisms as volatile repellents,mimicry and morphological features like hairs, thorns andresin ducts. Resistance is usually of a chemical nature. Littleis known of tolerance; it is very difficult to measure and isusually confounded with quantitative forms of resistance.Parasites classified as fungi, bacteria, viruses or viroidsare considered disease inciting parasites or pathogens.Resistance mechanisms are by far the most important defencemechanisms employed by host plants, including our crops,against pathogens. Avoidance and tolerance play a minor rolehere. In the never-ending arms race between plant andpathogen, the latter have developed widely different hostranges. Pathogens such as some Pythium species, *Rhizoctoniasolani*Kühn, and *Sclerotiniasclerotiorum* (Lib.) de Baryhave a wide host range; they are non-specialized, polyphagouspathogens or generalists. The latter one, for instance, hasbeen reported to attack hundreds of plant species belongingto at least 64 families of flowering plants and gymnosperms. A large proportion of the pathogens,however, have a narrow host range restricted to a few closelyrelated plant species; they are specialized, monophagouspathogens or specialists. *Pucciniahordei*Otth. And*Phytophthoraphaseoli*, pathogenic on barley (*Hordeumvulgare* L.) and lima beans (*Phaseoluslunatus* L.) respectively,are typical specialists.As resistance is by far the most important defence ofplants against pathogens this chapter discusses the variousaspects of disease resistance.

Unit 2: Resistance in Plants

1.0 Types of Resistance

1.1 Vertical Resistance

A new concept of vertical resistance (VR) and an equally new idea ofhorizontal resistance (HR) were put forward by van der Plank (1968).Vertical resistance is conditioned by oligogenes and is effective against someraces of a pathogen, but not all, whereas HR, which is polygenic in inheritanceis effective against all races of that pathogen. It is said that plantpathologists have been preoccupied with individual plants and individualraces (this is true in the speaker's case too). This, however, is understandableas research at depth in a single host pathogen model system gives enoughpersonal satisfaction. It is now clear that a study o f ' population resistance ',where a given pathogen population cannot increase and damage a host population, possessing VR or HR, or a combination of them, is achallenging task and needs immediate attention.

The mechanism of action of multilines has been studied in detail ina number of crops. The pathogen increases from an initial inoculum ata given rate and results in a known proportion of susceptible tissuebecoming infected. A given variety with VR being selectively resistantto the race population, reduces increase in the initial inoculum level butthe proportion of susceptible tissue may become very large at the end ofthe disease season. Therefore, VR is valuable only as long as it gives resistanceto all prevalent races and helps keep down increase of pathogen levelfrom the initial inoculum. In cases of focal outbreaks and mild epidemics,VR is of sufficient value in effecting control measures, but has been foundunsatisfactory against widespread epidemics. On the other hand, avariety with HR, showing resistance, in a large measure, to all races of thepathogen, does not reduce increase in pathogen population from theinitial inoculum level but it does reduce the rate at which such increase takesplace normally. Therefore, with the rate of increase small, the rate of epiphytotic development is reduced to such a level where the host recordslittle damage with low proportion of susceptible tissue becoming infected.

As a multiline cultivar possesses many genes for VR, the initial inoculum ofthe pathogen, in course of time, becomes small.The oligogenes give VR ease of manipulation in greenhouse and fieldtrials and were found superior in yield assessments. There is also thepossibility that the next resistant gene might not be ephemeral.Plant pathologists have been accustomed to working with populations andthe breeders pursued the boom yields quite unaware that in the face ofadversity there was no chance of biologically containing the pathogen. Infact, the disease importance increased not only with the degree ofinbreeding but also with the innate

cause of extensive use of varieties having the same germplasm. The medial method suggested was the use of non-uniform crop varieties.

1.2 Horizontal Resistance

The basic pointin favour of HR breeding techniques is that the effectiveness of theresistance does not 'break down' whereas, VR does so. Furthermore,while VR confers complete but impermanent protection, HR confersincomplete but permanent protection, it is well to recognize some terms introduced in HR breeding programmes. A 'pathodeme' is a host populationin which all individuals have a given resistance in common. A' pathotype ' is a pathogen population in which all individuals have a givenpathogenicity in common. When a given series of pathodemes is inoculatedwith a series of pathotypes, and the amounts of disease display a differentialinteraction between pathodemes and pathotypes, the resistance and pathogenicityare called vertical. When there is no differential interaction, theyare called horizontal. The pathodemes and pathotypes can also be describedas vertical or horizontal as the case may be. VR involves mechanismswhich are within the pathogen's capacity for change. HR, on the otherhand, involves mechanisms which are beyond the pathogen's capacityfor change. This phrase 'capacity for change' would mean that everypathogen can change as it is an in-built capacity within the well understoodterm 'natural variability '. There are, however, limits to that variabilityand HR involves mechanisms beyond those limits. It should beunderstood that change here means population dynamics and not evolution.Furthermore, VR is inherited oligogenically (i.e., controlled by a few genesfor major heritable changes by looking for applied characters) but HRis almost always polygenically inherited resistance (i.e., controlled by anumber of genes). However, oligogenic HR does occur in rare cases and notall of HR is inherited polygenically, and vice versa, not all oligogenicresistance is VR. The most important point is that oligogenic horizontalresistance is qualitative in its inheritance, mechanism of functioning and itsfinal effects. As opposed to these rare cases, the general run of universalhorizontal resistance is quantitative. The influence of breeding techniquescomparing oats and rye may well illustrate this point.It may be difficult in some diseases to obtain sufficient HR to controla disease in natural growing conditions. It would seem best to initiatebreeding with HR first and then to reinforce with VR should HR proveinadequate to meet the situation. For instance, a good horizontal pathodemecan be used as the basis of a multiline of several different verticalpathodemes. The result then would be a slowing down of an epidemicas the epidemiological effects of a multiline are similar to those of HR.This approach has much merit as it is nearer natural conditions where HRis essential and VR is a supplementary protection occurring as 'natural'multilines.During the absence of a pathogen, erosion of horizontal resistance cantake place in nature. There are two types of erosions, one called ' phenotypicerosion' and the other 'genotypic erosion '. Generally, in mostcrops, a high degree of susceptibility these local materials will have to go beyond locally available cultivarsincluding wild progenitors.Any factor(s) which masks horizontal resistance will reduce pressureon selection for it. These factors can be fungicides and similar artificialdisease control measures, or VR itself. VR can be eliminated making certainthat the population does not possess genes for it. This has been foundpossible in the case of potato

bred against *Phythopthorainfestans* but notpossible in wheat where complete absence of VR to *Pucciniagraminis* isunknown. Individuals showing hypersensitivity reactions such as ' flecking'are evidences of VR and such plants can be eliminated. Similarly, if VRconfers complete resistance against non-matching vertical pathotypes, screeningof the host populations can be clone for 'slight disease' than ' no disease'condition. Also VR can be eliminated by ensuring that all individuals in thehost population are susceptible to a single vertical pathotype. VR providesa complete and lasting control of a disease only when the host population.Flexibility is maximal and the pathogen population flexibility is minimal.In crops where breeding for horizontal resistance is undertaken, the basicassumption should be that the existing levels of HR are due to phenotypicerosion, in which case, breeding could be confined to existing cultivars.However, if this assumption is not warranted a search may have to be made beyond existing cultivars and efforts channelled for getting together a widegenetic base. Genetic heterogeneity can be achieved by random polycrosswith the assistance of a male gametocide. By suitably increasing theintensity of epidemic conditions sufficient selection pressure for HR can bemounted.

2.0 Resistance break down

As the new race takes over, resistance of the old variety is no longer effective.Depending on the genetic plasticity of the pathogen and the particular gene or combination of genes involved in host resistance, resistant varieties with only vertical resistance, need to be replaced periodically.This means that breeding programmes for new resistant varieties has to continue so that some new varieties can be kept in readiness for the replacement of the old ones in case of any eventuality.It is hoped that genetic engineering techniques would come to the aid of such breeding programmes and make it possible for a quick transfer of individual genes or a combination of such genes to preferred susceptible host varieties in a much shorter time.

3.0 Maintenance of resistance

Disease management strategies, such as sanitation, seed treatment or use of fungicide reduce the exposure of resistant variety to large pathogen population.For pathogens with low inoculum production and slow dispersal rate, resistance of the host variety usually lasts longer.The use of varietal mixtures has been widely used in a variety of crops as a possible measure in disease control in cereals, legumes and potatoes.A cultivar mixture is simply compounded by mixing seeds of cultivars on the basis of their predicted performance.Diversification of resistance naturally presents the pathogen with a difficult target than in the traditional monoculture.

4.0 Multiline varieties

Jenson (1952) first proposed the idea of multiline varieties that is a composite of various isogenic lines sharing most agronomic characters, but carrying different genes for vertical resistance in one or a few of its constituents of the multiline variety.Use of multiline variety results in overall reduction of pathogen for a disease, which consequently reduces the

rate of disease and also the inoculum presence on each of the component varieties.The most fully developed multiline programme involved wheat rusts and crown rust of oats.Multilines can delay the onset of disease and also reduce the rate of an epidemic.If a constituent variety loses its resistance to a new race of the pathogen, it can be replaced by a suitable alternative line.There are, however, certain limitations on the use of multiline varieties.The components must be distinct from each other, have different race-specific genes, and also ripen simultaneously.

5.0 Reliable resistance

It is now accepted that crop resistance based on single or few vertical resistant genes is liable to become non-functional soon, mostly within 4 years.In the long run, the production of varieties with many additional genes for horizontal resistance may perhaps provide the only answer.

Unit 3 Breeding of resistant varieties

1.0 Introduction

Quite early in the twentieth century it became evident that breeding of resistant plant varieties was possible, and this provided the most desirable approach to plant disease control.The environment pollution in chemical control further highlighted the importance of such breeding.Plant breeding represents the most significant form of biological control of plant diseases.Genetic diversity can be regularly introduced into the plant genome through such breeding programme.Cultivated crop plants that we see today represent the results of natural selection or selection and breeding of different lines that evolved naturally in different regions over many thousands of years.It has been a very slow process.Many of them still exist as wild types at the place of their origin and have survived over such long periods in attack of various pathogens, because of many resistance genes they carried and also gradually acquired through natural crossing within the plant population.Weak and susceptible ones were eliminated in course of time.The survivors had sets of major and minor genes for resistance and much genetic diversity, adapted to the local health environment and suited to the needs of local population.Numerous varieties of each crop plant are cultivated throughout the world and they represent a non-uniform population.Widespread systematic efforts of plant breeders all over the world have further increased this diversity.Now, biotechnology has come in a big way with techniques aimed at further increasing this.The first step in breeding for disease resistance is mostly to decide on type and level of resistance required and whether the pathogen is seed-, soil- or air- borne.The decision will depend on the availability of a suitable source of resistance and whether or not it can be manipulated in a breeding programme.Many plant diseases cannot yet be properly controlled by host resistance, for example, powdery mildews of cereals, as this is complicated by pathogenic specialization and a complex resistance pattern.

2.0Source of resistance

Search for resistance is initially restricted to crop cultivars currently in use locally.Search has to be widened to include varieties grown in the adjacent regions, wild plant relatives, and species growing in the area where the disease is severe, or where the disease is originated.Plant breeders often take recourse to creation of new resistant genotypes for this purpose by inducing mutation or approach gene banks maintained in different countries.Larger public collections are maintained in different countries.

There are three common methods of developing resistance in the host. i) Selection ii) Hybridization iii) Mutation

Selection is an old practice of developing resistant varieties. When a large number of individuals grow under disease favourable environment, some individuals show some resistance to the disease which might be selected and tested again before recommendation as a resistant variety.Hybridization involves the crossing of two individuals (parents) with good commercial qualities lacking resistance to specific pathogens and another, a source of resistance lacking desired commercial traits.The source of resistance can be obtained by selection from variety or species much prevalent in the area.If such variety is not available in the area under cultivation in cultivated varieties or species, the desired individual can be obtained from some other species or related wild plants.Successful crossing of wild *Lycopersiconpimpinellifolium* with cultivated tomato *Lycoperisconesculentum* has produced material for the development of varieties resistance to *Fusarium wilt*.Mutation is a sudden heritable change in the genetic makeup of the individual plant. In nature, chance mutations are possible, however, little success has been found for developing resistant varieties by this method in the field. Newly developed resistant plants have to be tested for resistance after artificial inoculation with the pathogen or natural infection under field conditions.Recently, molecular markers have been used in place of such inoculation for the selection of resistance, at least in the early stage of breeding.Resistance is not always stable and may also fail to function under certain conditions.To minimize such possibilities, precise standards have been set in respect of conditions for inoculation, environmental conditions in which inoculated plants are to be kept, and assessment of disease symptoms and incidence.

While searching for resistant genotypes, selection is done from existing crops in the following way:

i) Mass selection
ii) Pure line selection iii) Pedigree selection iv) Bulk hybrid method v) Recurrent selection vi) Other techniques

3.0Mass selection

Seeds are collected in mass from some selected, highly resistant plants surviving in a cropped field where natural infection occurs regularly, and seeds are composited after harvest for use in the next season.This method is no doubt simple, but plant improvement is slow. Further, in cross-pollinated plants there is no control over the source of pollen.

4.0Pure line selection

In pure line selection, seeds are collected only from individual highly resistant plants, and the progenies are grown separately.They are repeatedly inoculated with the target pathogen for disease resistance.This method is very effective for self-pollinated crops but not so with cross-pollinated ones.No new genotype is created by this method, which simply isolates the best genotype present in a mixed population.This, however, represents a more rapid method than allowing natural selection to take place and eliminates the more susceptible genotypes.Traditionally, mass or pure line selection methods are adopted for heterogenous plant populations.

Two more procedures of selection are commonly followed after hybridization to sort out desirable genotypes from the segregating progeny. These are pedigree selection and bulk hybrid methods.

5.0Pedigree selection

In this method of selection, plants with desired combination of characters are selected in the F2 generation after hybridization between two homozygous lines carrying different genes for resistance.Their progenies are propagated separately and inoculated, and the progenies of each selected plants are maintained in succeeding generations for resistance.These steps are continued up to F7 or F8 generation, when a high degree of homozygosity is achieved. This method takes advantage of the phenomenon of heterosis (hybrid vigour).

6.0Bulk hybrid method

This method is practiced following hybridization between two selected parents.Their seeds are bulked, grown out again, and the process is repeated.At each generation, plants are exposed to natural infection or artificial inoculation with the pathogen and reselected for resistance.

7.0 Recurrent selection

When it is desired to quickly introduce a single simply inherited, dominant, resistant character into an existing susceptible plant with desirable agronomic qualities, a back-cross or recurrent selection is adopted. This involves a succession of crossing of the ‘donor’ plants with the dominant resistant progeny with the existing cultivar, i.e. the recurrent parent, ultimately consolidates the resistant gene in the genetic background of the desirable susceptible variety. However, this method is time-consuming, and not equally effective in all cases, particularly for the self-pollinated plants.

8.0 Other techniques

Some other techniques are also occasionally used for introducing disease resistance in plants. Both natural and artificially induced mutants that exhibit improved resistance and a change in the chromosome number in plants or production of euploids (4N, 6N) or aneuploids (2N + 1 or 2 chromosomes) by the use of mutagenic chemicals like colchicine have also shown good effect in some cases.

Tutor Marked Assignments

1. Differentiate between Vertical Resistance and Horizontal Resistance
2. How can acquired resistance be maintained?
3. What are multiline varieties?
4. What are the possible sources of resistance?
5. Describe the processes involved in the following;

i. Mass selection

ii. Pure line selection iii.Pedigree selection

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MODULE 3: PRINCIPLES AND METHODS OF DISEASE MANAGEMENT

Unit 1: Fundamental principles of disease management

Contents

1.0 Introduction

The goal of plant disease management is to reduce the economic and aesthetic damage caused by plant diseases. Traditionally, this has been called plant disease control, but current social and environmental values deem “control” as being absolute and the term too rigid. More multifaceted approaches to disease management, and integrated disease management, have resulted from this shift in attitude, however. Single, often severe, measures, such as pesticide applications, soil fumigation or burning are no longer in common use. Further, disease management procedures are frequently determined by disease forecasting or disease modeling rather than on either a calendar or prescription basis. Disease management might be viewed as proactive whereas disease control is reactive, although it is often difficult to distinguish between the two concepts, especially in the application of specific measures.

This topic is a general overview of some of the many methods, measures, strategies and tactics used in the control or management of plant diseases. Specific management programs for specific diseases are not intended since these will often vary depending on circumstances of the crop, its location, disease severity, regulations and other factors. Plant disease management practices rely on anticipating occurrence of disease and attacking vulnerable points in the disease cycle (i.e., weak links in the infection chain). Therefore, correct diagnosis of a disease is necessary to identify the pathogen, which is the real target of any disease management program. A thorough understanding of the disease cycle, including climatic and other environmental factors that influence the cycle, and cultural requirements of the host plant, are essential to effective management of any disease.

