DEPARTMENT OF PLANT PATHOLOGY
UNDER GRADUATE EDUCATION

PAT 201 PRINCIPLES OF CROP DISEASE MANAGEMENT (1+1)

COURSE TEACHER

Dr. V. PRAKASAM
PROFOESSOR (PLANT PATHOLOGY)

SYLLABUS

THEORY

Principles of Crop disease management —- Epidemiology of crop diseases – Disease surveillance, assessment of disease intensity - forecasting. Survival and mode of spread of plant pathogens – Types of resistance – Cross protection – mechanism of resistance,. Methods and management of plant diseases - Fungicides – Characteristics of an ideal fungicide - Classification – groups of fungicides – antibiotics. Formulations – compatibility. Phytotoxicity – precautions and safety measures in handling. Management of diseases – seed, soil foliar and post harvest diseases – seed health testing methods – Simple diagnostic techniques for identification of diseases. Biological control and their scope – biocontrol agents – Fungi, bacteria, vesicular arbuscular mycorrhizae – Plant products and antiviral principles. Biotechnological approaches in plant disease management.

PRACTICAL

Various groups of fungicides and antibiotics – Preparation of Bordeaux mixture and Bordeaux paste – Preparation of fungicidal spray solution – methods of application - seed treatment – Soil and foliar application —- demonstration of Phytotoxicity – Production of immunized seedlings in citrus – Biological control agents- Trichoderma, Pseudomonas and vesicular arbuscular mycorrhizae - Methods of mass production and application. Preparation of botanicals – leaf extracts, oil emulsions and anti viral principles – Diagnostic techniques – iodine test for rice tungro virus, tetrazolium chloride test for banana bunchy top virus and paraquat technique for post harvest diseases. – Survey and assessment of crop diseases.

LECTURE SCHEDULE

THEORY

1. Principles of disease management exclusion – plant quarantine – domestic and foreign embargo – Exotic diseases, phytosanitary certificate.
2. Eradication – physical, chemical and cultural methods.
3. Immunization – Cross protection – Types of resistance, vertical resistance and horizontal resistance, mechanism of resistance, morphological, physical and chemical.
4. Protection – chemical protection, cultural methods.
5. Epidemiology of crop diseases weather factors and their role in disease development – Temperature, rainfall, relative humidity, dew and inoculum potential.
6. Disease surveillance, assessment and forecasting.
7. Survival and mode of spread of plant pathogens.
8. Fungicides – definition characteristics of an ideal fungicide, protectant, eradicant, therapeutant, fungistat. Groups of fungicide – Copper, Sulphur, Mercury, Heterocyclic nitrogen compound, Quinones, and miscellaneous fungicides.
9. Mid Semester Examination
10. Systemic fungicides
11. Antibiotics
12. Formulations and Methods of application of fungicides – Seed treatment, dry and wet, soil drenching, foliar spray, post harvest treatment, corm injection, root feeding, capsule application and acid delinting.
13. Compatibility and phytotoxicity, precautions and safety measures in storage and handling of fungicides.
14. Biological control – biocontrol agents, fungi, bacteria, vesicular arbuscular mycorrhizae and plant products – methods of application of biocontrol agents – plant products and anti viral principles.
15. Seed health testing methods- dry seed examination and blotter test.
16. Diagnostic techniques in identification of crop diseases.
17. Biotechnological approaches for crop disease management such as meristem tip culture and somoclonal variation.

PRACTICAL

1. Identification of major groups of fungicides
2. Identification of major groups of fungicides
3. Preparation of Bordeaux mixture and Bordeaux paste.
4. Preparation of fungicidal solution – phytotoxicity of fungicides.
5. Methods of application of fungicides – seed treatment, dry, wet, foliar spraying and soil drenching.
6. Root feeding, corm injection and capsule application
7. Acid delinting and post harvest treatment.

8. Cross protection – Demonstration of production of immunized seedling against citrus tristeza.
9. Mass Production of *Trichoderma viride*
10. Mass Production of *Pseudomonas fluorescens*
11. Mass Production of vesicular arbuscular mycorrhizae
12. Preparation of leaf extracts, oil emulsion, botanicals and antiviral principles.
13. Diagnostic techniques for detecting crop pathogens – Iodine test for rice tungro virus, tetrazolium chloride test for banana bunchy top virus and paraquat technique for post harvest diseases.
14. Seed health testing methods – Dry seed examination, blotter test.
15. Survey and assessment of foliar crop diseases, post harvest diseases, soil borne and viral diseases.
16. Visit to Seed testing laboratory and Pesticide testing laboratory
17. Practical examination.

REFERENCES

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GROUP OF FUNGICIDES

FUNGICIDES

The word ‘fungicide’ originated from two latin words, viz., ‘fungus’ and ‘caedo’. The word ‘caedo’ means ‘to kill.’ Thus the fungicide is any agency/chemical which has the ability to kill the fungus. According to this meaning, physical agents like ultra violet light and heat should also be considered as fungicides. However, in common usage, the meaning is restricted to chemicals only. Hence, fungicide is a chemical which is capable of killing fungi.

Fungistat

Some chemicals do not kill the fungal pathogens. But they simply arrest the growth of the fungus temporarily. These chemicals are called fungistat and the phenomenon of temporarily inhibiting the fungal growth is termed as fungistatis.

Antisporulant

Some other chemicals may inhibit the spore production without affecting the growth of vegetative hyphas and are called as ‘Antisporulant’. Eventhough, the antisporulant and fungistatic compounds do not kill the fungi, they are included under the broad term fungicide because by common usgage, the fungicide has been defined as a chemical agent which has the ability to reduce or prevent the damage caused to plants and their products. So, some of the plant pathologists prefer the term ‘Fungitoxicant’ instead of fungicide.

Although chemicals have been used in the management of plant diseases caused by fungi, bacteria, nematodes, viruses and other nutritional deficiencies, the use of chemicals in controlling fungal diseases has been established than other diseases. Fungicides can be broadly grouped based on their (i) mode of action (ii) general use and (iii) chemical composition.

Protectant

As the name suggests, protectant fungicides are prophylactic in their behaviour. Fungicide which is effective only if applied prior to fungal infection is called a protectant, eg., Zineb, Sulphur.

Therapeutant

Fungicide which is capable of eradicating a fungus after it has caused infection and there by curing the plant is called chemotherapeutant. eg. Carboxin, Oxycarboxin antibiotics like Aureofungin. Usually chemo therapeutant are systemic in their action and affect the deep-seated infection.