The many strategies, tactics and techniques used in disease management can be grouped under one or more very broad principles of action. Differences between these principles often are not clear. The simplest system consists of two principles, prevention (prophylaxis in some early writings) and therapy (treatment or cure). The first principle (prevention) includes

disease management tactics applied before infection (i.e., the plant is protected from disease), the second principle (therapy or curative action) functions with any measure applied after the plant is infected (i.e., the plant is treated for the disease). An example of the first principle is enforcement of quarantines to prevent introduction of a disease agent (pathogen) into a region where it does not occur. The second principle is illustrated by heat or chemical treatment of vegetative material such as bulbs, corms, and woody cuttings to eliminate fungi, bacteria, nematodes or viruses that are established within the plant material. Chemotherapy is the application of chemicals to an infected or diseased plant that stops (i.e., eradicates) the infection. Although many attempts have been made to utilize chemotherapy, few have been successful. In a few diseases of ornamental or other high value trees, chemotherapy has served as a holding action that must be repeated at intervals of one to several years. For example, antibiotics have been infused into plants to reduce severity of phytoplasma diseases of palms (lethal yellowing) and pears (pear decline) and fungicides have been injected into elms to reduce severity of Dutch elm disease (caused by *Ophiostomaulmi*) but in all cases the chemotherapeutant must be reapplied periodically.

Fundamental principles of disease management are;
i) Avoidance: Geographical area, selection of a proper field, planting time and disease escaping varieties, avoidance of insect vectors and wed hosts
ii) Exclusion: Quarantine, inspection & certification, seed treatment
iii) Eradication: Crop rotation, sanitation, rouging, soil treatment, heat and chemical treatment to diseased plant material, use of antagonists
iv)Protection: Chemical treatment
v) Immunization: Resistant varieties, induced systemic resistance vi) Therapy: Chemotherapy, thermotherapy

1.1 Avoidance

It involves tactics that prevent contact between the host and the pathogen.The selection of geographic area, selection of a proper field, planting time and disease escaping varieties play an important role in avoiding the disease.For example bean anthracnose is common in wet areas. Similarly smut and ergot of pearl-millet are serious in areas where rainfall occurs for long durations during flowering of the crop.Successful cultivation of a crop depends to a great extent on the selection of a proper field especially in soil borne diseases, e.g., root knot nematode disease, wilt of pigeon-pea etc.In many diseases the incidence or disease severity depends upon the coincidence of susceptible stage of the host and favourable conditions for the pathogen.This can be achieved by alteration in the date of planting/sowing.Certain insects especially aphids, beetles and leafhoppers are known to transmit viruses and mollicutes from infected plants to healthy plants.Perennial weeds including pokeweed, milkweed, Johnson grass and horse nettle serve as over-wintering reservoirs of some viruses.Curly top in sugar-beet is a leaf hopper-transmissible viral disease and weeds play a significant role in its spread.Some of the important weeds involved in the spread of curly top disease are certain species of Chenopodium, Russian thistle, Amaranthus, deadly nigh shade, shepherd's purse and knotweed.In some cases, aphids feed on some of the early-appearing weeds and then move to new crop plantings,

thus introducing viruses which are then spread in secondary cycles within the planting.Bean yellow mosaic virus (BYMV) is a common problem in bean growing areas.Forage legumes (red clovers) are found to be the source of primary inoculumfor aphids to carry BYMV into bean fields.For lettuce mosaic virus, only 10 to 15 seconds of feeding is needed by an aphid to acquire the virus and another 10 to 20 seconds on another plant suffices for the aphid to transmit the virus.

1.2 Exclusion

It means preventing the entrance and establishment of pathogens in uninfected crops in a particular area.It can be achieved using certified seed or plants, sorting bulbs before planting, discarding any that are doubtful, possibly treating seeds, tubers or corms before they are planted and most importantly refusing obviously diseased specimens from dealers. In order to prevent the import and spread of plant pathogens into the country or individual states, certain federal and state laws regulate the conditions under which certain crops may be grown and distributed between states and countries.Such regulatory control is applied by means of quarantine, inspection of plants in the field or warehouse and occasionally by voluntary or compulsory eradication of certain host plants.Plant quarantines are carried out by experienced inspectors, stationed in all points of entry into the country, to stop persons or produce likely to introduce new pathogens.Similar quarantine regulations govern the interstate and even intrastate sale of nursery stock, tubers, bulbs, seeds and other propagative organs, especially of certain crops such as potatoes and fruit trees.For example, the outbreak of citrus canker in USA in 1910 through planting material imported from Southeast Asian countries.Due to heavy destruction, strict quarantine was imposed against entry of citrus planting material.However in 1981, 1984 and 1991, fresh outbreaks were reported due to illegal importation of citrus planting material. In India, interstate quarantine is in place for the movement of potato from Darjeeling area of West Bengal to prevent the spread of potato wart which is restricted to that area only.

1.3Eradication

It involves elimination of a pathogen once it has become established on a plant or in a field. It can be accomplished by:Removal of diseased plants or parts as in roguing to control virus diseases or cutting off a cankered tree limb.Cultivating to keep down weed hosts and deep ploughing or spading to bury diseased plant debris.Rotation of susceptible with non-susceptible crops to starve out the pathogen.Disinfection usually by chemicals, sometimes by heat treatment.Spraying or dusting with sulphur to kill the mildew mycelium.Treating the soil with chloropicrin to kill nematodes and fungi.Soil treatment with various nematicides (Telone II, Temik 15G, Counter 15 and 20G) is useful to control sugar-beet nematodes.

1.4 Protection

It is the use of some protective barrier between the susceptible part of the suscept or host and the pathogen.In most cases, a protective spray or dust applied to the plant in advance of the arrival of the fungus spores.Sometimes, it is achieved by killing insects or other inoculating agents.Sometimes it is achieved by erection of a wind-break or other mechanical barrier.Fungicidal sprays that act as protectants are used to control

Cercosporaleaf spot of sugar-beet, especially in those fields where inoculum has carried over from the previous year.The principle of protective fungicides is to disrupt the natural sequence of infection.These fungicides act on the leaf surface to kill the newly germinated spores.Sulphur is used as a protectant fungicide to control powdery mildew of sugar-beet.There is a long list of chemicals available in the literature that can be used in protective spraying and dusting, along with eradicant chemicals.The commercially sold chemicals are provided with instructions or notes on compatibility and possibilities of injury.Improvement of aeration under crop canopy reduces the humidity on aerial parts of the plant and thus checks the growth of fungi which flourish in humid atmosphere.

1.5 Immunization/Disease resistance

Disease resistant and tolerant varieties are the cheapest, easiest and most efficient way to reduce disease losses.Varieties should be selected that possess resistance or tolerance to one or more disease organisms.For some diseases, such as the soil-borne vascular wilts and the viruses, the use of resistant varieties is the only means of ensuring control.Certified seed of resistant varieties is available and sold commercially.The use of varieties of plants resistant to particular diseases has proved to be very effective against stem rust of wheat, rust of dry bean and Rhizoctonia root rot of sugar beet.Most plant breeding is done for the development of varieties that produce greater yields of better quality.When such varieties become available, they are then tested for resistance against some of the most important pathogens present in the area where the variety is developed and where it is expected to be cultivated.If the variety is resistant to these pathogens for that area, it may be released to the growers for immediate production.There are degrees of resistance to certain diseases, some varieties being completely immune, others partially susceptible.Resistant varieties may become susceptible to new races of a pathogen, as happens with cereal rusts, powdery mildews, downy mildews and P. infestans.Modern DNA technology has made it possible to engineer transgenic plants that are transformed with genes for resistance against specific disease, for tolerance of adverse environmental factors or with nucleic acid sequence that lead to gene silencing of the pathogen.Use of microorganisms and chemicals to induce systemic acquired resistance and activations of plants' defense system could also be used for the management of plant diseases.

1.6 Therapy

It is used on individual plants and cannot be used on a large scale.It is achieved by inoculating or treating the plant with something that will inactivate the pathogen.Chemotherapy is the use of chemicals to inactivate the pathogen, whereas heat is sometimes used to inactivate or inhibit virus development in infected plant tissues so that newly developing tissue may be obtained which is free of pathogen.Thermotherapy involves the exposure of diseased plants or parts of them to hot water or high air temperature for different periods of time. Loose smut of wheat is controlled by treating the seeds with hot water, but growing resistant varieties is a simpler method of control.Hot water treatment has been used to kill nematodes in bulbs, corms, tubers and fleshy roots while they are in a dormant condition.Dormant chrysanthemum stools can get rid of foliar nematodes by submerging in water at 112°F (44°C) for 30 minutes.

Unit 2: Physical Agents Used For Disease Control

Contents

1.0 Physical Agents Used For Disease Control

The physical agents used most commonly in controlling plant diseases are:

i) Temperature (high or low)

ii) Dry air

iii) Unfavourable light wavelengths iv) Various types of radiations

v) Cultivation in glass or plastic greenhouses vi) Plastic or net covering

1.1 Soil sterilization by heat

Soil sterilization is completed when the temperature in the coldest part of the soil has remained for at least 30 minutes at 82oC or above, at which temperature almost all plant pathogens in the soil are killed.Soil can be sterilized in greenhouses, and sometimes in seed beds and cold frames, by the heat carried in live or aerated steam or hot water.The soil is steam sterilized either in special containers (soil sterilizers), into which steam is supplied under pressure, or on the greenhouse benches, in which case steam is piped into and is allowed to diffuse through the soil.At about 50oC, nematodes, some oomycetes, and other water moulds are killed, whereas most plant pathogenic fungi and bacteria along with some worms, slugs, centipedes, are usually killed at temperatures between 60 and 72oC.Most weeds, rest of plant pathogenic bacteria, most plant viruses in plant debris, and most insects are killed at about 82oC.Heat tolerant weed seeds and some plant viruses, such as Tobacco mosaic virus (TMV) are killed at or near the boiling point that is between 95 and
100oC.Excessively high or prolonged high temperatures should be avoided during soil sterilization.High temperatures destroy all normal saprophytic microflora in the soil and result in release of toxic levels of some (e.g., Manganese) salts.High temperatures also result in the accumulation of toxic levels of ammonia (by killing the nitrifying bacteria before they kill the more heat resistant ammonifying bacteria), which may damage or kill plants planted afterward.

1.2 Soil solarization

When clear polythene film is placed over moist soil during sunny summer days, the temperature at the top 5 cm of soil may reach as high as 52oC compared to a maximum of

37oC in unmulched soil.If sunny weather continues for several days or weeks, the increased soil temperature from solar heat, known as solarization inactivates (or kills) many soil borne pathogens, viz., fungi, nematodes, and bacteria near soil surface, thereby reducing the inoculum and its potential for causing disease.

1.3 Hot water treatment of propagating organs

Hot water treatment of certain seeds, bulbs, and nursery stock is used to kill pathogens with which they are infected or which may be present in seed coats, bulbs, scales, and so on, or which may be present in external surfaces or wounds.Seed treatment with hot water was the only means of control in some diseases for many years, as in the loose smut of cereals, in which the fungus overwinters as mycelium inside the seed where it could not be reached by chemicals.Treatment of bulbs and nursery stock with hot water frees them from nematodes that may be present within them, such as *Ditylenchusdipsaci* in the bulbs of various ornamentals and *Radopholussimilis* in citrus rootstocks.The effectiveness of this method is based on the fact that the dormant plant organs can withstand higher temperatures than those of their respective pathogens can do for a given time.The temperature of the hot water used and the duration of the treatment vary with the different host pathogen combinations.In case of loose smut of wheat, seed is kept in hot water at
50^{o}C for 11 minutes, whereas bulbs treated for the control of *Ditylenchusdipsaci* are kept at 43^{o}C for 3 hours.A short (15 seconds) treatment of melon fruit with hot (59 + 1^{o}C) water rinse and brushes result in a significant reduction of fruit decay while maintaining fruit quality after prolonged storage.Treated fruit had less soil, dust, and fungal spores at its surface while many of its natural openings in the epidermis were partially or entirely sealed.

1.4 Hot air treatment of storage organs

Treatment of certain storage organs with warm air (curing) removes excess moisture from their surfaces and hasten the healing of wounds, thus preventing their infection by certain weak pathogens.Keeping sweet potato at 28 to 32^{0}C for 2 weeks helps the wounds to heal and prevents the infection of Rhizopus and by soft rotting bacteria.Hot air curing of harvested ears of corn, tobacco leaves, and so on removes most moisture from them and protects them from attack by fungal and bacterial saprophytes.Dry heat treatment of barley seed at 72^{o}C for 7 to 10 days eliminates the leaf streak and black chaff- causing bacterium *Xanthomonascampestrispv. transluscens* from the seed with negligible reduction of seed germination.

1.5 Control by eliminating certain light wavelengths

Alternaria, Botrytis and Stemphylium are examples of plant pathogenic fungi that sporulate only when they receive light in the ultraviolet range (below 360 nm).Diseases can be controlled on greenhouse vegetables caused by several species of these fungi by covering or constructing the greenhouse with a special ultraviolet absorbing vinyl film that blocks the transmission of light wave lengths below 390 nm.

1.6 Drying stored grains and fruits

All grains, legumes, and nuts carry with them a variety and number of fungi and bacteria that can cause decay of these organs in the presence of sufficient moisture.Such decay, however, can be avoided if seeds and nuts are harvested when properly mature and then are allowed to dry in the air or treated with heated air until the moisture content is reduced sufficiently (to about 12% moisture) before storage.Subsequently, they are stored under conditions of ventillation that do not allow build-up of moisture to levels (about 12%) that would allow storage fungi to become activated.Fleshy fruits, such as peaches and strawberries, should be harvested later in the day, after dew is gone, to ensure that the fruit does not carry surface moisture with it during transit, which could result in decay of the fruit by fungi and bacteria.Many fruits can also be stored dry for a long time and can be kept free of disease if they are dried sufficiently before storage and if moisture is kept below a certain level during storage.Grapes, plums, dates and figs can be dried in the sun or through warm air treatment to produce raisins, prunes, and dried dates and figs, respectively, that are generally unaffected by bacteria and fungi as long as they are kept dry.Even slices of fleshy fruit such as apple, peaches, apricots can be protected from infection and decay by fungi and bacteria if they are dried sufficiently by exposure to the sun or to warm air currents.

1.7 Disease control by refrigeration

Refrigeration is the most widely used and the most effective method of controlling post-harvest diseases of fleshy plant products.Although low temperature at or slightly above the freezing point does not kill any of the pathogen that may be on or in the plant tissues, they do inhibit or greatly retard the growth and activities of all such pathogens, thereby reducing the spread of existing infection and the initiation of new ones.Most perishable fruits and vegetables should be refrigerated as soon as possible after harvest, transported in refrigerated vehicles, and kept refrigerated until used by the consumer.Regular refrigeration of especially succulent fruits and vegetables is sometimes preceded by quick hydro cooling or air cooling of these products, aimed at removing the excess heat carried in them from the field as quickly as possible to prevent the development of any new and latent infections.The magnitude of disease control through refrigeration and its value to growers and consumers is immense.

1.8 Disease control by irradiation

In this method, various electromagnetic radiations are used for controlling postharvest diseases of fruits and vegetables by killing the pathogens present on them, such as:

- UV light
- X-rays
- Gamma rays
- Particulate radiations, such as a-particles and ß-particles

Unit 3: Host Eradication
Content

1.0 Introduction

When a plant pathogen enters into new area despite quarantine, a plant disease epidemic may occur. All the host plants infected by pathogen may have to be removed and burnt to prevent such epidemics. This eliminates the pathogen and prevents greater losses from the spread of pathogen to additional plants.

2.0Eradication of the crop/main host

This type of eradication of pathogen was done in Florida and other southern states for control of bacterial canker of citrus in 1915, where more than three million trees had to be destroyed.Another outbreak of citrus canker occurred in Florida in 1984, and by 1992; and the disease was apparently brought under control through painful destruction of nursery and orchard trees in the United States.Host eradication is also carried out routinely in many nurseries, greenhouses, and fields to prevent spread of numerous diseases by eliminating infected plants that provide a ready source of inoculum within this crop.However, attempts to eradicate certain diseases like fire blight of apple and pear caused by the bacterium *Erwiniaamylovora* and plum pox virus of stone fruits in the United States, and coffee rust in several South American countries to eradicate them have not been successful.

3.0Eradication of the wild/volunteer host plants

Certain pathogens of annual crops, e.g., Cucumber mosaic virus overwinters only or mainly in perennial wild plants.Eradication of host in which the pathogen overwinters is sometimes enough to eliminate completely or to reduce drastically the amount of inoculum that can cause infection in the following season.In some crops like potatoes, the pathogens overwinter in the infected tubers.These tubers produce infected plants in the spring that allow pathogen to come on aboveground parts from where it can spread further by insects, rain and wind.Eradication of such volunteer plants of a crop helps greatly to reduce the inoculum of these pathogens.

4.0Eradication of alternate hosts

Some pathogens require alternate hosts to complete their life cycle, e.g., *Pucciniagraminis*tritici requires wheat and barberry, and *Cronartiumribicola* requires pine

and currants.Eradication of wild or economically less important alternate host interrupts the life cycle of pathogen and leads to the control of the disease.

5.0Crop Rotation

Soil borne pathogens that infect plants of one or a few species or even families of plants can sometimes be reduced in the soil by planting non-host crops for 3 or 4 years.Crop rotation can reduce population of pathogens (e.g., Verticillium).

6.0Fallowing

The field is tilled and left fallow for a year or part of year in some cases.

During fallowing, pathogen debris and inoculum are destroyed by microorganism with little or no replacement.In areas with hot summer, fallowing allows greater heating and drying of the soil, which leads to a marked reduction of nematodes and some other pathogens.Other cropping systems utilize herbicides, reduced tillage and fallowing.In such systems, certain diseases, e.g. stalk rot of grain sorghum and corn, caused by *Fusariummoniliforme* have been reduced dramatically.In other diseases, such as Septoria leaf blotch of wheat and barley scab were increased.

7.0 Sanitation

Sanitation consists of all activities aimed at eliminating or reducing the amount of inoculum present in a plant, field or a warehouse and at preventing the spread of the pathogen to other healthy plants and plant products.

Ploughing under infected plants after harvest, such as leftover infected fruit, tubers or leaves, helps cover the inoculum with soil and speed up its disintegration and concurrent destruction of most pathogens carried in or on them.Removing the infected leaves of house or garden plants helps remove or reduce the inoculum.Infected crop debris of grasses and rice crops is destroyed by burning in some parts of world, which reduces or eliminates the surface inoculum of several pathogens.By washing their hands before handling certain kinds of plants, such as tomatoes, workers who smoke may reduce the spread of Tobacco mosaic virus.Disinfecting the knives used to cut propagative stock, such as potato tuber and disinfecting pruning shears between trees reduce the spread of pathogen through such tools.Washing the soil of farm equipment before moving it from one field to another may also help in preventing the spread of pathogens present in the soil.

Unit 4: Practices for Creating Conditions Unfavourable to the Pathogen

Content

1.0 Introduction

Stored product should be aerated properly to hasten the drying of their surface and inhibit germination and infection by any fungal or bacterial pathogens present on them.The appropriate choice of fertilizers or soil amendments may also lead to change in the soil pH, which may unfavourably influence the development of pathogen.In the production of many crops, particularly containerized stock, using decomposed tree bark in the planting medium has resulted in the successful control of diseases caused by several soil borne pathogens, e.g. Phytophthora, Pythium and Thielaviopsis causing root rots , Rhizoctonia causing damping off and crown rot, Fusarium causing wilt, and nematode diseases of several crops.

2.0Polyethylene Traps and Mulches

Many plant viruses, such as cucumber mosaic virus are brought into crops such as peppers, by airborne aphid vectors.When vertical, sticky, yellow polyethylene sheets are erected along edges of susceptible crop fields, a considerable number of aphids are attracted to and stick to them.If reflectantaluminum or black, whitish-grey or coloured polyethylene sheets are used as mulches between the plants or rows in the field, incoming aphids, thrips and possibly other insect vectors are repelled and misled away from the field.Reflectant mulches, however, cease to function as soon as the crop canopy covers them.

3.0 Evading or avoidance of the pathogen

For several plant diseases, control depends on attempts to evade pathogens.

Bean anthracnose, caused by the fungus *Colletotrichum lindemuthianum*, and the bacterial blight of bean caused by bacteria *Xanthomonasphaseoli* and *Pseudomonas phaseolicola* are transmitted through the seed. Therefore, they can be successfully controlled by using disease free seed and seed treatments.In many cases, the susceptible crop is planted at a great enough distance from field containing infected plants so that the pathogen would not infect the crop.Crop isolation is practiced mostly with perennial plants, such as peach orchards isolated from choke cherry shrubs or trees infected with X disease phytoplasma.

Various activities which evade the pathogens include:

i) Using vigorous seed

ii) Selecting proper dates and proper sites

iii) Maintaining proper distances between fields and between rows and plants iv) Planting windbreaks or trap crops

v) Planting in well-drained soil
vi) Using proper insect and weed control

Such practices increase the chances that the host will remain free of pathogen or at least that it will go through its most susceptible stage before the pathogen reaches the host.

4.0 Pathogen Free Seed and Propagative Material

Seed may carry internally one or a few fungi such as those causing anthracnose and smuts, certain bacteria causing bacterial wilts, spots and blights and certain viruses (Tobacco ring spot virus in soybean, Bean common mosaic virus, Lettuce mosaic virus, Barley stripe mosaic virus, Squash mosaic virus and Prunusnectroic ring virus). Such diseases cn be controlled effectively by producing and using disease free seed.True seed, however, is invaded by relatively few pathogens, although several may contaminate its surface.All types of pathogen can be carried in or on propagating material.When a pathogen is excluded from the propagating material of the host, it is often possible to grow the host free of that pathogen for the rest of its life, e.g., woody plants, generally affected by non- vectored viruses.

4.1 Production of pathogen free vegetative propagating material

Vegetative propagating material free of pathogens that are distributed systemically throughout the plant is obtained from mother plant that had been tested and shown to be free of particular pathogen or pathogens.To ensure continuous production of pathogen free buds, grafts, cuttings, rootstocks and runners of trees, vines, and other perennials; the mother plant is indexed for the particular pathogen at regular intervals.For certain crops, such as potato, complex certification programmmes have been evolved to produce pathogen free seed potatoes.For the seed to be certified the plants must show disease level no higher than those allowed by particular state.Sometimes it is impossible to find even a single plant of variety that is free of particular pathogen, especially of viruses. In that case, one or few healthy plants are initially obtained by meristematic tissue culture which most viruses do not invade.

4.2 Exclusion of Pathogens from Plant Surfaces by Epidermal Coatings

The plants are sprayed with compounds that form a continuous film or membrane on the plant surface for controlling diseases of aboveground parts of plant and inhibit contact of pathogen with the host and penetration of host.Water emulsion of dodecyl alcohol forms a high quality of lipid membrane. The membrane allows diffusion of oxygen and carbon dioxide but not of water. The membrane is not easily washed by rain and remains intact for about 15 days.Kaolin based films have also proved effective in protecting apple shoot from becoming infected by the bacterial disease fire blight, and apple fruit from powdery mildew. It also protects grapevine from Pierce disease caused by *Xylellafastidiosa* by interfering with its transmission by the vector.

Unit 5: Biological Control

Content

1.0 Introduction

Biological control of plant pathogens refers to the total or partial destruction of pathogen population by other organisms.It occurs routinely in nature. For example, several diseases in which the pathogen cannot develop in certain areas either because the soil, called suppressive soil, contains microorganisms antagonistic to the pathogen or because the plant that is attacked by a pathogen has also been inoculated naturally with antagonistic microorganisms before or after the pathogen attack.Sometimes, the antagonistic microorganisms may consist of avirulent strains of the same pathogen that destroy or inhibit the development of the pathogen, as happens in hypovirulence and cross protection.Agriculturalists have increased their efforts to take advantage of such biological antagonisms and to develop strategies by which biological control can be used effectively against several plant diseases.

2.0Suppressive Soils

Many soil borne pathogens, such as *Fusariumoxysporum* (causing vascular wilts), *Gaeumannomycesgraminis* (causing take-all of wheat), Pythium spp. (causing damping-off) and *Heteroderaavenae* (oat cyst nematode) develop well and cause severe diseases in some soils, known as conducive soils, whereas they develop much less and cause much milder diseases in other soils, known as suppressive soils.The mechanisms by which soils are suppressive to different pathogens may involve biotic and/or abiotic factors and may vary with the pathogen.They operate primarily by the presence in such soils of one or several microorganisms antagonistic to the pathogen.Many kinds of antagonistic microorganisms have been found to increase in suppressive soils; such as Trichoderma, Penicillium, and Sporidesmium, or bacteria Pseudomonas, Bacillus and Streptomyces.

3.0Reducing Amount of Inoculum through Antagonistic Microorganisms

3.1Control of soil borne pathogens

Several non-plant pathogenic oomycetes and fungi including some chytridiomycetes and hyphomycetes, and some pseudomonad and actinomycetous bacteria infect the resting spores of several plant pathogenic fungi.Among the most common mycoparasitic

fungi are *Trichoderma* sp., mainly *T. viride* and *T. harzianum*.It parasitizes mycelia of Rhizoctonia and Sclerotium and inhibits the growth of many oomycetes such as Pythium, Phythophthora, and other fungi, e.g., Fusarium and Heterobasidion (Fomes).Other common mycoparasitic fungi are Laetisariaarvalis (Corticium sp.), a mycoparasite and antagonist of Rhizoctonia and Pythium; *Sporidesmiumsclerotivorum*, *Gliocladiumvirens* and *Coniothyriumminitans*.

3.2 Control of aerial pathogens

Many fungi have been shown to antagonize and inhibit numerous fungal pathogens of aerial plant parts.*Chaetomiumglobosum* and *Atheliabombacina* suppress *Venturiainaequalisascospo re* and conidia production in the fallen and growing leaves, respectively.*Tuberculina maxima* parasitizes the white pine blister rust fungus *Cronartiumribicola*.*Darlucafilum* and *Verticilliumlecanii* parasitize several rusts.

3.2.1Control through Trap Plants

If a few rows of rye, corn, or other tall plants are planted around a field of beans, peppers, or squash, many of the incoming aphids carrying viruses that attack the beans, peppers, and squash will stop and feed on the peripheral taller rows of rye or corn.Trap plants are also used against nematodes which are sedentary endo- or ecto-parasites.Crotolaria plants trap the juveniles of root- knot nematodes.

3.2.2Control through Antagonistic Plants

Plants such as asparagus and marigold are antagonistic to nematodes. They release substances in the soil that are toxic to several plant parasitic nematodes.

4.0Resistant Varieties

Grow varieties that have both vertical (initial inoculum- limiting) and horizontal (rate limiting) resistance and most resistant varieties have both type of resistance.Many of them carry only one or a few genes of vertical resistance and an unspecified number of genes of horizontal resistance.Such varieties are resistant only to some of the races of pathogen and if the pathogen is air borne, a new race can be brought in easily as happens with cereal rusts, powdery mildews and *Phytophthorainfestans*.The new race virulent to the resistant variety may appear and become wide spread in this way.

5.0Use of transgenic bio-control microorganisms

Genetic engineering techniques have been used to add new genes or to enhance the genetic make-up of the bio-control organisms so that it may attack the pathogen better.Such genes may be of plant or microbe origin that code for toxins, enzymes, and other compounds affecting the pathogen adversely, or regulatory genes that over-express appropriate bio- control genes already present in that organism.

6.0Direct protection by biological control agents

The most commonly used microorganisms include:

Gliocladiumvirens, for the control of seedling diseases of ornamental and bedding plants
Trichodermaharzianum, for the control of several plant pathogenic fungi
Trichodermapolysporum, for the control of wood decays
Agrobacterium radiobacter K-84, for the control of crown gall
Pseudomonas fluorescens, against Rhizoctonia and Pythium causing damping off and other diseases
Bacillus subtilis, used as a seed treatment

7.0Biological Control of Postharvest Diseases through Fungal and Bacterial Antagonists

Post-harvest rots of several fruits could be reduced by spraying the fruits with spores of antagonistic fungi and saprophytic yeasts at different stages of fruit development, or by dipping the harvested fruit in their inoculum.Yeast treatments reduced post-harvest rotting of peach and apple.Botrytis rot of strawberries was reduced by several sprays of Trichoderma spores on strawberry blossoms and young fruits.Several antagonistic yeasts protected grapes and tomatoes from Botrytis, Penicillium, and Rhizoctonia rots.

8.0Biological Control of Postharvest Diseases through Fungal and Bacterial Antagonists

- In bacterial antagonists, Pseudomonas protected lemons from Penicillium (green mould) and pear from various storage rots.
- Two *Pseudomonas syringae* strains control the post-harvest decay in citrus, apple and pear under the trade name Bio-Save.
- Stone fruits such as peaches, nectarines, apricot and plums when treated with suspensions of the antagonistic bacterium *Bacillus subtilis*, they remain free from brown rot, caused by the fungus *Moniliniafructicola* for nine days.
- *Bacillis subtilis* also protected avocado from storage rots.
- Pseudomonas protected lemons from Penicillium (green mould) and pear from various storage rots.
- Two *Pseudomonas syringae* strains control the post-harvest decay in citrus, apple and pear under the trade name Bio-Save.
- Stone fruits such as peaches, nectarines, apricot and plums when treated with suspensions of the antagonistic bacterium *Bacillus subtilis* remain free from brown rot, caused by the fungus *Moniliniafructicola* up to nine days.
- *Bacillus subtilis* also protects avocado from storage rots.

Unit 6: Integrated Disease Management

Content

1.0Introduction

- Integrated disease management (IDM) came under focus in 1960's when chemicals especially, fungicides and insecticides came under the attack from environmentalists due to the overuse of chemicals that created the problems of environmental pollution, chemical residues in food stuff, land, water and air, and the associated health hazards.
- It focused on the other methods of disease control.
- It involved cultural, biological, epidemiological and alternative means to achieve the disease control.
- Nowadays, there is an emphasis on disease "management" rather than on
- "Control".

Definition of IDM

"Disease management system that in the context of associated environment and population dynamics of microorganisms, utilizes all suitable techniques and methods in a manner as compatible as possible and maintains the disease below economic level".In general, it is the integration of all possible and suitable management techniques for the control of diseases.The practices which need to be avoided in IDM are indiscriminate use of fungicides, monoculture and growing of susceptible cultivars.Integrated disease management ensures the proper management of soil health, use of healthy seeds and planting material, application of fungicides when required, field sanitation, cultural practices which suppress the disease , use of bio-control agents and growing resistant plant genotypes .

2.0 Different Approaches of Integrated Disease Management System

1. The combined control approach: It is a combination of control methods like adjustment in sowing time, seed treatment, use of resistant variety, chemical spray schedule etc. This type of IDM is widely practiced as a package of practice where the occurrence of disease is certain and sure.
2. The surveillance based approach: It is an advanced IDM approach based on crop health monitoring and surveillance, and takes into account the economic threshold levels or economic damage levels.
3. Advanced integrated disease management system: It involves the high input technology like computer supported forecasting, remote sensing, scouting, multiple pathogen thresholds, information on life cycle of pathogens, epidemiology of diseases, environmental factor and knowledge based decision making.

3.0 Main components of integrated disease management (IDM)

1. Host resistance
2. Induced systemic resistance
3.Genetically improved plants
4. Cultural practices
5. Physical methods
6.Plant nutrition
7. Biological control
8.Use of pesticides of plant origin
9. Judicious use of chemicals

3.1 Host resistance

Resistant varieties can be the simple, practical, effective and economical method of plant disease control.Apart from ensuring protection from diseases, they can also save time, money and energy spent on other methods of control and avoid environmental pollution with chemicals.They are the only practical method of controlling such diseases as wilts, rusts and others caused by viruses in which chemical control is very expensive and impractical.In low value crops, where other methods are often too expensive, development of varieties resistant to common and important diseases can be an acceptable recommendation for the farmers.Disease resistance in plants is also governed by their genetic constitution and can be monogenic, oligogenic or polygenic.

3.1.1 Advantages of host plant resistance

- No adverse effect on environment and man, rather the resistant cultivars put a constant and cumulative effect on pathogen.
- Host plant involves no extra cost to the farmers and does not require inputs and
- application skills.

3.1.2 Disadvantages of host plant resistance

The development of pathogen resistant variety takes 5-10 years.

- Host plant resistance can put a selection pressure on pathogen to the extent that it may lead to the evolution of new biotypes of pathogen.
- Introduction of varieties with resistance to one pathogen leads to the emergence of new pathogen problem because of the absence of competition from the key pathogen.

3.2 Induction of host resistance

Plants actively respond to a variety of environmental stimuli, including gravity, light, temperature, physical stress, water and nutrient availability.Plants also respond to a variety of chemical stimuli produced by soil- and plant-associated microbes.Such stimuli can either induce or condition plant host defence through biochemical changes that enhance resistance against subsequent infection by a variety of pathogens.Induction of host defence can be local and/or systemic in nature depending on the type, source, and amount of stimuli.The systemic acquired resistance (SAR) is mediated by salicylic acid (SA), a compound which is frequently produced following pathogen infection and typically leads to the expression of pathogenesis-related (PR) proteins.These PR proteins include a variety of enzymes, some of which may act directly to lyse the invading cells, reinforce cell wall boundaries to resist infections, or induce localized cell death.Whereas, the induced systemic resistance (ISR) is mediated by jasmonic acid (JA) and/or ethylene, which are produced following applications of some non-pathogenic rhizobacteria.Interestingly, the SA- and JA- dependent defense pathways can be mutually antagonistic, and some bacterial pathogens take advantage of this to overcome the SAR.Pathogenic strains of *Pseudomonas syringae* produce coronatine, which is similar to JA, to overcome the SA-mediated pathway.Because various host-resistance pathways can be activated to varying degrees by different microbes and insect feeding, it is plausible that multiple stimuli are constantly being received and processed by the plant.Thus, the magnitude and duration of host defence induction will likely vary over time.

3.3 Genetically improved plants

Genes from plants, microbes and animals can be combined and introduced in to the living cells of other organisms, and the organisms that have genes from other species inserted into their genome are called transgenics.Production of disease resistant transgenic plants has been achieved by this method; certain genes are inserted in to plant genome that confer resistance to pathogens such as viruses, fungi and insects.These transgenic plants reduce the pesticide use and thereby provide environmental benefits while reducing farmers cost.Genetically modified plants are generally used to control the viral diseases, e.g., a transgenic papaya cultivar 'Rainbow' has been developed which is resistant to papaya ring spot virus in the US.