Eradicant

Eradicant are those which remove pathogenic fungi from an infection court (area of the host around a propagating unit of a fungus in which infection could possibly occur). eg. Organic mercurials, lime sulphur, dodine etc. These chemicals eradicate the dormant or active pathogen from the host. They can remain effective on or in the host for some time.

II. Based on general uses

The fungicides can also be classified based on the nature of their use in managing the diseases.

1. Seed protectants : Eg. Captan, thiram, organomercuries carbendazim, carboxin etc.
2. Soil fungicides (preplant) : Eg. Bordeaux mixture, copper oxy chloride, Chloropicrin, Formaldehyde Vapam, etc.,
3. Soil fungicides (for growing plants) : Eg. Bordeaux mixture, copper oxy chloride, Capton, PCNB, thiram etc.
4. Foliage and blossom protectants : Eg. Capton, ferbam, zineb, mancozeb, chlorothalonil etc.
5. Fruit protectants : Eg. Captan, maneb, carbendazim, mancozeb etc.
6. Eradicants : Eg. Organomercurials, lime sulphur, etc.
7. Tree wound dressers : Eg. Boreaux paste, chaubattia paste, etc.
8. Antibiotics : Eg. Actidione, Griseofulvin, Streptomycin, Streptocycline, etc.,
9. General purpose spray and dust formulations.

III. Based on Chemical Composition

The chemical available for plant disease control runs into hundreds, however, all are not equally safe, effective and popular.Major group of fungicides used include salts of toxic metals and organic acids, organic compounds of sulphur and mercury, quinones and heterocyclic nitrogenous compounds. Copper, mercury, zinc, tin and nickel are some of the metals used as base for inorganic and organic fungicides. The non metal substances include, sulphur, chlorine, phosphorous etc. The fungicides can be broudly grouped as follows and discussed in detail.

Sulphur fungicides

Use of sulphur in plant disease control is probably the oldest one and can be classified as inorganic sulphur and organic sulphur. Inorganic sulphur is used in the form of elemental sulphur or as lime sulphur. Elemental sulphur can be either used as dust or wettable sulphur, later being more widely used in plant disease control. Sulphur is best known for its

effectiveness against powdery mildew of many plants, but also effective against certain rusts, leaf blights and fruit diseases. Sulphur fungicides emit sufficient vapour to prevent the growth of the fungal spores at a distance from the area of deposition. This is an added advantage in sulphur fungicides as compared to other fungitoxicants.

Organic compounds of sulphur are now widely used in these days. All these compounds, called as 'carbamate fungicides', are derivatives of Dithiocarbamic acid, Dithiocarbamates are broadly grouped into two, based on the mechanism of action.

Dithiocarbamates

Monoalkyl Dithiocarbamates	Dialkyl Dithiocarbamates
Eg. Zineb, Maneb, Mancozeb, Nabam, Vapam	Eg. Thiram, Ziram, Ferbam

List of sulphur fungicides and the important diseases controlled by them are tabulated below:

	Trade Name	**Diseases Controlled**
Inorganic Sulphur		
1. Elemental Sulphur (i) Sulphur dust	Sulphur dust Cosan, Wetsulf, Microsul	Sulphur is a contact and protective fingicide, normally applied as sprays or as dust. It is generally used to control powdery mildews of fruits, vegetables, flowers and tobacco. This is also effective against apple scab (Venturia inaequallis) and rusts of field crops.
2. Lime Sulphur (Calcium poly sulphide)	It can be prepared by boiling 9 Kg or rock lime and 6.75 Kg of sulphur in 225 litres of water.	Lime Sulphur is effective againstt powdery mildews as a protective fungicide.
Organic Sulphur (Dithiocarbamates) a. Monoalkyl	Hexathane 75% WP, Dithane Z-78, Funjeb, Lonocol, Parzate C,	It is used to protect foilage and fruits of a wide range of crops

dithiocarbamate 1. Zineb (Zinc ethylene bisdithiocarbamate)	Du Pant Fungicide A, Polyram.	against diseases such as early and late blight of potato and tomato, downy mildews and rusts of cereals, blast of rice, fruitrot of chilly etc.
2. Maneb (Manganese ethylene bisdithiocarbamate)	Dithane M22, Manzate WP, MEB	These two are protective fungicide used to control many fungal diseases of field crops, fruits, nuts, ornamentals and vegetables, especially blights of potatoes and tomatoes, downy mildews of vines, anthracnose of vegetables and rusts of pulses.
3.Mancozeb (Maneb + Zinc ion)	Dithane M45, Indofil M45, Manzeb.	
4. Nabam (DSE) (Di Sodium ethylene bisdithiocarbamate)	Chembam, Dithane A-40, Dithane D-14, Parzate Liquid	Nabam is primarily used for foilar application against leaf spot pathogens of fruits and vegetables. Soil applications were also reported to have a systemic action on *Pythium, Flusarium* and *Phytophthora.* It is also used to control algae in paddy fields.
5. Vapam (SMDC) (Sodium methyl dithiocarbamate)	Vapam, VPM, Chemvape, 4-S Karbation, Vita Fume.	It is a soil fungicide and nematicide with fumigant action. It is also reported to have insecticidal and herbicidal properties. It is effective against damping off disease of papaya and vegetables and wilt of cotton. It is also effective against nematode infestation in citrus, potato and root knot nematodes in vegetables.

b. Dialkyl Dithiocarbamate 1. Ziram (Zinc dimethyl dithiocarbamate)	Cuman L. Ziram, Ziride 80 WDP, Hexaazir 80% WP, Corozate, Fukiazsin, Karbam white, Milbam, Vancide 51Z, Zerlate, Ziram, Ziberk, Zitox 80% WDP.	iram is a protective fungicide for use on fruit and vegetables crops against fungal pathogens including apple scab. It is non phytotoxic except to zinc sencitive plants. It is highly effective against anthracnose of beans, pulses, tobacco and tomato, and also against rusts of beans ect.
2. Ferbam (Ferric dimethyl dithiocarbamate)	Coromat, Febam, Ferberk, Femate, Fermate D, Fermicide, Hexaferb 75% WP, Karbam Black, Ferradow.	Ferbam is mainly used for the protection of foilage against fungal pathogens of fruits and vegetables including *Taphrina deformans* of peaches, anthracnose of citrus, downy mildew of tobacco and apple scab.
3. Thiram (Tetra methyl thiram disulphide)	Thiride 75 WDP, Thiride 750, Thiram 75% WDP, Hexathir, Normerson, Panoram 75, Thiram, TMTD, Arasan, Tersan 75, Thylate, Pomarsol, Thiuram.	t is used for seed treatment both as dry powder or as a slurry. It is a protective fungicide also suitable fo application to foilage to control *Botrytis spp.* on lettuces, ornamental, soft fruits and vegetables, rust on ornamentals and *Venturia pirina* on pears. It is also effective against soilborne pathogens like *Pythium, Rhizoctonia* and *Fusarium.*