3.4 Integration of different cultural practices

Different cultural practices like crop rotation, mulching, tillage, different soil amendments, soil solarization, soil sterilization, change in date of sowing, plant spacing etc. when applied alone are able to control diseases up to some extent; but when these cultural practices are combined with each other, they not only control the diseases but also increase the yield of crops.The inter-cropping of maize and sorghum with peppers serves as barriers against the aphid vectors of pepper veinal mottle virus and reduces the virus spread.Soil solarization for 40 days along with the addition of cabbage, cauliflower, broccoli and sarson leaf residues controlled the gladiolus wilt (*Fusariumoxysporumf.sp. gladioli*) by 74.6% whereas soil solarization (for 40 days) alone reduced the gladiolus wilt by 67.3% compared to the un-solarized control.

3.5 Physical methods of disease control

Solar heat treatment of the water soaked wheat seed in May-June for 5-6 hours provides good control of loose smut of wheat.Most of the post-harvest diseases can be avoided by irradiation, refrigeration, Controlled Atmosphere Storage etc.Soil solarization has been used to control soil borne diseases caused by otherwise difficult to control fungi, e.g., *Rhizoctoniasolani*, *Fusarium spp., Sclerotium*etc .In this the soil beds are first irrigated and then covered with thin (20 µm) transparent mulch in the months of April, May and June.It raised the soil temperatures in some cases up to 500C, which is deleterious to many plant pathogens in the soil.It has been used in raising disease free nursery in tropical and subtropical climatic areas. It also provides excellent weed control.Hot water treatment of cabbage seed at 520C for 15-20 minutes controls black rot disease (caused by *Xanthomonascampestrispv. campestris*).

3.6 Plant nutrition

The nutrition of crop plants has direct effect on the diseases, and is an important component of integrated disease management (IDM).Both deficient and over-nourished plants invite high incidence of diseases as well as loss in yield and quality of produce and products.The amount, proportion, time and method of application of fertilizers affect the metabolism of plants and thus occurrence and severity of diseases.Fertilization with both P and K significantly reduces the leaf rust damage and powdery mildew infection in wheat.The deficiency of macronutrients may also affect the incidence of many diseases.Potassium (K) plays an important role in survival of crop plants under environmental stress conditions.Potassium also affects the reaction of plants to pests or diseases by having direct effect on the pathogen number, development, multiplication, survival, vigour and length of life cycle.

3.7 Biological control

Bio-control agents are used as a core component of integrated disease management system.The science and art of using living organisms as bio-control agents is an important component of

environment friendly disease management procedures.These biocontrol agents are of enormous value in integrated diseases management for sustainable agriculture where they often replace the need of fungicides.The biocontrol agents either suppress the pathogen growth either by the antibiotic production, hyperparasitism or by competition.Various biocontrol agents used in control of various diseases are *Bacillus subtilis, Pseudomonas fluorescens, Gliocladium spp., Trichoderma spp., Chaetomiumglobosum, Pseudomonas cepacia, Bacillus cereus, Agrobacterium radiobacter* etc.*Trichodermaviride* is the most important and versatile biocontrol agent used for the control of a number of plant pathogens like *Rhizoctoniasolani* and *Sclerotiumrolfsii* which are otherwise difficult to control by other methods.Similarly, *Fusariumlateriticum* has been used to cover primary wounds of apricot for avoiding the canker disease caused by Eutypaarmeniacae.Application of *Peniophoragigantea*oidia paste on pine stumps provided effective control of *Heterobasidionannosus* root rot disease which spreads through unprotected stumps left over after felling.*Ampelomycesquisqualis* and *Darluca* spp. hyperparasitize powdery mildew and rust fungi, respectively, and therefore exploited for their biological control.*Agrobacterium radiobacter* K-84 strain has been used against crown gall disease world over.

3.8 Use of pesticides of plant origin

Pesticides of plant origin are derived from plant parts and their genes are also used to transform crops to express resistance to insect, fungal and viral attack.The plant parts and their extracts with antifungal properties play an important role in plant disease management.Garlic (*Allium sativum*) has a long history of reputed value and actual use for its medicinal, antimicrobial and pesticidal properties.The growth of *Rhizoctoniasolani* can be reduced with ethanolic extracts of Eucalyptus sp., *Chenopodiumambrosioides*, *Lippiaalba*, *Aeglemarmelos* and *Cestrum diurnum* leaves.The seed extract of *Piper nigrum* was found to be effective against *R. bataticola*.

3.9 Judicious use of fungicides

Chemicals have been used successfully to combat the ravages of these diseases for many years.Fungicides with different modes of action like protective (broad spectrum fungicides), post infection activity (EBI), pre- symptom and post symptom (benzimidazoles and triazoles) may be used for controlling a wide array of plant diseases ravaging various crops.The over-use of these chemicals resulted in water pollution, residues on food and fruit crops, effect on non- target organisms and development of resistance in pathogens against the chemicals have drawn the attention toward the rational use of fungicides by including monitored control strategies and cultural practices.

4.0 Types of Integrated Disease Management

i) Integration of cultural and chemical control

The integration of chemicals and cultural practices (including improved cultivars) has resulted in a continuous supply of fresh watermelons, reduced diseases caused by *Colletotrichumagenarium*, *Pseudomonassyringae* pv. *lachrymans* and *Pseudoperonosporacubensis*.The covering the tomato nursery seedlings with nylon net for 25-30 days plus 4 sprays of monocrotophos at 10-days intervals after transplanting, delayed the spread of Tomato leaf curl virus for 3-5 weeks and increased tomato yields.

ii) Integration of chemical and biological control

Bio-control agents such as *Pseudomonas fluorescens, Trichodermaviride, T. harzianum, Bacillus subtilis, Pseudomonas putida, P. cepacia, Talaromyces flavus,* and *Agrobacterium radiobacter* strain K 84 etc. can be used with integration of chemicals for the effective control of certain diseases.

iii) Integration of resistance, cultural, biological and chemical control

The integration of cultural practices (crop rotation, good farm hygiene procedures, quarantine), fertilizers, soil fumigation and solarization, pesticides (fungicide transplant dips, soil drench, soil incorporations, seed treatments, trace elements and surfactants), resistant cultivars and biocontrol agents are used for the control of club root (*Plasmodiophorabrassicae*) of vegetables.

Tutor Marked Assignments

1. Discuss the following principles of disease management i. Avoidance
ii. Exclusion iii. Eradication iv. Protection
v. Immunization/Disease resistance vi. Therapy
2.List four (4) Physical Agents Usedfor Disease Control and write short notes on any two (2)
3. Define Host Eradication as a method of pest control.
4. Write short notes on the following;
i.Introduction
ii. Eradication of the crop/main host iii. Crop Rotation
iv. Fallowing v. Sanitation
5.Describe how pathogens can be evaded or avoidedin the cultivation of crops.
6. Discuss how Pathogen Free Seed and Propagative Material are prerequisites for reduced pathogen load during a growing season.

7. Define biological control.
a. Describe the control of soil borne and aerial pathogens as a method of biological control.

b. What are transgenic bio-control microorganisms

8. What is Host resistance as a component of Integrated Disease Management?
a. List the advantages of host plant resistance
b. List the disadvantages of host plant resistance
9. Write short notes on the following;

a. Induction of host resistance b. Genetically improved plants c. Plant nutrition
d. Use of pesticides of plant origin e. Judicious use of fungicides

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MODULE 4 PESTICIDES AND THIR APPLICATION IN THE CONTROL OF FIELD AND STORAGE PESTS, DISEASES AND WEEDS

Unit 1: Classification of Chemical Pesticides
Unit 2: Methods of Applications of Fungicides
Unit 3: Classification of Plant Protection Equipment
Unit 4: Spray Nozzles and Their Classification
Unit 5: Spraying Technique – I (High Volume Spraying) Unit 6: Spraying Technique – II (Low Volume Spraying)
Unit 7: Spraying Technique - III (Ultra Low Volume Spraying Technique) Unit 8: Electrostatic Spraying
Unit 9: Dusters and Dust Applications
Unit 10: Calibration of Sprayer
Unit 11: Some Worked Examples

Unit 1: Classification of Chemical Pesticides

Content

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2.1.4 Pyrethroids
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2.4.1 Microbial pesticides
2.4.2 Plant incorporated protectants
2.4.3 Biochemical pesticides
2.5 Other Minor Classes of Pesticides
2.5.1 Classification based on mode of action

1.0 Introduction

Chemicals used for controlling insect pests, diseases and weeds are known as pesticides; and those used for controlling fungal diseases are called fungicides, those used against viruses are called viricides. Antibiotics are generally used for controlling bacterial diseases. One of the important or common mean of controlling the plant diseases is through chemical compounds which are toxic to the pathogens.These chemicals inhibit the germination, growth and multiplication of the pathogen or are lethal to the pathogen.

2.0 Classification of Chemical Pesticides

Depending upon the pathogens they affect, they may be classified as fungicides, bactericides, nematicides, viricides etc.Out of these, some chemicals are broad-spectrum and they are toxic to all pathogens.Most of the chemicals used in plant protection are foliar and are used as aboveground parts of the plants.Some of them are soil disinfectants, and some are used as protectants for seed, tubers and culms etc. There are some of the chemicals which have been used prior to disease spread.A few chemicals are aimed to eradicate the general inoculum before it comes in contact with the plant hosts. They are called eradicants or chemotherapeutants.

2.1 Classification Based on Chemical Structure

According to its chemical structure, pesticides areclassified into different families, ranging fromorganochlorine and organophosphorus compounds toinorganic compounds. In this paper, we refer only tosome families of pesticides relevant for the damage theycause to human health and high demand for its use. Themost common way to classify them based on theirchemical structure is split into four main groups:

2.1.1 Organochlorines

These are basically organic compounds that have been chlorinated. Organochlorines are lipophilic and show much affinity for fatty tissue of animals. Organochlorines have very low bio-degradation; get accumulated in environment causing serious problems. Important examples of organochlorines are (a) DDT, (b) BHC, (c) Aldrin and (d) Endosulphan.

(a) DDT (Dichlorodiphenyltrichloroethane): DDT was first synthesized by a German chemist OthnarZeidler in 1874 and its insecticidal value was discovered by Paul Muller in 1939. DDT is the most famous pesticide of the world and is a non-biodegradable pollutant. Spraying of DDT on crops produces pollution of air, soil and water. In India, as a result of prolonged use of DDT, 13-31 ppm of DDT can be detected in the body fat of the people, highest in the world. DDT concentrates from water into the body and magnified in higher members of the food web.9 DDT tolerance level is 10ppm for a freshwater crustacean Daphnia and this means Daphnia will die beyond that concentration. DDT has become ineffective for killing mosquitoes because of the development of adaptive resistance. DDT does not inhibit cholinesterase activity and is relatively non-toxic to mammals, but in oil solution it is absorbed by skin. Pesticide (DDT) is banned now a days because DDT interacts with the food-chain in

our ecosystem and causes serious damages and loss of biodiversity. For example; bio-magnification, or bio-amplification is the increasing concentration of a substance, such as a toxic chemical like DDT or mercury, in the tissuesof organisms at successively higher levels in a food chain. This happens because a toxic substanceaccumulated by an organism cannot be metabolised or excreted, and is thus passed on to the next higher trophic level. In this manner, the concentration of DDT is increased at successive trophic levels; say if it starts at 0.003 ppb (parts per billion) in water, it can ultimately reach 25 ppm (parts per million) in fish-eating birds, through bio- magnification. High concentrations of DDT disturb Ca^{2+}-metabolism in birds, which causes thinning of eggshell and their premature breaking, eventually causing decline in bird populations. Toxaphene, a cotton pesticide is also banned in USA causes serious health problems of nervous system.

(b) Lindane: γ-hexachlorocyclohexane/Gammaxene/Lindane was 1st synthesized by Michael Faraday in 1825 and its insecticidal value was independently discovered by Dupire (1941) in France and Leicester (1942) in England. It is most common pesticide used in India, represents about 50% of total volume of pesticides used in India. Lindane canbioaccumulate in food-chain thus more toxicant than DDT. Lindane is used in shampoos and lotion.

(c) Aldrin (Octalene): Aldrin is an insecticide named after German chemist Kurt Alder, applied to foundations of buildings to prevent termites. It has been successfully used in control of locusts and grasshoppers in Asian countries. Aldrin, Dieldrin and Endrin are very poisonous pesticides.

(d) Endosulphan (Thiodan) $C_9H_6Cl_6O_2S$:Endosulphan is a pesticide and is useful used in agriculture in the control of insect pests including whiteflies, aphids, leafhoppers, Colorado potato beetles and cabbage worms. It is also endocrine disruptor and carcinogenic to humans.

(e) Mirex: it is insecticide used to kill fire ants in agricultural lands. It was banned in USA because of biomagnifications to the turtles, coyotes, and other animals. It is potent endocrine disruptor to animals including human being.

2.1.2 Organophosphates

They are esters derived from phosphoric acid. In man they acton the central nervous system by inhibiting acetylcholinesterase, an enzyme that modulates the amountand levels of the neurotransmitter acetylcholine,disrupting the nerve impulse by serine phosphorylation ofthe hydroxyl group in the active site of the enzyme.The symptoms are causing loss of reflexes, headache,dizziness, nausea, convulsions, coma and even death. Also described withalkylating properties, which from the point of view ofmutagenesis is paramount because they act directly onthe deoxyribonucleic acid (DNA) adding alkyl groups, methyl and ethyl mainly to the nitrogenous bases withnucleophilic groups capable of reacting with electrophiles. Organophosphorus compounds are mostcommonly used in agriculture, and most are insecticides andmiticides. They are used in vegetable crops,fruit trees, grains, cotton, sugarcane, among manyothers.Malathion, parathion and fenitrothion are main organophosphates used in Nigeria.

2.1.3 Carbamates

They are esters derived from acids or dimethyl N-methylcarbamic acids and are used as insecticides, herbicides,fungicides and nematicides. They are less persistentthan organochlorines and organophosphates andlikewise the latter inhibit acetyl cholinesterase. However,in the case of carbamates action is fast and the kineticsof blocking is through the carbamylation of the enzyme bythe covalent attachment of the electrophilic group'ssteric carbamoyl sites of the enzyme. Some commonly used carbamates are Carbofuran (Furadan), Propoxur (Baygon) and Aldicarb. Derivatives of carbamates are also used as herbicides (phenylcarbamates, thiocarbamates) and Fungicides dithiocarbamates. Carbamates are useful in the control of nematodes and snails.

2.1.4 Pyrethroids

They originate from natural insecticide derived frompyrethrum extract derived from chrysanthemum flowers,known as pyrethrins. Subsequently were obtainedsynthetically and are presently manufactured around 100different commercial products. Your income is the insects by contact or ingestion.They act on the central nervous system causing changes in the dynamics of the Na^+ channels in the membrane ofthe nerve cell, causing it to increase its opening timeprolonging sodium current across the membrane in bothinsects and vertebrates.These events can lead to neuronal hyperexcitation

2.1.5 Others

In addition other pesticides are as triazine herbicides,ureic, hormonal, amides, nitro compounds,benzimidazoles, ftalamidas, bipyridyl compounds,ethylene dibromide, sulfur containing compounds, copperor mercury, among others.

2.2 Classification Based on Mode of Entry

The ways pesticides come in contact with or enter the target are called*modes of entry*. These include systemic, contact, stomach poisons, fumigants,and repellents.

2.2.1Systemic pesticides

Systemic pesticides are pesticides which are absorbed by plants or animalsand transfer to untreated tissues. Systemic herbicide moves through theplant and can reach to untreated areas of leaves, stems or roots. They arecapable in killing of weeds with partial spray coverage. They can effectivelypenetrate in the plant tissues and move through plant vascular system tokill specific pests. Some systemic insecticides are also applied and movethrough animals to control pests such as warble grubs, lice, or fleas. Themovement of pesticides in plant tissues may be unidirectional ormultidirectional. Some pesticides may only move in one direction either upor down within the plant while other pesticides may only move upwards inplants. If applied to the root zone, it will travel throughout the plant, but ifapplied to the leaves it will not move throughout the plant. Furthermore,few pesticides are considered locally systemic and move only to a shortdistance in a plant from the point of contact. Examples of systemic pesticidesinclude 2, 4-Dichlorophenoxyacetic acid (2, 4-D) and glyphosate.

2.2.2Non-systemic (Contact) pesticides

The non-systemic pesticides are also called contact pesticides as it acts ontarget pests when they come in contact. Pesticides must come into physicalcontact with the pest to be effective. The pesticide enters the body of pests*via* their epidermis upon contact and causes death by poisoning. Thesepesticides do not necessarily penetrate the plant tissues and consequentlynot transported through the plant vascular system. Examples of contactpesticides are paraquat and diquatdibromide.