Copper Fungicides

The fungicidal action of copper was mentioned as early as 1807 by Prevost against wheat bunt disease *(Tilletia caries),* but its large scale use as a fungicide started in 1885 after the discovery of Bordeaux mixture by Millardet in France. The mixture of copper sulphate and lime was effective in controlling downy mildew of grapevine caused by *Plasmopara viticola* and later, late blight of potato *(Phytophthora infestans).*

Some other copper sulphate preparations later developed were Borduaux paste, Burgandy mixture and Cheshnut compound which are all very effectively used in the control of several plant diseases. In addition some preparations of copper oxy chloride preparations arev also mused. These are all insoluble copper compounds very successfully used in managing several leaf diseases and seeding diseases in nursery.

Some of the important diseases controlled by copper fungicides are listed below.

Common Name	Trade Name	Diseases Controlled
1. Copper Sulphate Preparations		
1. Bordeaux mixture	It is prepared by mixing copper sulphate and lime in water (to get 1% mixture, mix 1 kg of $CuSO_4$ and 1 kg of lime in 100 litres of water)	Boredeaux mixture is used as a protective fungicide for foilage applications. The freshly prepared mixture have high tenacity. Major uses include the control of *Phytophthora infestans* on potatoes, *Venturia inaequalis* on apples, Downy mildew of graphs, damping off, leaf diseases of several crops and rust of coffee.
2. Bordeaux paste	It is prepared by mixing 1 kg of $CuSO_4$ and 1 kg of lime in 10 litres of water.	It is used as a wound dressing fungicide. It is painted after removing dead tissues or after pruning in tree crops. It is a best substitute for
3. Burgundy mixture	It is prepared by mixing 1 kg of $CuSO_4$ and 1 kg of Sodium Carbonate in 100 litres of water,	Bordeaux mixture. It is used in the crops sensitive to Boreaux mixture.

4. Cheshnut compound	It is prepared by mixing 2 parts of copper sulphate and 11 parts of Ammonium Carbonate.	It is used as a soil fungicide against diseases caused by *Pythium* and *Rhizoctonia.*
II. Copper carbonate preparation		
Chaubattia Paste	This is prepared by mixing 800 g of copper carbonate and 800 g of Red lead in 1 litre of linseed oil or lanolin.	It is successfully used in managing pink disease, stem canker and collar rot diseases in apple, peach and pear. It is also a wound dressing fungicide.
III. Cuprous oxide Preparation	Fungimar, Perenox, Copper Sandoz, Copper 4% dust, Perecot, Cuproxd, Kirt i copper.	Cuprous oxide is a protective fungicide, used mainly for seed treatment and for foilage application against blight, downy mildew and rusts.
IV. Copper oxychloride Preparation.	Blitox, Cupramar 50% WP, Fytolan, Bilmix 4%, Micop D-06, Micop w-50, Blue copper 50, Cupravit, Cobox, Cuprax, Mycop.	It is a protective fungicide, controls *Phytophthora infestans* on potatoes and several leaf spot and leaf blight pathogens in field.

Mercury Fungicides

Mercury fungicides can be grouped as inorganic and organic mercury compounds. Both the groups are highly fungitoxic and were extensively used as seed treatment chemicals against seed borne diseases. Ignorance compounds show bactericidal property also. However, due to their residual toxicity in soil and plants and their extreme toxicity nature to animal and human beings, the use of mercury fungicides is beings discouraged. In most of the countries, the use of mercury fungicides is banned andin countries like India, the use of mercury fungicides is restricted only in seed treatment for certain crops. The list of diseases against which mercury fungicides used are listed below:

Common Name	Trade Name	Diseases Controlled
I. Inorganic Mercury		
1. Mercuric chloride	Merfusan, Mersil	It is used for treating potato tubers and propagative materials of other root crops
2. Mercurous chloride	Cyclosan, M-C Turf fungicide.	Mercurous chloride is limited to soil application in crop protection use because of its phytotoxicity.
II. Organomercurials		
Methoxy ethyl mercury chloride	Agallol, Aretan, Emisan, Ceresan wet (India)	These are used mainly for treatment of seeds and planting materials. These fungicides are used for seed treatment by dry, wet or slurry method. For seed treatment 1% metallic mercury is applied at 0.25% concentration.
Phenyl mercury chloride	Ceresan Dry (India), Ceresol, Leytosan.	
Ethyl Mercury Chloride	Ceresan (USA)	
Tolyl mercury acetate	Agrosan GN.	

Heterocyclic Nitrogen Compounds

Heterocyclic nitrogen compounds are mostly used as foliage and fruits protectants. Some compounds are very effectively used as seed dressers. Some of the commonly used fungicides are listed below.

Common Name	Trade Name	Diseases Controlled
1.Captan (Kittleson's Killer) (N-trichloromethyl thio-4- cyclohexence-1,2-dicarboximide)	Captan 50W, Captan 75 W, Esso Fungicide 406, Orthocide 406, Vancide 89, Deltan, Merpan, Hexacap.	It is a seed dressing fungicide used to control diseases of many fruits, ornamental and vegetable crops against rots and damping off.
2. Captafol (Cis-N-1,1,2,2-tetra chloro hexane 1,2-dicarboximide)	Foltaf, Difolaton, Difosan, Captaspor, Foleid, Sanspor.	It is a protective fungicide, widly used to control foliage and fruit diseases of tomatoes, coffee potato

3. Glyodin	Glyoxaliadine, Glyoxide, Glyodin, Glyoxide Dry, Glyodex 30% liquid and 70% WP.	It has a narrow specrum of activity. As a spray, it controls apple scab and cherry leaf spot.
4.Folpet (Folpet) [N-(trichloromethyl-thi)] phthalimide	Phartan, Acryptan, Phaltan, Folpan, Orthophaltan.	It is also a protective fungicide used mainly for foliage application against leaf spots, downy and powdery mildews of many crops.

Benzene compounds

Many aromatic compounds have important anti-microbial properties and have been developed as fungicides. Some important benzene compounds commonly used in plant disease control are listed below:

Common Name	Trade Name	Diseases Controlled
1. Quintozene (PCNB)	Brassicol, Terraclor, Tritisan 10%, 20%, 40% D and 75% WP, PCNB 75% WP.	It is used for seed and soil treatment. It is effective against *Botrytis, Sclerotium, Rhizoctonia* and *Sclerotinia spp.*
2. Dichloran	Botran 50% WP and 75% WP, Allisan.	It is a protective fungicide and very effective against *Botrytis, Rhizopus and Sclerotinia* spp.
3. Fenaminsosuplh (Sodium-p-dimethylamino benzene-diazosulphonate	Dexon 5% G and 70% WP.	It is very specific in protecting germinating seeds and growing plants from seeds as well as soil-borne infection of *Phythium, Aphanomyces* and *Phytophthora* spp.
4.Dinocap (2,4-dinitro-6-octyl phenylcrotonate)	Karathane, Arathane, DNOPC, Mildex, Crotothane, Crotothane 25% WP, Crotothane 48% Liq.	It is a non-systemic acaricide and control fungicide recommended to control powdery mildews on various fruits and ornamentals. It is also used for seed treatment.

Quinone Fungicides

Quinone areresent naturally in plants and animals and they exhibit anti-microbial activity and some compounds are successfully developed and used in the plant disease control. Quinones are very effectively used for seed treatment and two commonly used fungicides are listed below:

Common Name	Trade Name	Diseases Controlled
1. Chloranil (2,3,5,6-tetrachlora-1,4-benzoquinone)	Spergon	Chloronil is mainly used as a seed protectant against smuts of barely and sorghum and bunt of wheat.
2. Dichlone (2,3-dichloro-1,4- napthoquinone)	Phygon, Phygon XL WP.	Dichlone has been used widely as seed protectant. This is also used as a foliage fungicide, particularly against apple scab and peach leaf curl.
Organo – Phosphorous fungicide Ediphenphos (Edifenphos) (O-ethyl-SS-diphenyl-dithiophosphate)	Hinosan 50% EC and 2% D.	It has a specific action against *Pyricularia oryzae* (Rice blast). It is also effective against *Corticium sesakii* and *Cochliobolus miyabeanus* in rice.

Organo Tin compounds

Several other organic compounds containing tin, lead, etc. have been developed and successfully used in plant disease control. Among them, organo tin compounds are more popular and effective against many fungal diseases. These compounds also show anti bactericidal properties. Some of the organo tin compounds commonly used are listed below.

Common Name	Trade Name	Diseases Controlled
1. Fentin hydroxide (TPTH-Tiphenyl tin hydroxide)	Du-Ter WP 20% or 50% WP. Du-Ter Extra-WP, Farmatin 50 WP, Du-Terforte WP, Tubotin.	It is a non-systemic fungicide recommended for the control of early and late blight of potato, leaf spot of sugar beet, blast of rice and tikka leaf spot of ground nut.

2. Fentin acetate (TPTA- Triphenyl tin acetate)	Brestan WP 40% and 60% WP.	It is a non systemic fungicide recommended to control *Ramularia* spp. on celery and sugar beet anthracnose and downy mildew
3. Fentin Chloride (TPTC- Triphenyl tin chloride)	Brestanol 45% WP, Tinmate.	It is effective against Cercospora leaf spot of sugarbeet and paddy blast.

Systemic Fungicides

Since the late 1960s there has been substantial development in systemic fungicides. Any compound capable of being freely translocated after penetrating the plant is called systemic. A systemic fungicide is defined as fungitoxic compound that controls a fungal pathogen remote from the point of application, and that can be detected and identified. Thus, a systemic fungicide could eradicate established infection and protect the new parts of the plant. Several systemic fungicides have been used as seed dressing to eliminate seed infection. These chemicals, however, have not been very successful in the cases of trees and shrubs. On the basis of chemical structure, systemic fungicides can be classified as Benzimidazoles, Thiophanates, Oxathilins and related compounds, pyrimidines, morpholines, organo-phosphorus compounds and miscellaneous group.

I. Oxathilin and related compounds

Oxathalins were the earliest developed compounds. This group of systemic fungicide is also called as carboxamides, carboxyluc acid anillides, carboxaanillides or simply as anillides which are effective only against the fungi belong to *Basidiomycotina* and *Rhizoctonia solani.* Some of the chemicals developed are (i) Carboxin (DMOC: 5,6 - dithydra-2-methyl-1, 4-oxathin-3-carboxanillide) and (ii) Oxycarboxin (DCMOD-2,3-dihydro-5-carboxanillido-6-methyl-1, 4 oxathilin-4, 4, dioxide). The diseases controlled by these chemicals are listed below.

Common Name	Trade Name	Diseases Controlled
1. Carboxin (5,6-dinydro-2-methyl-1-4-oxanthin-3-carboxanlido)	Vitavax 10% D, Vitavax 75% WP, Vitavax 34% liq. Vitaflow.	It is systemic fungicide used for seed treatment of cereals against bunts and smuts, especially loose smut of wheat
2. Oxycarboxin (5,6-dihydro-2-methyl-1,4-oxathin-3-carboxianilid-4,4-dioxide)	Plantvax 5G, Plantvax 5% liq. Plantvax 1.5 EC, 10% dust, 75 WP.	It is a systemic fungicide used for the treatment of rust diseases of cereals, pulses, ornamentals, vegetables and coffee.

3.Pyracarbolid (2-methyl-5,6-dihydro- 4H-Pyran-3-carboxylic acid anilide)	Sicarol.	It controls rusts, smuts of many crops and *Rhizoctonia solani,* but is slightly more effective than carboxin.

II. Benzimidazoles

The chemicals of this group show a very broad spectrum activity against a variety of fungi. However, they are not effective against bacteria as well as fungi belongs to *Mastigomycotina*. Two types of fungicidal derivates of benzimidazoles are known. The first type of derivates includes fungicides such as thiabendazole and fuberidazole. The fungicidal moiety of the second type is methyl-2-benzimidazole carbamate (MBC). The fungicides of this group may be simple MBC such as carbendazim or a complex from such as benomyl, which transforms into MBC in plant system. Some of the important diseases controlled by these compounds are shown below:

Common Name	Trade Name	Diseases Controlled
1.Benomyl (Methyl - 10 (butly carbomyl)-2 benzimidazole carbamate)	Benlate 50 WP, Benomyl.	It is a protective and eradicative fungicide with systemic activity, effective against a wide range of fungi affecting field crops, fruits and ornamentals. It is very effective against rice blast, apple scab, powdery mildew of cereals, rose, curcurbits and apple and diseases caused by *Verticillium and Rhizoctonia.* It is also used as pre-and post-harvest sprays of dips for the control of storage rots of fruits and vegetables.
2. Carbendazim (MBC) (Methyl -2-benzimidazole carbamate)	Bavistin 50 WP, MBC, Dersol, B.Sten 50, Zoom, Tagstin, Agrozim, Jkenstin.	Carbendazim is a systemic fungicide controlling a wide range of fungal pathogens of

		field crops, fruits, ornamentals and vegetables. It is used as spray, seedling dip, seed treatment, soil drench and as post harvest treatment of fruits. It is very effective against wilt diseases especially, banana wilt. It controls effectively the sigatoka leaf spot of banana, turmeric leaf spot and rust diseases in many crops.
3. Thiabendazole (TBZ) (2,4-thiazoyl benzimidazole)	Thiabendazole, Mertect, Tecto, Storite.	It is a broad spectrum systemic fungicide effectivel against many major fungal diseases. Pathogenic fungal control includes species of *Botrytis, Ceratocystis, Cercospora, Colletotrichum, Fusarium, Rhizoctonia, Sclerotinia, Septoria and Verticillium.* It is also effective for the post harvest treatment of fruits and vegetables to control storage diseases.
4.Fuberidazole (2, (2-buryl) - benzimidazole)	Voronit.	It is used for the treatment of seeds against diseases caused by *Fusarium,* Particularly *F.nivale* on rye and *F.culmorum* of peas.

III. Thiophanates

These compounds represent a new group of systemic fungicides based on thiourea. They are the derivatives of thioallophanic acid. These fungicides contain aromatic nucleus which is converted into benzimidazole ring for their activity. Hence, thiophanates are often classified under benzimidazole group and the biological activity of thiophanates resembles of benomyl. Two compounds are developed under this group are discussed.

Common Name	Trade Name	Diseases Controlled
1. Thiophanate(1,2 - bis (ethyl carbonyl-2-thioureido) benzene)	Topsin 50 WP, Cercobin 50 WP, Enovit.	It is a systemic fungicide with a broad range of action, effective against *Venturia* spp., on apple and pear crops, powdery mildews, *Botrytis* and *Sclerotinia* spp. on various crops.
2. Thiophanate - methyl (1,2 bis (3-methoxy-carbonyl-2-thioureido) benzene.)	Topsin-M70 WP, Cercobin-M 70 WP, Envovit-methyl, Mildothane.	It is effective against a wide range of fungal pathogens, including *Venturia spp.* on apples and pears, *Mycosphaerella musicola* on bananas, powdery mildews on apples, cucurbits, pears and vines, *Pyricularia oryzae* on rice, *Botrytis and Cerospora* on various crops.
Common Name	**Trade Name**	**Diseases Controlled**
IV.Morpholines Tridemorph (2-6 - dimethyl-4-cyclo - tridecyl morpholine)	Calixin 75 EC, Bardew, Beacon	It is an eradicant fungicide with systemic action, being absorbed through foilage and roots to give some protective action. It controls powdery mildew diseases of cereals, vegetables and ornamentals. It is highly effective against

		Mycosphaerala musicola, Exobasidium vexans and rust diseases or cereals, pulses and coffee.
Dodemorph(2-6-dimethyl-4-cyclo-dodecyl morpholine	BAS 238F	It is very effective against powdery mildew of ornamental plants, especially roses.

V. Pyrimidines, Pyridines, Piperidines and Imidazole

Common Name	Trade Name	Diseases Controlled
1. Triadimefon (1-(4-chlorophenoxy)-3, 3-dimethyl-1-(1-2-triazol-1 yl) butan-2-one)	Bayleton, Amiral	It is very effective against powdery mildews and rusts of several crops.
2. Triadimenol (1-(4-Chlorophenoxyl-3, 3-dimethyl-1(1,2,4-triazol-1-yl) butan-2-ol)	Baytan.	It is also very effective against powdery mildews and rusts of several crops.
3. Bitertanal (B-(1-1-biphenyl-4-yloxy-a-(1-1-dimethyl-ethyl-1-H-1,2-4-triazole-1-ethanol)	Baycor	It is highly effective against rusts and powdery mildew of a variety of crops. It is also used against *Venturia* and *Monilinia* on fruits and *Cereospora* leafspots of groundnut and banana.
4. Etridiazole (5-ethaoxy-3-trichloromethyl, 1,2-4-thiadiazole)	Terrazole 30% WP, Terrazole 95% WP, Terrazole 25% EC, Koban, Pansol EG, Pansol 4% DP, Turban WP, Terracoat Aaterra.	It is very effective against *Phytophthora* and *Pythium* spp. and seeding diseases of cotton, groundnut, vegetables, fruits and ornamentals.

VI. Hydroxy Pyrinidines

Common Name	Trade Name	Diseases Controlled
1. Ethirimol (5-butyl 2-ethyl amino-4-hydrop-6-methyl pyrimidine)	Milliatem 80 WDP, Milcurb Super, Milgo	It is effective against powdery mildew of cereals and other field crops. It is also effective against powdery mildews of cucumber and ornamentals.
2. Dimethirimol (5-butyl 2-dimethylamino-4-hydroxy-6-methy pyrimidine)	Milcurb	It is very effective against powdery mildews of chrysanthemum and cucurbits.
VII. Furan derivatives		
1. Furcarbanil (2-5-dimethyl-3-furanilide)		It is used as seed or soil application, It systemically controlled bean rust and is being used as a seed dressing fungicide against loose smut of wheat and barley.
2. Cyclafuramid (N-cyclohexyl-2,5-dimethyl firamide)		It is effective against bunts, smuts and rusts of cereals, coffee rust, blister blight of tea, smut and red rot of sugarcane, *Fusarium wilt* of tomato, *Rhizoctonia* on tomato, potato, groundnut, rice as well as *Armillaria* sp. on rubber.
VIII.Benzanilide derivative		
1. Mebenil (2-methyl benzanilide)		It is effective against yellow rust on wheat and barley *(P. striiformis)* and brown rust on barley *(P. hordei).* It is also having direct fungitoxic activity against *Sclerotium rolfsli* and *Rhizoctonia.*

2. Benodanil (2-iodobenzanilide)	Calirus.	It is effective against rust fungi in cereals such as yellow rust of wheat and barley, brown rust of wheat, black rusts of wheat, rye, barley and oats and rust of fig.