2.2.3 Stomach poisoning and stomach toxicants

Stomach poisoning pesticide enters the pest's body through their mouthand digestive system and causes death by poisoning. Stomach poisons areacquired during feeding of pests, when they ingest the insecticide applied inthe leaves and other parts of the plant. Stomach toxicants may also enterthe body of insects through the mouth and digestive tract, where they areabsorbed into the insect's body. This is more appropriate especially in vectorcontrol including bacteria, or their toxins, applied to the water where filterfeedingmosquito or black fly larvae will consume the poison. Theseinsecticides kill the vector by destroying the midgut (or stomach) of thelarvae. Example: Malathion.

2.2.4 Fumigants

Fumigants are such pesticides which acts or may kill the target pests byproducing vapor. These pesticides form poisonous gases when applied. Thesepesticides in vapor form enter the body of pests *via* their tracheal system(respiratory) through spiracles and causes death by poisoning. Some of theiractive ingredients are liquids when packaged under high pressure but changeto gases when they are released. Other active ingredients are volatile liquidswhen enclosed in an ordinary container and are not formulated under pressure.Fumigants are used to remove stored product pests from fruits, vegetablesand grains. They are also very useful in controlling of pests in soil.

2.2.5 Repellents

Repellents do not kill but are distasteful enough to keep pests away from treatedareas/commodities. They also interfere with pest's ability to locate crop.

2.3 Classification based on types of pesticide formulation

Pesticide formulations are a mixture of the active ingredient (AI) and inertingredients. Active ingredients are chemicals that aimed to control targetpests, while inert ingredient (such as water, petroleum solvent, wettingagents, spreaders, stickers, extenders) are the materials added to the AI tomake pesticide safer, more effective and easier to measure, mix and apply. They are also more convenient in handling. One group of pesticide may bemixed with another group of non-pesticides or used in combination to producesuch pesticides. One group of pesticides is combined with another group ofpesticides in such a way that the effectiveness of one pesticide increasedand will provide better protection against one pesticide compound. Also,they are capable of controlling multiple pesticides in single dose of application.Pesticide formulations can be divided into three main types: solids, liquidsor gases. Some formulations are ready for use while others need furtherdilution with water or, a petroleum-based solvent, or air (as in air blast orULV applications) before they are applied. The most commonly usedformulations are listed under following headings:

2.3.1 Liquids

These formulations consist of concentrated oil solutions of technical gradepesticides combined with an emulsifier added to permit further mixing withwater. Emulsifiers are detergent-like materials that allow the suspensionof very small oil droplets in water to form an emulsion. Emulsifiableconcentrates are used with water dilutions widely to control vector.

2.3.2 Powders

These dispersible powders are finely ground. Dry powders consisting ofactive pesticide ingredients mixed with other ingredients to help in mixingand dispersion. They are of two types: - wettable and soluble powder. Wettablepowders are designed for mixture with a liquid, usually water, for applicationby spray equipment. They are generally mixed with water to form slurrybefore being added to the spray tank, where they require continual agitation.WPs can be used for most pest problems and in most spray equipment. Soluble powders are similar to wettable powders,except that the active ingredient, as well as the diluent and all formulatingingredients are completely soluble in water. Uses of soluble powders aresimilar to those of wettable powders.

2.3.3 Granules

Under this formulation, the active ingredient is mixed with various inertclays to form particles of various sizes. The size of granules used in vectorcontrol usually ranges from 20 to 80 mesh. Granular formulations areprepared for direct application and require specialized dispersal equipment.They can be applied from the air or on the ground. They may be used withsmall hand-cranked units, or simply scattered by hand (with appropriatepersonal protection). Granular applications of pesticides are especially usefulin treating mosquito larvae in locations where heavy vegetation wouldotherwise prevent the insecticide from reaching the water. They are alsofavored in situations where drift would otherwise be a problem.

2.3.4 Baits

Baits contain active ingredients that are mixed with a pest food or attractant.The main usages of baits include control of household pests such as ants,mice, rats, roaches, and flies. They are also used outdoors to control birds,ants, slugs, snails, and agricultural pests such as crickets and grasshoppers.

2.3.5 Dust

Dust pesticides formulations are finely ground mixtures of active ingredientand a carrier material. Dust formulations are intended for direct applicationwithout further mixing. Use of dusts are not suggested where drift is apotential problem. For this reason, herbicides are not formulated as dusts.In vector control, dusts are frequently used to control fleas and other ecoparasiteson pets. They are also applied to rodent burrows and bait stationsto control fleas in plague control operations.

2.3.6 Ultra low volume liquid

Ultra low volume concentrates (ULV) are sold as technical product in itsoriginal liquid form, or solid product dissolved in a small amount of solvent.These concentrates may approach 100% active ingredient. They are designedto be used as is or to be diluted with only small quantities of specifiedsolvents. These special-purpose formulations are used in agricultural,forestry, ornamental, and mosquito control programs. Larger droplets areconsidered inefficient, wasteful, and can have undesirable environmentaleffects. However,

ULV applications, when done correctly, are very effectiveand very safe to people and other non-target organisms.

2.4 Classification based on sources of origin

Pesticide is a chemical or biological substance that aims to destroy thepests or prevent the damage caused by pests. Based on sources of origin,pesticide may be classified into chemical pesticide and bio-pesticides. Themain benefits of using biological pesticides are host specificity. They act onthe target pest only and strongly linked organisms, whereas chemicalpesticides are usually of wide range which affects large group of non-targetorganisms. Bio-pesticides are usually environmentally friendly as they areless toxic, decomposed easily and required in small quantities. Chemical pesticides cause major environmental pollution as they are quite toxic andnot always biodegradable. Another important advantage of using bio-pesticideis the fact that they are less susceptible to genetic modification in plantpopulations. This confirms the little chance of pesticide resistance in pests,which is hardly seen in case of chemical pesticides. Chemical pesticides arefurther divided into organochlorine, organophosphate, carbamate andpyrethroids and are discussed already in previous section. Bio-pesticides group of pesticides derived from natural materials such as animal, plantand microorganism (bacteria, viruses, fungi, and nematodes). They are classified into three groups.

2.4.1 Microbial pesticides

The active ingredient in microbial pesticides is microorganism such asbacterium, fungus or protozoan. These pesticides kill insects either by toxinsreleased by microbial organisms, or by infection by the organisms. Twomost common pesticides that fit within this group include the bacterialtoxin produced by *Bacillus thuringiensis*(*Bti*), and the live bacteria, *Bacillussphaericus*(*Bs*). The mode of action generally is producing a protein thatbinds to the larval gut receptor which starves the larvae. These two bacterialtoxins are used against mosquito larvae and black fly larvae. Most microbialpesticides are more selective than biochemical pesticides.

2.4.2 Plant incorporated protectants

These groups of pesticides are produced by plants naturally. Also, the genenecessary for production of pesticide is introduced into the plant throughgenetic engineering. Hence, the pesticide then produced by such plant andthe genetic material introduced are together defined as plant incorporatedprotectants (PIPs).

2.4.3 Biochemical pesticides

The third class is Biochemical pesticides which include natural materialsthat have nontoxicmechanisms to control pests. Examples of Biochemicalpesticides are insect sex pheromones (act by interfering in mating), a rangeof aromatic plant extracts (work by attracting insect pests into traps).

2.5 Other Minor Classes of Pesticides

2.5.1 Classification based on mode of action

Based on mode of action, pesticides are classified as:

Physical poison

These classes of pesticides bring about killing of one insect by exerting aphysical effect. For example: Activated clay

Protoplasmic poison
These pesticides are responsible for precipitation of protein. Example ofthis pesticide is Arsenicals
Respiratory poison
Respiratory poisons are chemicals which inactivate respiratory enzymes.Example: Hydrogen cyanide

Nerve poison
Chemicals inhibit impulse conduction. Example: Malathion

Chitin inhibition
These classes of chemicals inhibit the chitin synthesis in pests. Example:Diflubenzuron

Unit 2: Methods of Applications of Fungicides
Content
1.0 Spraying and dusting
2.0 Soil treatment
3.0 Fumigation
4.0 Disinfection of warehouses
5.0 Seed treatment
6.0 Tree wound treatment
7.0 Post-harvest treatment
8.0 Spraying Techniques

1.0Spraying and dusting

Most important method of applying chemicals on the aerial plant parts which are exposed to different pathogens.Different chemicals particularly fungicides are sprayed either as protective, curative or post-symptom treatments.These chemicals provide a continuous covering on the vulnerable plant surfaces and do not allow the plant pathogens particularly fungi to invade them.They also eradicate the already established infections and reduce the secondary inoculum.Different equipments are available for high, low and ultra- low volume sprays in the field.Fungicides generally used as sprays are mancozeb, carbendazim, dodine, etc.Sulphur and copper fungicides can also be dusted on the crops for controlling some diseases under high humidity conditions.

2.0Soil treatment

Vegetables, ornamentals and trees are attacked by many pathogens which are present in the soil, like Fusarium and Verticillium and some bacteria.Different chemicals are used as soil drench, dust or granules inside the soil at the time of planting of the nursery or seedlings to control damping off, seedling blight, crown and root rot and many other soil borne diseases.These chemicals can also be applied with the irrigation water, wherever the irrigation is possible, especially with the drip irrigation system.Fungicides such as captan, metalaxyl, PCNB and chloroneb, etc. can be used as soil treatment to overcome above diseases.

3.0Fumigation

Most important method for controlling the nematodes and other soil borne diseases, and chemicals thus used are known as fumigants.Fumigants like formalin, chloropicrin, methyl-bromide, dazomet and metham sodium are now being used as fumigants in plant protection programmes.These chemicals are used as volatile or in gaseous form in the soil and are useful against various groups of organisms like nematodes, insects, fungi certain bacteria and weeds.

4.0Disinfection of warehouses

Stored products are the carrier of inoculum of many pathogens for the next season.These materials should be first treated with such chemicals before they are used for next planting season.The storage areas like rooms and the walls should also be bleached or treated with copper sulphate solution or some other sanitizing agents.

5.0Seed treatment

Seeds, tubers, bulbs and roots are usually treated with chemicals to prevent the pre- and post-emergence damping off of the young seedlings.These chemicals prevent the disease inoculum carried on the planting material.Since 1970's seed material is treated with the systemic fungicides to control and inactivate the pathogen in infected seed, e.g., carboxin for the control of loose smut of wheat, metalaxyl for the downy mildew of oats, etc.The fungicides used for seed treatment are chloroneb, captan, maneb, mancozeb, PCNB carboxin, benomyl, thiabendazole and triadimenol.Some are used for specific diseases and a few of them are used for controlling various type of diseases caused by fungi.They are applied directly on seed as dust or as thick water suspension mixed with the seed or tossed soaking with the chemical solution which is allowed to dry thereafter.

6.0Tree wound treatment

Fruit plants are often prone to cuts and wounds during the dormant period when they are pruned.The exposed portion of the plant is first sterilized by swabbing it with antiseptic solution of either sodium hypochlorite or ethyl alcohol.Finally, the entire wounded portion is painted with permanent tree wound dressing such as lanolin paste, Chaubattia paste or Bordeaux paste/ paint.

7.0Post-harvest treatment

There are number of fungicides evolved for the control of post-harvest diseases.Most of them are used as dilute solutions into which the fruits or vegetables are dipped before storage or as solution used for the washing of fruits and vegetables immediately after harvesting.Among the compounds used for commercial control of post-harvest diseases of fruits are borax, biphenyl, sodium o-phenylphanate and widely used fungicides benomyl, thiabendazole and imazalil.

8.0Spraying Techniques

Most of the pesticides are applied as sprays. The liquid formulations of pesticide either diluted (with water, oil) or directly are applied in small drops to the crop by different types of sprayers. Usually the EC formulations, wettable powder formulations are diluted suitably with water which is a common carrier of pesticides. In some cases however, oil is used as diluent or carrier of pesticides. The important factors for spray volume consideration are the volume of spray liquid required for certain area depends upon the spray type and coverage, total target area, size of spray droplet and number of spray droplets. It is obvious that if the spray droplets are coarse-size then the spray volume required will be larger than the small size spray droplets. Also if the thorough coverage (eg. both the sides of leaves) is necessary then the spray volume requirement has to be more.

On the basis of volume of spray-mix the technique of spraying is classified as:

1. High volume spraying
2. Low volume spraying
3. Ultra low volume spraying

The range of volume of spray mix in each of the above case is arbitrary. Usually for field crop spraying the following spray volume ranges are taken as guide.

High Volume Spraying 300 - 500 L/ha Low Volume Spraying 50 - 150 L/ha Ultra Low Volume Spraying < 5 L/ha

There is distinct advantage in the case of lower volume of application over the high volume application. The higher the volume to be applied the more the time, the more the labour and the more the cost of application due to labour cost. However the lower volume applications are concentrated spraying of pesticide which should also be considered properly.

Unit 3: Classification of Plant Protection Equipment
1.0 Sprayers (Hydraulic energy)
2.0 Sprayers (Gaseous energy)
3.0 Sprayers (Centrifugal energy)
4.0 Other Sprayers
5.0 Dusting Equipment
6.0 Granule Applicator

1.0Sprayers (Hydraulic energy)

Manually operated

1. Syringes, slide pump type)
2. Stirrup pumps mounted
3. Knap sack or shoulder-slung:
   - Lever operated K.S. sprayer
   - Piston pump type
   - Diaphragm pump type
4. Compression sprayer
   - Hand compression sprayer
   - Conventional type
   - Pressure retaining type
5. Stationary type
   - Foot operated sprayer
   - Rocker sprayer

Powered operated

1. High pressure sprayer (hand carried
2. High pressure trolley/ Barrow
3. Tractor mounted/ trailed sprayer
4. High pressure knap sack sprayer
5. Air craft, aerial spraying (Fixed wing, helicopter)

2.0 Sprayers (Gaseous energy)

Manually operated

1. Hand held type
2. Hand/ Stretcher carried type
3. Tractor mounted

Powered operated

1. Knap sack, motorized type

3.0Sprayers (Centrifugal energy)

1. Hand held battery operated ULV sprayer.
2. Knapsack motorized type
3. Tractor/ vehicle mounted ULV sprayer
4. Aircraft ULV sprayer

4.0 Other Sprayers

1. Aerosol sprayers
2. Liquefied-gas type dispensers
3. Fogging machines
4. Exhaust Nozzle Sprayer

5.0Dusting Equipment

Manually operated

1. Plunger duster
2. Bellow duster

Powered operated

1. Knapsack motorized duster
2. High pressure trolley/ Barrow mounted

3. Rotary duster:
• Belly mounted model
• Shoulder-slung model

3. Tractor mounted/trailed duster
4.Aircraft

6.0Granule Applicator

Manually operated

1. Broad-casting tins
2. Knapsack Rotary granule
3. Aircraft

Powered operated

1. Knapsack motorized type
2. Tractor mounted/ trailed duster

Unit 4: Spray Nozzles and Their Classification

1.0 Introduction

All types of sprayers generally speaking emit pesticide solution in very fine spray form. Spraying nozzle thus is a device for emitting spray liquid, breaking it up into small droplets and throwing the droplets away from the nozzle orifice. Different designs of nozzle are used to produce appropriate droplet size spectrum. In order to break the liquid into droplets energy is needed. The spray nozzles therefore are classified as:

Hydraulic energy nozzles Gaseous energy nozzles Centrifugal energy nozzles Thermal energy nozzles

Almost all sprayers used for high volume spraying methods are fitted with hydraulic nozzles. The knapsack type low volume sprayers are generally worked with air blast nozzle or gaseous energy nozzle. The hand held battery operated sprayers also called CDA sprayers are fitted with spinning disc type nozzle which works on centrifugal energy. Thermal energy nozzle also called hot tube nozzles are used with fogging machines for ULV applications. Recently electrical energy has also been used to produce charged spray droplets for ULV application of pesticides.

2.0Hydraulic Energy Nozzles

The hydraulic nozzles are most commonly used spray nozzles for pesticides application. Almost all the hydraulic sprayers use this type of nozzle. The following types of hydraulic nozzles are used for spraying pesticides:

1. Hollow cone type
2. Fan type
3. Impact type

2.1 Hollow cone nozzles:

This is a very popular type of hydraulic nozzle for spraying insecticides and fungicide. It produces a hollow cone pattern of spray consisting of mixture of different sizes droplets. In its simplest design this type of nozzle is made of brass metal having orifice hole drilled in it and a rotaral with tangential cut grooves provides swirl motion to spray liquid which breaks down into droplet when emerging from the nozzle under pressure. This simple brass nozzle is screwed onto a hand lance/ boom. There are different designs of hollow cone nozzle. Other designs of nozzles consist of a stainless steel disc with a central circular hole through which the spray emerges from a swirl chamber behind it. The disc and the swirl plate (core) are suitably fitted in the body of the nozzle which has threads for screwing (fitting) it to the lance/ boom. The normal working pressure of hollow cone nozzle is about 40 psi. Hollow

cone nozzles are good for treating complex targets because spray particles move in infinite angles and various planes providing better penetration of spray. These nozzles are generally not recommended for herbicide application due to possible drift of fine spray particles and difficulty in obtaining an even distribution of spray across the swath. The variation of liquid pressure can vary discharge rate, spray angle and also droplet size. The nozzles are made from brass, stainless steel and plastic materials. The nozzles tips wear due to chemical corrosion and abrasive action. The stainless steel tips or plastic tips are better wear resistant and help consistent spraying.

2.2 Fan nozzle

They are also called flat fan nozzles. The spray liquid is thrown from an orifice which is elliptical to give a flat shaped sheet of spray. These are used for band spraying. These nozzles are generally used on booms with proper distance in between and overlapping to give even distribution. The normal working pressure is about 40 psi. However these fan nozzles can also be used for herbicide application but the application is done at low pressure like 15 - 20 psi to avoid drift of fine droplets.

2.3 Impact nozzle

These nozzles are also known as deflector nozzles or flood jet nozzles. In these nozzles, the spray liquid emerging from a circular hole strikes an inclined smooth face and is deflected at an angle. The liquid thus spreads as a sheet in a wide angled fan pattern. These nozzles are used for herbicide spraying and are low pressure (15 - 25 psi). The spray pattern essentially consists of coarse droplets.

2.4 Adjustable nozzle

These are also called as triple action nozzle. They are so called because of varying patterns of sprays that can be obtained by manipulating the swirl velocity of spray liquid in the eddy chamber. The hollow cone spray pattern consisting of fine spray particles, or a jet spray for orchard/ tree spraying and a medium coarse spray patterns can be obtained by simple adjustments. These nozzles are generally used with foot operated sprayers, rocking sprayers or high pressure hydraulic sprayers for spraying trees.

3.0Gaseous Energy Nozzles

In this type of nozzle spray liquid is injected into a stream of high velocity air. The force of the air stretches the liquid to form ligaments which ultimately break into fine spray droplets. The airstream further transports the droplets to the target. The liquid flow into the airstream is metered. Motorized knapsack sprayer or mist blower is fitted with this type of air blast nozzle. The spray droplet size depends upon the nozzle design. The positioning of liquid flow and air velocity is very important. By increasing the liquid flow rate the droplet size also increases. In larger models of sprayer's hydraulic nozzle atomise the liquid first and then the droplets are further sheared by the air blast. Vertical nozzles also work on gaseous energy for ULV spraying.

4.0Centrifugal Energy Nozzles

If liquid is fed on fast rotating disc, then it is carried by centrifugal force to the outermost edges of the disc and spray droplets are issued. Rotating cylindering cage of fine mesh also produce fine spray if liquid is fed into it. The revolving speed of the disc or cage is very important for size of droplets. The disc has serrated teeth on the periphery which make droplet spectrum narrow. The physical properties of the spray liquid are important for droplet

size besides the speed of rotation. These types of nozzles are generally used for ULV spraying and for L.V spraying methods.

5.0Thermal Energy Nozzles

Fogging machines work with thermal energy nozzles, also called hot tube nozzles. Spray liquid is injected into stream of hot gases (exhaust of engine) where it vaporises due to high temperature but then it condenses when issued out of the nozzle due to outside temperature and forms fog of fine droplets. Exhaust nozzle sprayers (vehicle mounted) are used for ULV application in locust control operation. Pulse jet engine models are used for pesticide fogging for public health purposes.

Unit 5: Spraying Technique – I (High Volume Spraying)

1.0 Introduction
2.0 Slide Pump or Hand Sprayers
3.0 Stirrup Pump Sprayer
4.0 Compression Sprayer
5.0 Foot Operated Sprayer
6.0 Rocker Sprayer
7.0 Lever Operated Knapsack Sprayer
8.0 High Pressure Power Sprayer

1.0 Introduction

This is very common and popular method of pesticide spraying. The spray solution is prepared by mixing water with pesticide formulation in appropriate quantities. This diluted mixture is sprayed through hydraulic nozzles. The spraying is usually to the point of drip from foliage. In this method large volume of spray liquid is applied. Usually the spraying volume is 300-500 L/ha. The spray volume is not always rigid. The spray volume requirement depends on many factors eg. Sprayer capability, nozzle charecteristics, stage of growth of crop, type of crop etc. A variety of high volume sprayers are available in the market. Almost all types of high volume sprayers have some kind of pump to supply pressurised spray liquid to the hydraulic nozzle which breaks the liquid into spray droplets and throws the spray away from it. The high volume sprayers are both manually operated or power operated type.

2.0 Slide Pump or Hand Sprayers

This is a simple sprayer. It creates hydraulic pressure by forcing spray solution to a nozzle by the direct action of hand pumping. The spray solution is filled in a plastic can (5-10L) which is usually shoulder slung. A dip-tube draws liquid from the tank due to hand actuation of the plunger. Held by both the hands the piston pump is worked by sliding action. For want of a pressure chamber it is not possible to retain pressure and therefore the operator has to pump continuously without break. Due to constant engagement of both the hands it is difficult for the operator to ensure thorough coverage. Further due to pressure fluctuation the nozzle performance is not stable. The discharge rate varies, spray angle changes and spray droplets size fluctuates. This sprayer is suitable for small scale application in nursery or kitchen gardens etc. It is not a good sprayer for large area treatment. The capacity of this sprayer is about 0.5 acre per day.

3.0Stirrup Pump Sprayer

This is a simple hydraulic sprayer. It consists of hand operated hydraulic pump. The suction part of the pump is immersed in the spray solution kept on floor in a bucket. The pump is operated by hand by one person while the other person holding the delivery line, tigger cut-off device and lance nozzle sprays pesticide. In few models an air chamber is also provided in the pump system which helps continuous spraying. Also in some models provision of hydraulic agitation is made. This sprayer is used both for public health spraying and agricultural spraying purposes.

4.0Compression Sprayer

It comprises of a cylindrical metal tank for holding the spray liquid, a hand operated piston type air pump, a filler hole in the tank out let with delivery pipe, cut-off, lance and hydraulic nozzle. A pair of adjustable shoulder straps is provided for mounting the sprayer on the back of the operator. The sprayers with tanks of different capacities are manufactured, but 18 litre capacity sprayers are commonly used for field spraying. The filtered spray solution is filled to 2/3 of the tank capacity. Then the air pump is operated by hand and air pressure (50-60 psi) is built up. The compressed air exerts pressure to move spray liquid to the nozzle via delivery pipe, cut-off device & lance system. The spray design is strong and sturdy. It is also easy to operate. The operator need not pump continuously so that he can divert his attention to better coverage. However, as the pressure cannot remain constant due to gradual decrease of pressure, the nozzle discharge rate changes so also angle of spray and droplet size. This sprayer is not recommended for herbicide spraying due to high initial pressure. The field capacity is 0.75 - 1.0 acre/day.

5.0 Foot Operated Sprayer

The pump of the sprayer is worked by operating a pedal lever by the foot of the operator. It requires two persons to work. The spray liquid is kept in bucket or container and it is sucked by a suction hose through a filter (strainer) due to piston movement. A suitable ball valve is provided in the piston assembly to serve as suction valve. The liquid from the pump cylinder is then delivered into a pressure chamber where from the pressurized liquid reaches hydraulic nozzle. Minimum two person team is required to work on this machine. Hydraulic pressure of 10 kg/cm^2 can be achieved which is necessary to project the jet of spray to tall trees simultaneously from two spray nozzles. The foot operated sprayer is basically for orchard and tree spraying. The design is strong and sturdy. Hydraulic pressure of 10 kg/cm^2 can be achieved which is necessary to project the jet of spray to tall trees simultaneously from two spray nozzles. An adjustable type hydraulic nozzle (Triple Action Nozzle) is generally used which can generate different types of spray patterns viz., fine spray (hollow cone), medium spray and coarse spray (jet). The fine and medium spray are suited for low height orchards, jet spray are necessary for tree spraying. The spray jet can reach height of 15 - 20 feet. For spraying taller trees an extra extension like bamboo lance may be used to gain additional height by 8 - 10 feet. It is difficult to treat field crops by foot sprayers because the sprayer is kept on ground and pesticide solution tank is also kept on ground separately and so movement of the long delivery hose becomes very difficult.

6.0Rocker Sprayer

It is very much similar to the foot sprayer. The main difference is the operation of pump. The pump actuation is done by hand of the operator. The sprayer pump mounted on wooden platform is kept on ground and the spray solution is kept in a separate tank or container. It

can develop high pressure 10 kg/cm2. For spraying tall trees, an extension bamboo lance can be fitted. The adjustable type hydraulic nozzle (Triple Action Nozzle) is normally used.

7.0Lever Operated Knapsack Sprayer

It is commonly known as knapsack sprayer. The sprayer ismounded on the back of operator with help of a pair ofmounting straps. The pump of the sprayer is actuated byworking a hand lever up and down by one hand of theoperator and the other hand holds the cut off device forspraying purpose. This sprayer consists of liquid tank,hydraulic pump, operating lever, pressure chamber, agitator,delivery hose, spray lance and nozzle. A bean shaped plastictank of 14-16 liters capacity is commonly used. It isnecessary to operate the hand lever continuously at the rateof 15-20 strokes per minute. The normal working pressure is40 psi.

8.0High Pressure Power Sprayer

These are high capacity power operated hydraulic sprayers. They are the high volume spraying machinesgood for large scale application in orchards and tree crops.The source of power is engine or electrical motor. Apressure regulator is used to control the pressure in thedischarge lines and bye-pass from the pressure regulator isused for hydraulic agitation in spray tank. High pressurelike 400 psi can be built up and large spray discharge ratelike 30 L/min. can be obtained. The engine or electricalmotors 3 - 5 H.P capacity power the sprayer.

Unit 6: Spraying Technique – II (Low Volume Spraying)

1.0 Spraying Technique – II (Low Volume Spraying)

The high volume spraying is labour intensive and time consuming. In water scarcityarea it is difficult to practice high volume spraying. Also in situation where large areatreatment in very short time is important, the high volume spraying has limitations. The lowvolume spraying methods essentially reduce quantity of spray solution. Spraying as against300 to 500 L/ha in H.V. spraying technique is reduced to 50 to 150 L/ha in L.V. sprayingtechnique.

Motorised knapsack sprayer, also called Mist blower is a L.V. sprayer in whichgaseous energy nozzle is used for fine breakup of spray liquid. This type of nozzle is alsocalled Air blast nozzle. The force of escaping air at high velocity is utilised to shear down thespray liquid into fine spray droplets. The size of spray droplets depends upon:

1. Air velocity and volume
2. Liquid flow rate
3. Properties of spray liquid

The spray droplets are then blown away from the nozzle outlet. The blast of airdisperses the droplets over wide area and helps penetration of spray into the crop canopy. Thegyrating movement of droplets in the canopy improves the under leaf depositing of the sprayparticles. A two-stroke petrol engine (35 cc capacity) is used as prime mover to run a fanblower. The engine runs usually at 5000 - 6000 RPM and the blower emits at nozzle outletabout 5 m3 air per minute and at about 170 km/hr velocity.The spray droplets are about 150 - 220 micron VMD size. The nozzle flow rate can beadjusted by a regulator provided in the liquid line. The regulator can be a variable restrictortype or different size fixed aperture type. The later type is better because in the variablerestrictor type regulator, it is difficult to achieve exact repeat application rates. The flow rateup to 2 L/min can be obtained.

The horizontal reach of spray particles (swath) depends upon the type of crop canopy.Thick and high canopy restricts the droplets filtering down over wide area resulting in

smallerswaths. However 2 to 4 meter swaths can be achieved. To help ensure constant rate of flow ofliquid from the nozzle the spray tank is pressurised by allowing some air from the blower casevia suitable tubes. This tank pressurisation attachment helps vertical throw of spray to alimited extent only and therefore might not be sufficient to spray high orchards and trees. Fortrees spraying very large volume of air is necessary to carry spray all through the tree canopyand the two stroke 35 cc engine is not enough for this.While operating this sprayer the engine should be run at full throttle and the operatorshould take advantage of prevailing cross-wind for wider dispersal of the spray and also tokeep away the spray from himself. The spray nozzle should be held and aimed at rows whichare about one meter away from the the nozzle and the operator should try to create a littlefluttering of leaves to improve coverage. In a day 2 - 3 hectare area treatment is possible withthis machine. Since fine particles in concentrated form are sprayed out, the operator shouldwear adequate protective clothing and he should especially guard against inhalation hazards.The motorized knapsack sprayer can be converted into power duster also. Then it iscalled motorised knapsack sprayer- cum-duster. In most of the machines the spray tank itselfis used as dust hopper. In such a tank (dust hopper) suitable dust agitator attachment is fixedinside the hopper and dust-ejector tubes are fitted in the outlet of the discharge pipe. It isnecessary to avoid compaction of pesticide dust while filling it in the hopper. The rate of flowof the dust from hopper to the discharge tube is controlled by variable restrictor aperture. Insome models this is achieved by placing a butterfly type restrictor.

For improving the dust adhering and retention on foliage a useful modification onmotorised knapsack duster is suggested. It is called wet dusting attachment. In thismodification one small water container (1-2 L) is fitted additionally and a tube suitably isconnected to the spray nozzle. During operation, water is sprayed in a form of mist while thedust is also simultaneously discharged. The mist of water creats moistening of foliage and thewet dust sticks well for prolonged period of time. This saves wastage of pesticide and avoidsunnecessary drift.Another useful attachment is a long dusting hose. About 15 meter long thin polythenepipe with suitable perforations is attached to the dust discharge outlet of the machine and thusthe dust is emitted now from many holes (perforations) enabling very wide area treatment bypesticide dust.

Besides usual methods of maintenance of sprayer involving cleaning and lubrication,the engine in this equipment has to be properly looked after. The fuel petrol should be mixedwith lubricating oil in correct ratio before filling it in the fuel tank.The air cleaner should beserviced regularly. The spark plug should be cleaned to remove carbon deposition and itselectrode-gap should be checked and corrected whenever necessary. The engine must not beoperated beyond safe recommended speed. The two stroke engine in this type of sprayer is aircooled; therefore the engine cooling is important. The dust and mud if any on the engine mustbe removed. If the flow of air from the nozzle is not satisfactory, and then it may benecessary to clean the blower fan where dry leaves, cotton waste like materials cause thechoking.

For low volume spraying the aircrafts are also used to spray pesticides at 20 - 25 L/ha.Tractor mounted air carrier sprayers are also used for low volume spraying in orchard andtree spraying. For tall tree spraying like Rubber plantation a mist blower type system run by 3H.P engine and carried by two persons on stretcher poles is available, called turbo-sprayer.Motorized knapsack sprayer, also called Mist blower, isa L.V. sprayer in which gaseous energy nozzle is used forfine breakup of spray liquid. The force of escaping air athigh velocity is utilized to shear down the spray liquid into fine spray droplets.The spray droplets are then blown away from the nozzleoutlet. The blast of air disperses the droplets over widearea and helps penetration of spray into the crop canopy.The gyrating movement of droplets in the canopyimproves the under leaf depositing of the spray particles.

Unit 7: Spraying Technique - III (Ultra Low Volume Spraying Technique)

1.0 Spraying Technique - III (Ultra Low Volume Spraying Technique)

The ULV spraying is the method of pesticide application at minimum volume toachieve economic pest control. In this technique of pesticide application the volume appliedper hectare is less than 5 litres which is extremely low as compared to the conventional HighVolume and Low Volume spraying methods.The spray droplets in ULV spraying methods are very fine in size. Therefore, thenozzles used in these methods are different. Various designs of rotary atomiser are used togenerate droplets of 70 to 100 μ VMD. The vortex nozzles produce droplets in aerosol rangei.e. 20 μ VMD. For large area ULV spraying as in the case of locust control exhaust nozzlesprayer which is mounted on a vehicle is used where thermal energy of the engine exhaustgases is used to atomise the pesticide liquid in droplets of 20–50 μ. The thermal foggers usingpulse jet engines are used for indoor ULV application. The fogging machines are also used bypublic health personnel's for mosquito control.The rotary atomiser utilises centrifugal energy to break the pesticide liquid intodroplets. The range of spray droplet diameter produced by centrifugal nozzle is generallynarrow spectrum. Therefore, this method of ULV spraying with the help of centrifugalenergy nozzle is also called as Controlled Droplet Application (CDA).The movement of extremely fine spray droplets depends upon natural air movement.These small particles usually take long time to settle and very much influenced due toprevailing wind. The spray therefore is not direct type but it is drift spraying. Obviously forsmall field treatment the pesticide spray may be drifted to outside the target. Thus the drifthazard is always present in this technique of spraying.The spray droplets which are fine in size are also subjected to higher rate ofevaporation due to increased surface area. Therefore, pesticide spraying diluted with water isnot recommended for ULV technique. The rate of evaporation increases if the temperature ismore. Also the relative humidity influences evaporation. Due to evaporation the effectiveaqueous droplet size which actually reaches the target becomes smaller and thereforeconcentrated pesticide droplets are deposited. The extremely fine size droplets maycompletely evaporate before landing and can cause pollution. It is, therefore, recommendedto apply only special ULV formulation which is basically oil-bound and non-volatile. Someauthors have reported use of sugar or mollases solution with the EC formulation to reduce theevaporation losses.