IX. Organo phosphorous compounds

Common Name	Trade Name	Diseases Controlled
1. Pyrazophos (2-0-0-Diethyl-thionophosphoryl) -5-methyl-6-carbethoxy pyrazolo-(1-5a)pyrimidine)	Afugan, Curamil, WP, Missile EC.	It is used to control powdery mildews of cereals, vegetables, fruits and ornamentals.
2. Iprobenphos (IBP) (S-benyzl-0-0-bisisopropyl-phosphorothiate)	Kitazin 48% EC, Kitazin 17G, Kitazin 2% D.	It is used to control *Pyricularia oryzae* and sheath blight of rice.
X. Piperazine		
1. Triforine(N,N-bis-(1-foramido-2,2,2-trichloroethyl- piperazine)	Saprol-EG, Fungitex.	It is effective against powdery mildew, scab and other diseases of fruits and rust on ornamentals and cereals. It is also active against storage diseases of fruits.
XI. Phenol derivative		
1. Choloroneb (1-4-dichloro-2,5-dimethoxy benzene)	Demonsan 65 WP, Tersan SP, Turf fungicide	It is highly fungistatic to *Rhizoctonia* spp., moderately so to *Pythium* spp. and poorly to *Fusarium* spp. It is used as a supplemental seed treatment for beans and soyabeans to control seedling diseases.
XII. Triazole compounds.		
1. Triazbutyl		

(4-n-butyl-1-2, 4-trialzole)	Indar	It is selectively effective against leaf rust of wheat (Brown trust) caused by *Puccinia recondita* f.sp. tritici and not to any other spices of *Puccinia* or *Uromyces* causing rust diseases.

XIII. Other systemic fungicides

Common Name	Trade Name	Diseases Controlled
1. Metalaxyl (methyl-DL-N-(2,6-dimethylphenyl-N-)2-methoxyacetyl	Apron 35 SD, Ridomil	It is a systemic fungicide and highly effective for specific use as seed dressing against fungal pathogens of the order Peronosporales.
2. Metalaxyl + Mancozeb	Ridomil MZ 72 WP (8% Metalaxyl + 64% Mancozeb)	It is a fungicide with systemic and contact action and effective against damping-off, root rots, stem rots, and downy mildew of grapes and millets.
3. Tricyclazole (5-methyl-1,2,4 triazole(3,4b)-benzothiazole)	Beam, Bim	It is a specific fungicide used against paddy blast fungus, *P. oryzae*
4. FosetylAl. (Aluminium - Tris-aluminium	Alliette 80 WP	It is a very specific fungicide for Oomycetous fungi, especially against

ethyl phosphite)		damping off, *Phytophthora* diseases of citrus, pepper, rubber and downy mildew of grapes.
5. Pyroquilon (1,2,5,6-tetrahydro-4- pyrrolo(3,2,1-i,j) quinoline-4-one)	Fongorene 50 WP & 5 G.	It is a specific fungicide for paddy blast fungus.
6.Hexaconazole	Contaf 5 EC, ANVIL 5 EC	It is very effective against powdery mildew and rust of several crops.
7. Propiconazole	Tilt 25 EC	It is also effective against rust and powdery mildews in addition to leaf sopt pathogens, especially to sigatoka leaf spot of banana.
8. Terbuconazole	Folicur 25 EC, Raxil 2 DS	It is used as a seed treatment fungicide for smuts and also effective against powdery mildew and rust diseases.
9. Penconazole	Topas 10 EC	It is a systemic fungicide with preventive and urative properties. It controls powdery mildew of various vegetables, fruits and ornamentals.
10.Difenoconazole	Sare 25% EC	It is very effective against leaf spot, rust and powdery mildew of many crops.
11.Cyperocoanazole	SAN 619	It is also very effective against rust and

		powdery mildew pathogen and leaf spot of groundnut and other crops.
12.Probenazole	Orizemate	It is also specific against rice blast.
13.Isoprothiolane	Fuji - 1	It is also specific against rice blast.
14.Pyroxychior	Dowco 269, Nurelle	It is very effective against pythiaceous fungi. It effectively controls tobacco blank shank as soil drench.
15.Cymoxanil	Curzate	It is effective against downey mildew diseases of several crops.

Other Fungicides

Some of the fungicides which are not included in any of the groups described earlier are listed below.

Common Name	Trade Name	Diseases Controlled
1. Binapacryl	Morocide 50% WP and 40% EC, Acricide 50% WP and 40% EC, Endosan.	It is a non systemic acaricide effective against powdery mildews of apple, citrus and pears and also effective against all stages of spider mites.
2. Chinomethionat (Oxythioquinox) (6-methyl- quinoxaline-2,3-dithol- cyclic carbonate)	Morestan 25% WP, Morestan 2% D.	It is also a selective non-systemic acaricide and fungicide specific to powdery mildews on fruits, ornamentals and vegetables.

3. Chlorothalonil (Tetra chloro isophthalonitrile)	Kavach 25% WP, Bravo, Daconil, Termil, Chlorothalonil 40 SC, Safegaurd, Spektrum.	It is a broad spectrum contact fungicide effective against many fungi diseases of field, orchard, ornamental and plantation crops. It is very effective against leaf spot and rust diseases of groundnut, early and late blight of potato and scab of apple.
4.Dodine	Cyprex 65% WP, Guanidol, Melprex WP, Syllit.	It is a non-aromatic organic fungicide. It is highly effective against apple scab. It is a protective fungicide recommender for the control of fungal diseases of fruits, nuts, vetables, ornamentals and shade trees. It is also effective against apple scab.

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ANTIBIOTICS

Antibiotic is defined as a chemical substance produced by one micro-organism which is low concentration can inhibit or even kill other micro-organism. Because of their specificity of action against plant pathogens, relatively low phytotoxicity, absorption through foliage and systemic translocation and activity in low concentration, the use of antibiotic is becoming very popular and very effectively used in managing several plant diseases. They can be grouped as antibacterial antibiotics and antifungal antibiotics. Most antibiotics are products of several actinomycetes and a few are from fungi and bacteria.

I. Antibacterial antibiotics

1. Streptomycin sulphate

Streptomycin is an antibacterial, antibiotic produced by streptomyces griseus. Streptomycin are streptomycin sulphate is sold as Agrimycin,-100, Streptomycin sulphate, Plantomycin, Streptocycline, Paushamycin, Phytostrip, Agristrep and Embamycin, Agrimycin -100 contains 15 per cent streptomycin sulphate + 1.5 percent terramycin (Oxy tetracycline). Agristerp contains 37 percent streptomycin sulphate. Phytomycin contains 20 percent streptomycin. Streptocycline and paushamycin contains 9 parts f streptomycin and 1 part of tetracycline hydrochloride.