A hand held battery operated model of ULV sprayer is very simple and convenient.This sprayer consists of a spray head which includes an electric motor with a spraying discand liquid container mounted on the spray head, a holding stick, source of battery power andoff- on switch. The electrical motor is a 6 V or 12 V DC motor. The motor drives a directlyfitted spinning disc usually plastic 2" to 3" diameter revolving at 6000 - 10000 RPM. Thespinning disc is very light weight plastic disc flat or cup shaped having fine serrations cut onits periphery. In certain designs fine feeder channels are also provided on the disc such thatthe liquid is fed uniformly through these channels to the disc serrations. The pointed edge atthe disc periphery serves as zero issue point so that uniform size spray droplets are releasedfrom the disc. The pesticide container is usually one litre capacity plastic bottle which isscrewed on the spray head. The flow of pesticide from the container is simply due to gravityand depends upon the size of opening provided in the spray head. However, in certain modelsthe rate of flow of liquid can be changed by replaceable orifice plates of different diameter orby changing liquid flow tubes of different size opening. The dry cells (4 or 8 Numbers) orrechargeable storage battery supply 6 V or 12 V DC power to run the electric motor whichrotates the plastic disc. The chemical moves by gravity to the spinning disc and due

tocentrifugal energy the liquid is broken into very fine spray droplets.The rate of flow ofchemical liquid is from 50 to 100 ml/min.
The transportation of fine droplets to the target is achieved due to prevailing wind.The spray droplets are distributed over wide swaths. The effective swath width depends uponthe wind velocity and crop growth(The higher the wind velocity, wider the swath of spray)Theswath of 2 m to 10 m is reported at different stages of crop growth. Since the total weight ofthe machine is very less (about 2 kg) the operator can walk swiftly achieving 1 m/sec speed.Therefore, the time required to treat crop area is very less as compared to high volume or lowvolume methods. One operator can treat 3-4 hectare area in one day with this type of sprayer.Due to pesticide drift hazard and concentrated form of spraying the operator must becareful. The operator must always avoid wind moving the pesticide spray on to him. Theoperator should always walk across the prevailing wind direction so that the spray isalways moving away from his body. He should also wear protective clothing like nose andmouth respirator, hand gloves and full length trousers and shirts. The ULV spraying shouldbe avoided in still-wind conditions as the distribution of pesticide is very much reduced andspray particles might drift on to the operator himself. Similarly application should not bemade when the wind velocity is more than 12 km/hr. This spraying is better done in windvelocity between 3-10 km/hr
The ULV spraying is good in dry land areas where water is scare and thereforeconventional high volume spraying is not feasible. This technique is also called waterlessspraying due to special ULV formulations. But as the ULV formulations are not available, theadvantage of this method is not being availed at present.The speed of rotation of the disc depends upon the battery condition. The run-down orused up battery are of no use as they cannot run the electric motor at proper speed. The spraydroplets size tends to become large if the rotational speed of the disc is reduced. The speedshould not come below 4000 RPM otherwise the droplet size shall increase drastically whichwill affect the coverage and swath width. A set of battery can last for 8-10 hours of sprayingtime. But the life of battery really depends upon the
quality of electric motor. Some electricmotors consume more power and hence less battery life. Usually these electric motorsconsume 3 - 8 W of power. If rechargeable battery is used to run the motors then it should bekept fully charged.

Unit 8: Electrostatic Spraying
1.0 Introduction
2.0 Advantages of Electrodyne Spraying
3.0 Limitations of Electrodyne Sprayer

1.0Introduction
The conventional high volume spraying is labour intensive and time consumingprocess. The hydraulic nozzles produce wide spectrum of spray droplets and more than 40 -60% of sprayed pesticide does not really deposit on the foliage. Neither the very small dropsnor very big drops are useful due to drift and run off problems. The Controlled DropletApplication (CDA) method improves pesticide deposits and lower application volumes ofless than 5 L/ha can be achieved. The ULV application method has serious problem ofpesticide drift too.
The electrostatic spraying system reduces the application volume substantially andgreatly improves pesticide deposits. The liquid atomisation is achieved by utilizingelectrostatic forces. The spray particles of about 50 μm size having high electrostatic chargeare issued from the nozzle. It is reported that the depositing increases by three times, or more.This system has great potential.By imparting electrostatic charge to spray droplets of hydraulic

nozzles and spinningdisc nozzles also depositing improves much. There are following three systems ofelectrostatic charging of sprays:

1. Corona charging
2. Contact charging
3. Induction charging

A high voltage pointed electrode issues ions of similar polarity to the liquid dropletswhich become electrically charged. The sprays from hydraulic nozzle and rotary nozzle canbe charged by these methods. The electrostatic application of paints industrially is also basedon Corona charging.In Contact charging system the high voltage potential is directly connected to thenozzle or to the spray liquid system. The electrical charge transfer occurs by conduction tospray liquid and finally to the spray droplets during disintegration. This system works wellwith the conductive liquids. The total system needs very good insulation.In the Induction charging system the electrical field force is used to charge the spraydroplets. This system needs good insulation between the conductive liquid and the chargingelectrodes.
The Electrodyne sprayer (developed by ICI) is good for electrostatic charged sprayingof pesticides. A high potential of 13 to 24 KV is applied to the spray head having pesticidebottle and electrodyn nozzle combination (called BOZZLE) resulting in dis-integration ofspray in very fine charged droplets of 30-50 μm size. The application volume is drasticallyreduced to 0.5 to 1.0 L/ha besides much improved deposition of pesticide. The chargeddroplets leaving the nozzle repel each other owing to similar charge and thereby formingspray cloud. These charged droplets are readily deposited to foliage being earthed object.The power requirement is met by 6 V DC (4 torch cells) sources which are multipliedto 24 KV by a solid state electronic generator. The power consumption is very low. Thecollection of spray is so efficient that penetration into the canopy can be poor. The nozzle isheld 40-50 cm above the crop canopy. Because of good depositing properties, the drift ofpesticide is very minimum, so also the wastage.

2.0 Advantages of Electrodyne Spraying

1. Better deposit of pesticide
2. Minimum drift losses/wastage
3. Low power consumption
4. Narrow spectrum of droplet size
5. Labour and time saving
6. Minimum volume per hectare

3.0 Limitations of Electrodyne Sprayer

1. Top few leaves are deposited heavily but not the lower leaves.
2. Good for broad leaf crops and not so efficient for narrow-leaf crops like paddy.
3. Special Electrodyne formulations are suitable.
4. Electrodyne formulations of various Pesticides are not available.

Unit 9 Dusters and Dust Applications

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2.1 Plunger Duster:
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5.0 Precautions
6.0Maintenance

1.0Introduction

The dusting powders are low concentration ready to use type, dry formulationscontaining 2 to 10% pesticide. The inert material or dry diluents is talc, soapstone,attapulgite, etc., and it is non-toxic. The sulphur dust is not diluted with inert material.The advantages of pesticide dusting application are:

1. Ready to use product reduces field tasks concentrate handling and further dilution (asin case of spraying)
2. In dry land agriculture where water is scare.

But the important disadvantage is pesticide drift. The fine dust particle cause seriousdrift problems and the operator and field labourer are exposed to dermal and inhalationhazards, besides pesticide being carried to neighbouring field/area and causing pollution. Thisis the main reason why the herbicides are not formulated as Dusting Powders. Precisemetering and even distribution of dusting powders in field conditions is very difficult.The dusts are applied at 20 - 50 kg/ha. It should be noted that the application is donein highly concentrated form, as compared to high volume or low volume spraying technique.Therefore, adequate precautions must be taken in handling the dust and during the applicationin field. The dusters are available both manually operated and power operated models.

2.0Manually Operated Dusters

2.1 Plunger Duster

They are very simple, low cost machines and useful in a limited way. The fieldapplication capacity is low. They hold 200 to 400 g of dust in a chamber into which air ispushed by an adjoining piston type air pump operated by hand. The dust cloud is issued fromthe discharge outlet.

2.2Bellows Type Duster

This is also a simple design low cost dusting machine. A collapsible bellows pushesair into a dust hopper of 1-2 kg capacity and dust is discharged from the nozzle outlet.

2.3Hand Shake Duster

This too is low cost very simple equipment which can be locally made by villageartesian. It is

particularly good for spot application of dust in rice crop.These dusters are good for small scale application and spot treatment and they do not causemuch drift problems, metering lacks in these equipment.

2.4Hand Rotary Duster

This type of duster makes use of a fan or blower to flow large volume of air at highspeed. The dust powder is fed into the stream of air and blown from the outlet tube. The fanor blower rotates at high speed by hand cranking handle, which is geared to it. The highergear-ratio and better blower design provide easy cranking and good volume of air is emitted.The dust hoppers are generally cylindrical and are provided with agitator, feeders and dustmetering mechanism.Such rotary dusters are either shoulder slung type or belly mounted type. Theshoulder-slung models are better balanced when the dust hoppers are filled. But it becomesinconvenient to operate in crops like sugarcane and cotton. The belly mounted type can beused in such situations. A hand rotary duster can discharge dust powder from 0 – 150 g/minand displace air about one m^3/min at 35 RPM. Such machine can treat 1 to 1.5 ha /day.

3.0Power Duster

These are bigger machines run with the help of engine or electrical motor. Somepower dusters are tractor mounted type and are driven by tractor. The equipment ismounted on iron frame (stretcher) and can be carried by 2-3 men. The engine/motor drives acentrifugal fan usually via V-belt drive. The engine is petrol/ diesel run and 3 - 5 H.P and thefan displaces 20 m3 air/min or more at 100-250 km/hr air velocity. These dusters are good forlarge area treatment and suitable for application on tall trees. In this type of duster design,usually the dust powder is not rotated in the fan-case but dust powder is aspirated in thedelivery channel by air blast. The dust hopper capacity is 10-20 kg and dust can bedischarged at a rate of 1 to 8 kg/min. A power duster can cover about 10 ha/day.

4.0 Knapsack Duster

The motorised knapsack sprayer can be converted to a duster by replacing someplastic fittings inside the hopper. Almost all mist blowers have provision of converting themfrom spraying unit to dusting unit. The two stroke petrol engine runs a blower fan anddelivers the air through a hose pipe system. The dust is agitated and lifted by the blast of airin the hopper and it is fed into the main air hose or a long dusting hose (40-50 ft longpolythene perforated hose) can also be attached to knapsack duster. Such an attachment isvery good for large area treatment in less time. The dust output can be adjusted from 0 to 1.5kg/min. The motorised knapsack sprayer-cum-duster unit is therefore useful for both lowvolume spraying and dusting operation.

5.0Precautions

The dusting powers are very finely divided particles which can remain air-borne forlong time and can drift far distances. The fine particles can very easily enter into body systemby inhalation. Therefore, the operator should wear protective clothing. He must cover hisnose and mouth in order to avoid inhalation of pesticide drift. The operator should neveroperate against the wind direction. Also if the wind velocity is more or wind turbulence exists, the dusting application should not be done. It is better to apply the dust power in earlymorning hours and in late evening hours, avoiding the mid-day and afternoons.

6.0Maintenance

The dry and well sieved dust power should be loose filled in hopper. It should not behand

compacted. The dust powders often absorb atmospheric moisture and clods are formed,such clods should be crushed before filling into the hopper. After the completion of the workthe dust powder should be removed from the hopper carefully. The dust materials which stillremain in the hopper, feeders, discharge tube should also be removed by briskly cranking andblowing action. Finally, a dry brush should be used to dust off from inside the hopper, etc.The lubricating oil should be applied on moving parts e.g., gearbox, crank handle, agitator,fan bearing, etc.

Unit 10: Calibration of Sprayer

1.0 Calibration of Sprayers
2.0 Some worked examples

1.0 Calibration of Sprayer

The rate of application of pesticide should be uniform over the whole of the field area.Too much application as well as too less application of pesticide dose is both undesirable.

Too much application - Wastage, crop injury, uneconomical
Too less application - Poor pest control, wastage of pesticide, time and money

The pesticide distribution by any sprayer is regulated by:
1. Nozzle spray discharge rate
2. Swath width
3. Walking speed of operator

Some equipment manufacturers provide tables about use and capacity of theirequipment. But it is difficult to always fully relay on such tables. As the sprayer gets old thepump and the nozzle also wear out. The performance of sprayer then changes and rate ofapplication becomes different. The calibration of sprayer, therefore, is essential to make surethat the pesticide is applied correctly and evenly. The sprayer should be checked andcalibrated frequently.There are many methods described for calibration of sprayer. The sprayer can becalibrated theoretically and practically in the field. It is good to frequently verify thecorrectness of theoretical calibration with field practical calibration.

A very simple and easy to remember formula is

$$F = \frac{SDA}{10000}$$

Where F - flow rate in L/min (This represents flow rate from all the nozzles of sprayer if theyare more than one. But if there is only one nozzle, then flow rate from one nozzle only) S - Swath width in meter
D - Operator's walking speed in m/min
A - Application rate in L/ha

The above formula is useful for calibration of any type of field spraying system i.e.high volume, low volume, ultra-low volume, tractor mounted sprayer or aerial spraying. Ifany three variables in this formula are known, the value of the remaining fourth variable canbe found out.

2.0 Some Worked Examples

I. A knapsack sprayer discharges 600ml liquid every minute and sprays one meterswath. If the operator walking speed is 30 m/min., what is the rate of application inL/ha?
F = 0.6 L/min; S = 1 meter; D = 30 m/min A = ?

$$F = \frac{SDA}{10000}$$

$$A = \frac{Fx10000}{S\ D}$$

$$= \frac{0.6 \times 10000}{1 \times 30}$$

= 200 L/ha

II. A motorized knapsack sprayer is to be used for spraying at 100 L/ha. The dischargerate from the nozzle is 1.2 L/min and the operator walking speed is 30 m/min. Findout the swath width.

F = 1.2 L/min; S = meters?; D = 30 m/min; A = 100 L/min.

$$S = \frac{F \times 10000}{A \; D}$$

$$= \frac{1.2 \times 10000}{100 \times 30}$$

= 4 meters

III. A battery operated ULV sprayer has to spray at 10 L/ha. If the operator walks 1 m/secand the swath width assessed is 3 meters, find out the flow rate of the sprayer?

F = ? L/min; S = 3 meters; D = 60 m/min; A = 10 L/ha

$$F = \frac{SDA}{10000}$$

$$= \frac{3 \times 60 \times 10}{10000}$$

= 0.18 L/min or 180 ml/min

The nozzle discharge rate, swath width and the walking speed of the operator can befound out without much difficulty and thus the application rate in L/ha can also betheoretically calculated. This way of calibration will help in planning for quantity of waterrequired, mixing tank/buckets, time required, etc. But it is further necessary to let the operatoractually spray a part of the field and calculate the rate of application. This will be morerealistic as the operator will have to work in the field conditions.

For this practical field calibration a small area is demarked, say 100 m2 (10 x 10 m).The sprayer is filled with a known volume of water, say 5 litres. Then the operator sprays thisarea uniformly and evenly. Afterwards the quantity of water still remaining in the sprayer ismeasured by a jar, say it is 2 litres. The quantity of water sprayed can be found out. In thiscase 5-2 = 3 litres sprayed in 100 sq meters. For one hectare or 10,000 sq meters, volumeneeded is 300 litres. This is the practical way of calibration and is very reliable. Before takingup spraying this procedure should be followed.

For very large area spraying the theoretical calibration and practical sprayingcalibration both should be done, as in the case of tractor mounted sprayer or aerial sprayer.But for small area treatment the field practical calibration method is enough and satisfactory.The pesticides are

generally diluted before field application. For high volumespraying or low volume spraying the pesticide formulation is diluted with water. Thepesticide dust formulations are ready to use type as they are already diluted with inertmaterial like talc to a low concentration eg. 2D, 5D, 10D. Similarly pesticide granuleformulations are also 5G, 10G concentrations.

The pesticide application recommendations are usually in terms of active ingredient(a.i) or % concentration (0.1%, 0.05% concentration) and sometimes in parts per million (100ppm, 200 ppm). It is essential that the pesticide is applied in exact quantity as perrecommendation.

After calibration of the sprayer the next stage is making spray mix. How muchquantity of the formulation should be mixed with water? There are different formulae for thiscalculation. However it is calculated very easily by simple steps.

Few Examples

1) Insecticide ABC 35 EC is recommended for spraying at 0.07% concentration solution. How much formulation is required to be added to water to spray one hectare area with100 liters water?

1% is 1 part in 100 parts
0.1% is 1 part in 1000 parts
0.01% is 1 part in 10000 parts
0.07% is 7 parts in 10000 parts, or 7ml in 10000 ml (10 L) So 70 ml (a.i) in 100 L
As 35 EC is 35 ml a.i in 100 ml formulations

So, 70 ml a.i will be in $\frac{100 \times 70}{35}$ = 200 ml formulation.

2) A fungicide xy 50 WP is recommended for spraying at 200 ppm. How much of WPformulation is required to mix to treat 1.5 ha area at 400 L/ha?