This group of antibiotics act against a broad range of bacterial pathogens causing blights, wilt, rots etc. This antibiotic is used at concentrations of 100-500 ppm. Some important diseases controlled are blight of apple and pear *(Erwinia amylovora)*, Citrus canker *(Xanthomonas campestris p.v. citri)*, Cotton black arm *(X.c*. p.v*. malvacearum)*, bacterial leaf spot of tomato *(Pseudomonas solanacearum)*, wild fire of tobacco *(Pseudomonas tabaci)* and soft rot of vegetables *(Erwinia carotovora)*. In addition, it is used as a dip for potato seed pieces against various bacterial rots and as an disinfectant in bacterial pathogens of beans, cotton, crucifers, cereals and vegetables. Although it is an antibacterial antibiotic, it is also effective against some diseases caused by Oomycetous fungi, especially foot-rot and leaf rot of betelvine caused by *Phytophthora parasitica var. piperina.*

2. Tetracyclines

Antibiotics belonging to this group are produced by many species of Streptomyces. This group includes Terramycin or Oxymicin (Oxytetracycline). All these antibiotics are bacteriostatic, bactericidal and mycoplasmastatic. These are very effective against seed-borne bacteria. This group of antibiotic is very effective in managing MLO diseases of a wide range of crops. These

are mostly used as combination products with Streptomycin sulphate in controlling a wide range of bacterial diseases. Oxytetracyclines are effectively used as soil drench or as root dip controlling crown gall diseases in rosaceous plants caused by Agrobacterium tumefaciens.

II Antifungal antibiotics

1. Aureofungin

It is a hepataene antibiotic produced in sub-merged culture of Streptoverticillium cinnamomeum var. terricola. It is absorbed and translocated to other parts of the plants when applied as spray or given to roots as drench. It is sold as Aurefungin-Sol. Containing 33.3% Aureofungin and normally sprays at 50-100 ppm. The diseases controlled are citrus gummosis caused by several species of Phytophthora, powdery mildew of apple caused by *Podosphaera leucotricha* and apple scab (Venturia inaequalis), groundnut tikka leaf spot, downy mildew, powdery mildew and anthracnose of grapes, potato early and late blight. As seed treatment it effectively checked are *Diplodia* rot of mango, *Alternaria* rot of tomato, *Pythium* rot of cucurbits and *Penicillium* rot of apples and citrus. As a truck application/root feeding, 2 g of aureofungin-sol+1g of copper sulphate in 100 ml of water effectively reduce Thanjavur wilt of coconut.

2. Griseofulvin

This antifungal antibiotic was first discovered to be produced by *Penicillium griseofulvum* and now by several species of *Penicillium,* viz., *P.patulum, P.nigricans, P.urticae, and P.raciborskii.* It is commercially available as Griseofulvin, Fulvicin and Grisovin. It is highly toxic to powdery mildew of beans and roses, downy mildew of cucumber. It is also used to control *Alternaria solani* in tomato *Sclerotinia fructigena* in apple and *Botrytis cinerea* in lettuce.

3. Cycloheximide

It is obtained as a by-product in streptomycin manufacture. It is produced by different species of *Streptomyces,* including *S.griseus* and S*. nouresi.* It is commercially available as Actidione, Actidione PM, Actidione RZ and Actispray. It is active against a wide range of fungi and yeast. Its use is limited because it is extremely phytotoxic. It is effective against powdery mildew of beans *(Erysiphe polygoni),* Bunt of wheat *(Tilletia spp.)* brownnot of peach *(Sclerotinia fructicola)* and post harvest rots of fruits caused by *Rhizopus* and *Botrytis* spp.

4. Blasticdin

It is a product of *Streptomyces griseochromogenes* and specifically used against blast disease of rice caused by *Pyricularia oryzae.* It is commercially sold as Bla-s.

5. Antimycin

It is produced by several species of *Streptomyces,* especially *S. griseus* and *S. Kitasawensis.* It is effectively used against early blight of tomato, rice blast and seeding blight of oats. It is commercially sold as Antimycin.

6. Kasugamycin

It is obtained from *Streptomyces kasugaensis.* It is also very specific antibiotic against rice blast disease. It is commercially available as Kasumin.

7. Thiolution

It is produced by *Streptomyces albus* and effectively used to control late blight of potato and downy mildew of cruciferous vegetables.

8. Endomycin

It is a product of *Streptomyces endus* and effectively used against leaf rust of wheat and fruit rot of strawberry *(Botrytis cinerea).*

9. Bulbiformin

It is produced by a bacterium, *Bacillus subtills* and is very effectively used against wilt diseases, particularaly redgram wilt.

10. Nystatin

It is also produced by *Streptomyces noursei.* It is successfully used against anthracnose disease of banana and beans. It also checks downy mildew of cucuribits. As a post harvest dip, it effectively reduces brown rot of peach and anthracnose of banana in stroage rooms. It is commercially marketed as Mycostain and Fungicidin.

11. Eurocidin

It is a pentaene antibiotic produced by *Streptomyces anandii* and called as pentaene G-8. It is effectively used against diseases caused by several species of *Colletotrichum* and *Helminthosporium.*

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FUNGICIDE FORMULATIONS

The names by which fungicides are known can be rather confusing, as there as usually several names referring to one substance. Firstly, the chemical names describing the structure and composition of the chemicals may be indicated. In the case of complex organic compounds, different chemical names may be used to describe the same compound according to the usages in different countries. Secondly, the common name may be identical to the chemical name with simple compounds, or it may be an abbreviated and simplified derivative of the chemical name, when this is complex. Thirdly, the trade names under which different formulations of the same compound and marketed by different companies vary widely. However, all marketed fungicides should state clearly the common name of the fungicide and the amount of active ingredient of it contained in the formulated product. Commercial fungicides are formulated in various ways and most commonly available formulations are Emulsifiable Concentrates (EC) Wettable Powders (WP), Dusts (D), etc.

Commercially available fungicides usually consist of a mixture of active ingredient (a.i.) and other substances including diluents, wetting agents, stickers, emulsifiers, etc. Formulations containing mixtures of different active ingredients (especially mixtures of protectant and systemic fungicides) are also widely used nowadays. Different formulations incorporating the same active ingredient may be used for distinct purposes like seed treatment, foilar application etc.