Quantity of solution required for treating 1.5 ha @ 400 L/ha = 400 x 1.5= 600 L

In terms of ppm means parts per million,
200 ppm means

1000000 parts of solution contain 200 parts (a.i)
So, 600000 ml (600lits.) should contain 200 x 6 = 120 ml a.i

50 W.P is 50 gma.i in a 100 gm formulation
So, 120 gma.i will be available in 240 g formulation.

3) 2D abc dust formulation has to be applied to 0.75 ha at 300 g a.i per ha. How much ofdust formulation should be applied?

a.i. to be applied in 0.75 ha. = 300 x 0.75 gm. = 225 g
2D formulation has 2 parts a.i in 100 parts of formulation

So 225 g a.i will be there in $\frac{100 \times 225 \text{ g}}{2}$ Formulation = 11.250kg

The mixing of pesticide should be done very carefully. It involves handling ofconcentrated formulations. It is good to wear hand gloves while opening pesticide container,pouring/measuring the formulation and stirring the solution. If the concentrated

formulationspills on hand or other body parts, it should be washed off thoroughly with water immediately.The measurement of small quantity of formulation should be done with the help of measuringcylinder. The mixture should be stirred with a long stick and never by hand.For preparing spray mix with wettable powder, first prepare a paste of requiredquantity of wettable powder with small quantity of water and subsequently add this paste tothe desired quantity of water and stir well. To help uninterrupted spraying always use cleanwater and use filter when filling solution into spray tank.The spray solution should not be prepared more than what can be sprayed during theday. The pesticide effect of dilute solutions becomes less if solution is left overnight.

Tutor Marked Assignment

1.Classifypesticides based on Chemical Structure and discuss any two (2)

2. Classify pesticides based on Mode of Entry and write short notes on any three (3) listed.

3.Write short notes on the classification of pesticides based on their sources of origin.

4. Differentiate the following sprayers; Hydraulic energy, Gaseous energy and Centrifugal energy.

5. List and write short notes of the methods of fungicide application.

6. Write short notes on the following;

a. Hollow cone nozzles b. Fan nozzle

c. Impact nozzle

d. Adjustable nozzle

7. Discuss any two of the following nozzle types. a. Gaseous Energy Nozzles

b. Centrifugal Energy Nozzles c. Thermal Energy Nozzles

8. Discuss the operation of a lever operated knapsack sprayer

9. What are the advantages and limitations of ElectrodyneSpraying

10. a. List the four types of manually operated crop dusters and discuss any one. b. List the precautions to be taken in using dusters.

c. Enumerate the maintenance measures to be observed in duster management.

11. Describe the calibration of sprayers.

12. A knapsack sprayer discharges 750 ml liquid every minute and sprays one meterswath. If the operator walking speed is 25 m/min., what is the rate of application inL/ha?

13. A motorized knapsack sprayer is to be used for spraying at 90 L/ha. The discharge rate from the nozzle is 1.3 L/min and the operator walking speed is 33 m/min. Findout the swath width.

14. A battery operated ULV sprayer has to spray at 20 L/ha. If the operator walks 5 m/secand the swath width assessed is 2.3 meters, find out the flow rate of the sprayer?

15. Dimethoate 35 EC is recommended for spraying at 0.05% concentration solution.
How much formulation is required to be added to water to spray one hectare area with100 liters water?

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MODULE 5 EQUIPMENT MAINTENANCE AND REPAIR; STORAGE OF PESTICIDES.

Unit 1 Care and Maintenance of Plant Protection (PP) Equipment
Unit 2: Standardisation and Testing Methods of Plant Protection Equipment
Unit 3: Problems of maintenance and repairs of plant protection Equipment
Unit 4: Pesticide Storage and Handling

Unit 1: Care and Maintenance of Plant Protection (PPEquipment

Content

1.0 Care and Maintenance of Plant Protection (PP) Equipment
1.1 General Maintenance
1.2 Care and Upkeep of Hand Sprayer and Duster
1.3 Care and Upkeep of Power Sprayers and Dusters
1.4 Care and Upkeep of PP Equipment when not in use
1.5 Care and Upkeep of PP Equipment when taken to field
1.6 Care and upkeep of PP equipment in transportation

1.0 Care and Maintenance of Plant Protection (PP) Equipment

1.1 General Maintenance

1) Clean outer surface with brush or cotton waste by using kerosene oil or plenty ofwater.
2) Oil the moving or rubbing surfaces of parts with lubricating oil (SAE 30) or grease, ifneeded.
3) Filter or strain the chemical solution/ fuel oil mixture while pouring into the tanks. Make the caps or lids leak-proof with gaskets.
4) Flush the equipment with clean water to wash inside parts of containers, tubes andnozzles to be free from chemicals.

1.2 Care and Upkeep of Hand Sprayer and Duster

1. Dry and sieved dust should be used for dusters.
2. Grease the duster gear box once in a month.
3. Clean the duster after the work by removing all dust from the hopper.
4. Oil the cup washers and bucket washers of sprayer frequently.
5. Spray tank discharge lines and nozzles should be flushed with clean water after theday's work.
6. Lances and nozzles should not keep on the ground. Nozzle parts should be cleaned with a brush.

1.3 Care and Upkeep of Power Sprayers and Dusters

1. Lubricating oil level should be checked and maintained in four stroke engines daily.
2. Mixture of engine oil and petrol in correct proportions should be used for two strokeengines, duly stirred and strained.
3. Clean the Air and Fuel filters with petrol frequently.
4. All the nuts and bolts should be tightened once in a week.

5. Check up the pressure gauges and safety valves frequently.
6. Drain the fuel tank after the day's work.
7. Stop two stroke engines by closing the petrol cock.
8. Belts should be kept tightened always, to be free from slip and slackness.
9. Keep proper inflated pressure in the tyre wheels of power sprayers.
10. Rubber tyre equipment should be rested on steel props when stationed.
11. Rubber hoses should not be bent at angles and dragged on the ground.
12. Equipment should be stored in clean, dry, cool store room.

1.4 Care and Upkeep of PP Equipment when not in use

1. Plant Protection Equipment's should be arranged properly in a store house. Theyshould be protected from sunlight.
2. Equipment of one category should be kept at one place and not in a mixed up fashion i.e., do not dump the equipment.
3. Attachment like discharge lines, lances, and nozzles should not be kept attached to theequipment.
4. The equipment should be cleaned with cotton waste every day and polished once in amonth.
5. The rubber/ plastic delivery hose should be coiled forming a big circle instead ofsmall spool. Otherwise the hose pipes break or crack when they are straightened.
6. All nozzles should be kept neat and clean separately.
7. The moving parts and washers are to be oiled or greased well once in a week.
8. The equipment should be tested for its normal performance once a week. Even theengines should be run for a short while.
9. The equipment in store should be classified and labelled to indicate its conditions as:
i) Working condition
ii) Needs servicing & repairs iii) Needs parts & repairs
iv) Not serviceable
10. Rubber tires should be inflated regularly or they should be jacked and propped.

1.5Care and Upkeep of PP Equipment when taken to field

1. Always carry tools required for attending to field troubles.
2. Carry some spares like washers, filters, gaskets & pins to the field.
3. Carry small quantity of kerosene, petrol, engine oil, grease, cotton waste, andcontainers.
4. Carry the Plant Protection Equipment properly and carefully.
5. Do not drop the equipment or attachments on the ground.
6. Clean the equipment before and after work is over.
7. Flush the equipment with clean water, after work is over.
8. Oil the moving parts and apply grease on gears and in grease cups.
9. Filter the chemical liquids and fuel oil mixtures before filling.

1.6 Care and upkeep of PP equipment in transportation

1. All knapsack equipment should be carried on operator's back, for short distances.
2. All the rubber tiered equipment's should be pulled on roads with full inflation inthe tier.
3. For longer distances, the equipment should be packed in a crate or box. Theaccessories should be dismantled and packed separately before placing in the box/crate.
4. Secure literature like parts catalogue, servicing manuals and special tools etc., forthe equipment and keep them handy for ready reference.

Unit 2: Standardisation and Testing Methods of Plant Protection Equipment

Content

1.0 Standardisation and Testing Methods of Plant ProtectionEquipment

The object of proper pesticide application cannot be achieved without good qualityPlant Protection Equipment. A well designed machine shall be efficient as far as pesticidedistribution and delivery to the target in minimum time with minimum wastages is concerned.

Therefore, the machines should be tested to ascertain that they are:

- Efficient
- Reliable
- Long lasting
- Comfortable to operate
- Minimum field problems

The machines should meet certain minimum requirements of performance, efficiencyand reliability. For this it is essential that standard specifications are laid down so that it willhave the above said qualities. The equipment standard specification parameters are:
Material of construction
Dimensions Ergonomics Stability Safety
Interchangeability Performance Strength, Reliability
Workmanship, Finishing
Besides the equipment, the components of the system should be standardized and tested such as: Nozzles, Cut- off devices, Lances etc.

Some important aspects of the specifications and testing methods are as under:

1.1 Compression sprayer

The routine specifications of material of construction, dimensions, workmanship areincluded. As the tank of the sprayers is subjected to high pressure, a tank fatigue test isrecommended. The spray tank is pressurized by hydraulic force and depressurized. Suchcycles of pressurization are imposed on the tank during which it should not leak.Similarly the impact strength of the sprayer is tested by dropping the filled andpressurized sprayer from a given height in different positions. Also the straps are testedfor supporting the weight of the sprayer when it falls from a certain height.

1.2 Knapsack sprayer

Besides the material of construction, dimensions, capacity, other aspects of performanceare specified. The volumetric efficiency of the pump should be above 80%, the ratiobetween the pump volume per stroke and the pressure chamber volume should beminimum 1:8. The

operating lever movement for full pump stroke should not be morethan 350 for each movement i.e. upward and downward. The pump discharge rate at16±1 stroke per minute at 40 psi pressure should be minimum 500 ml/min. Thereliability test for 48 hours continuous working of the sprayer is also recommended.

1.3 Foot sprayer & Rocking sprayer

The specifications in respect of material of construction, dimension, workmanship andfinishing are standardized. The volumetric efficiency of the pump should be minimum80%. Other parameters like discharge rate test, ratio of volume and pressure chambervolume, leakage test etc., are considered. The reliability test of 48 hours of continuousworking of the sprayer is recommended.

1.4 Motorized sprayer

The spraying systems except the engines are covered in the specifications. The usualspecification of material, dimension, capacity, discharge rate is standardized. The airdelivery volume and velocity of air at nozzle are also specified. The reliability test andfuel consumption test are recommended.

1.5 Hydraulic nozzle & Spray lance

The spray discharge rate and other physical parameters viz. spray angle and spraydistribution pattern are specified. The nozzle tip abrasion test is also recommended toascertain the reliability of performance of hydraulic nozzles.

1.6 Cut -off device

The reliability test of cut-off device for 5000 cycles of operation spraying with fine silicapowder (abrasive) is recommended. The test for measurement of effort to actuate thelever of the trigger is also specified.

Unit 3: Problems of maintenance and repairs of plant protection Equipment

Content

1.0 Problems of maintenance and repairs of plant protectionEquipment

Plant protection machines in general are not well maintained regularly either indepots where they are stored or in the field where they are used. Life of a machinedepends entirely on its care and maintenance. Even though machines are made with highstandards of skill and workmanship, they can easily be ruined due to improper care andmaintenance. Good and constant performance from machines can be obtained only when theyare used and serviced periodically. The purpose of maintaining a machine is for increasingthe useful life of the machine and to be available in working order whenever put to use. Themaintenance of a machine involves proper care, operation, servicing, repair and keeping it ingood working order.

1.1 Maintenance

Normal maintenance jobs include cleaning the equipment and applying necessarylubricating

oils and greases to the rubbing and moving parts. If this normal maintenance isneglected the machine gets rusted and moving parts wear out quickly resulting in loss ofefficiency, frequent replacement of spare parts and finally uneconomical working.Besides the normal maintenance as above, special care has to be taken for maintainingthe plant protection equipment. The pesticide formulations are chemically aggressive onmetals, etc. The cleaning and washing of the chemical tank, discharge lines, nozzles, etc., areto be done regularly after the day's spraying work is completed otherwise the residues ofchemicals used for spraying acts on the parts and causes corrosion and deterioration ofmaterials.If this aspect of thorough cleaning is not done on the plant protection machine, eventhough it is made of with high standard materials, it will not serve its normal life and wouldlead to premature condemnation.

1.2 Maintenance job for hand operated equipment

1. Cleaning the chemical tanks, hoses, valves and nozzles etc. and flushing sufficientlyto
   avoid pesticide residue which is corrosive.
2. Cleaning the machine equally well from outside also as it is contaminated due toleakage, spilling of pesticide.
3. Lubricating suitably the pump parts like piston, cylinder, valves and other rotating,sliding, moving parts.
4. Store the machine in dry place duly protected from sun and rain.

1.3 Maintenance job for power operated equipment

All the above maintenance jobs apply to power equipment also. But the engines haveto be taken care of specially. The life and efficiency of the engine mostly depends uponproper maintenance. For their running all engines need fuel, air and proper system of ignition.Thus in petrol engine, clean petrol, clean air and healthy ignition (spark plug & magnets) areessential. Besides those, the engine need perfect lubrication, too. In two stroke petrol engine,care must be taken to mix lubricating oil and petrol in exact ratio as recommended by enginemanufacturer. Similarly in four stroke petrol engine the lubricating oil should be kept insufficient quantity by observing the level gauge. The air cleaner should be cleanedoccasionally. The spark plugs should be also cleaned, carbon removed and proper electrodegap should be maintained. The 2-stroke petrol engines used in low volume spraying shouldinvariably be in good order otherwise the pesticide spraying will not be efficient.Sufficient care should be taken at the depots to clean, oil and check equipmentperiodically when they are stored, and whenever machines are sent out to work, and whenreturned from field work. This minimum care to inspect the equipment, clean and flush andkeep it duly oiled, would go a long way in improving the availability of good workingsprayers and dusters and also prolonging their useful life.

1.4 Repairs and replacements

The plant protection equipment is often found requiring frequent repairs andreplacements which are both minor and major in nature. Due to this, a good number are foundsick in the depots.Hand operated equipment generally need minor repairs such as replacement ofplunger washers, springs, nozzle etc., and these repair could as well be attended to by theoperators themselves with little training and experience. It is essential to supply themnecessary spare parts and tools well in time for repairing. In the case of power operatedsprayers the engine repairs are classified into minor and major ones.

1) Minor repairs:
Spark plug cleaning and adjustment, air cleaner, carburettor cleaning, fuel cock and linescleaning and starter repairs, etc. These can be attended to by the operators themselveswith little experience and training.

2) Major repairs:
These repairs include replacement of parts like piston, rings, liners, crankshaft,bearings, valves, etc. These repairs have to be carried out systematically in well-equipped workshops by the competent and trained mechanics. Untrained personnelshould not be allowed to handle such major repairs.

Unit 4: Pesticide Storage and Handling

Content

1.0 Pesticide Storage and Handling

When storing, transporting, mixing, loading, or applying pesticides, or cleaning pesticide spills, it is good practice to treat all pesticides as though they are toxic. Read all pesticide labels before use, and train all employees or pesticide handlers on personal protection procedures. Always keep unauthorized people, especially children, away from pesticide mixing, handling, and storage areas. Following are additional suggestions to use while storing and handling pesticides.

1.1 Storage

Proper storage of pesticides can greatly reduce the risk of unauthorized personnel, especially children, from contacting, spilling, or ingesting pesticide material.

- Keep the storage area locked. Pesticides can be very harmful when in the wrong hands.
- Post storage areas and buildings with signs reading "Danger - Pesticides." The signs will also inform fire fighters that pesticides are present.
- Always keep children, animals, and unauthorized persons away from pesticides.
- Store pesticides in well ventilated, dry areas.
- Don't keep large amounts of pesticides on hand; only purchase the amount you need.
- Keep an inventory of pesticides and other chemicals, and their respective locations.
- Keep pesticides in their original containers. Never put them in unmarked or food containers.
- Never store pesticides with food products, livestock feed, or fertilizer.
- Store personal protective equipment in a clean area away from pesticides.
- Periodically check pesticide containers for leaks or corrosion; some pesticides are caustic.

1.2 Transport

Use caution when loading and transporting pesticides. Make sure handlers know how to properly load and secure pesticide containers, and know how to react to pesticide accidents.

- Inspect the vehicle being used to transport the pesticides. Make sure it is functioning properly.
- Transport the pesticides in the back of the truck bed or in locations away from passengers.
- Secure pesticide containers to ensure that they will not roll around or fall out. Prevent the containers from moving by tying down, blocking, and bracing them.
- During loading, check the containers for leaks, make sure caps are secure, read the labels, and inventory the number and type of containers being transported.
- Never transport pesticides with food or feed.

- Never allow anyone to ride with the pesticides.
- Never carry pesticides in the passenger seating area.
- Be prepared for a spill during transportation.
- Carry a safety kit for use during clean up. The kit should contain an index card with emergency numbers, duct tape, shovel, respirator, goggles, rubber gloves, protective clothing, soap, and wooden dowels to plug leaks. Also carry kitty litter or sand as an absorbent material.
- If a spill happens, control and contain it. Put on safety equipment, and dike off the area. Contact the proper authorities for help.

Tutor Marked Assignments

1. List the general maintenance procedures for plant protection equipment.
2. Enumerate four each of the maintenance procedures for the following;
a. Hand Sprayer and Duster
b. Power Sprayers and Dusters
c. Plant protection Equipment when not in use
d. Plant protection Equipment when taken to field e. Plant protection equipment in transportation

3. Discuss the standardisation and testing methods of the following plant protection equipment
a. Compression sprayer b. Knapsack sprayer
c. Motorized sprayer
d. Hydraulic nozzle & Spray lance

4. Discuss the procedures for storage of pesticides.
5. How can pesticides be safely and effectively transported?

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