Emulsifiable Concentrates (EC)

These are liquid formulations which can be diluted with water before application. The active ingredient is dissolved in a solvent. The fungicides and solvents will opten not mix with water, so an emulsifying agent or water dispersible oil is mixed. When these emulsifiable concentrate is added to water, a milky mixture is formed which is a suspension of active ingredient and emulsified solvent in the water.

Wettable Powders (WP)

Wettable powder is a very common formulation for most of the fungicides, which is used for spray mixtures. The modern wettable powders are water-dispersible which have the quality to wet easily and disperse well in water. They are also called as Water-Dispersible Powders (WDP). The active ingredient is incorporated, usually at the rate of 30-80%, with a finely ground inert dust (filler) such as Kaolin, a wetting agent and a suspending agent. The commonly used suspending agents are sodium lignin sulphonate (Sulphite dye), methyl celluloses, polyvinyl acetate and aluminium silicate. In addition, spreader-sticker is sometimes desirable, especially on

plants with glossy or waxy leaves. Agitation is generally necessary to keep uniform suspension.

A highly developed type of water-dispersible powder is called as colloidal powder, which is so finely divided that the individual particles will never sediment out. A typical colloidal powder contains 5-50% active ingredient, non-ionic wetting agent (1-10% polyethylene oxide condensate), thickening agent like carboxy methyl cellulose and a hydrophilic diluent (carrier) such as bentonite.

Dusts (D)

Dust formulations usually contain 1-10% active ingredient for direct application in dry forms. They are manufactured in such a way that they are light enough to be carried by a slight breeze for a considerable distance. The finely divided particle of active ingredient is carried on a carrier particle. The commonly used carriers (diluents) are attapulgite, kaolin, talc, pyrophylite, diatomaceous earth, bentonite, calcium silicate, hydrated silica, calcium carbonate, magnesium carbonate, gypsum, lime etc.

Granules (Pellets)

Pellets are the formulations of the fugicide with inert materials formed into particles about the size of coarse sugar. The granules normally contain 3-10% of the active ingredient. Due to their size, the granules do not drift but have limited application being confined to soil and seed treatments. Granules have the advantage they can be measured in dry form more easily and acurately than dusts or wettable powders.

Suspension or slurries

These are formulation in which a dry form of the active ingredient is mixed with a liquid. Such formulations usually contain a high percentage of active ingredient similar to wettable powders. They are mixed with water for final use and require agitation. These are mostly used as seed dressers in seed processing companies.

Solutions

True solutions are formulations in which active ingredient or a combination of active ingredients and a solvent is dissolved in water Solutions have the advantage of requiring no agitation after formulation is added in water.

Nowadays, the manufacturers are concentrating to develop new formulations to increase the efficacy of the chemicals. Some new formulations developed are: Soluble Liquid (SL), Soluble Powder (SP), Water Soluble Concentrate (WSC), Suspension Concentrate (SC) and Aqua Flow (AF).

Adjuvants

The fungicides can be commonly applied either as spraying or dusting. In spraying method, the toxicant is made into a suspension in water. In order to increase the efficacy of the water mixed sprays, certain substances like wetting agents, dispersing agents, spreaders, stickers, etc. are added during the formulation of fungicides. These auxillary spray materials are also called adjuvants, which are usually inert materials added to improve the physical characteristics of the toxicant and its carrier. Most of the materials used are surface active agents and therefore induce variation either in surface tension or interfacial tension. The various adjuvants are grouped as follows.

Dispersing agents (Deflocculating agents)

These are the substances which keep fine particles away from each other to prevent deflocculation. These materials, when added to formulations, ensure uniform suspension and retard sedimentation of particles in the spray suspension. These are also called as deflocculating agents. Eg. Gelatin, plant gums and milk products.

Emulsifying agents

Powders (WDP). The active ingredient is incorporated, usually at the rate of 30-80%, with a finely ground inert dust (filler) such as Kaolin, a wetting agent and a suspending agent. The commonly used suspending agents are sodium lignin sulphonate (Sulphite dye), methyl celluloses, polyvinyl acetate and aluminium silicate. In addition, spreader-sticker is sometimes desirable, especially on plants with glossy or waxy leaves. Agitation is generally necessary to keep uniform suspension.

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Many surface active substances like soap, function as emulsifying agent, which retard the settling out of droplets of waterimmiscible liquids like oils. This helps in uniform mixing of substances in water suspensions.

Wetting agent (Wetters)

These are the materials which are added to ensure that there will be no layer of air between a solid and a liquid as they reduce the surface tension of the particles. Wetting agents, when added to aqueous fungicidal preparation, help in easy deposition on leaves. Eg. Polyethylene oxide condensat, esters of fatty acids and flour.

Spreading agent (Spreaders)

Spreaders are the materials added to establish improved contact between the spray materials and plant surface and thus ensuring a good coverage of fungicide. Wetting must precede spreading and this is the only distinction between wetting and spreading. Spreaders also reduce the surface tension and thus improve contact. Eg. Soap, flour, sulphated amines, soapamines, mineral oils, glyceride oil, terpene oil, resinates and petroleum sulphonic acids.

Stickers (Adhesives)

The materials which are added to spray or dust to improve the adherence to plant surfaces are called as stickers. They increase the tenacity of the fungicidal preparations, thus increasing the residual action. Eg. Polyvinyl acetate, polybutanes, fish oil, linseed oil, milk casein,gelatin, dextrines, polyethylene polysulphide, starch, gum arabic, hydrocarbon oils and bentonite clays; Milk casein, gelatin also act as good spreading and wetting agents besides acting as stickers.

Safeners

A Chemical which reduces the phytotoxicity of another chemical is called safener. For example copper sulphate is phytotoxic to plants, but with addition of lime its toxicity is reduced. Lime is, therefore, a safener. Lime is used universally with chemicals to prevent the formation of, or to neutralise arsenic, which is phytotoxic to plants. Glycerine oils are also used as safeners.

Toxicity levels of chemicals

The toxicity levels of the fungicidal formulations are based on the LD50 values, LD50 means the concentration of the chemical at which 50 percent of the test animals dead. The toxicity levels of the chemicals in all formulations as coloured triangle.

Triangle Colour	Toxicity Level	LD50 Value (mg/kg body weight)	
		Oral	Dermal
Red	Extremely toxic	1-50	1-200
Yellow	Highly toxic	51-500	201-2000
Blue	Moderately toxic	501-5000	2001-20000
Green	Slightly toxic(Least toxic)	> 5000	> 20000

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PREPARATION OF FUNGICIDES

Most of the fungicides in use commercially are available as wettable powders and emulsifiable concentrates and few as seed dressers. But some of the fungicides are to be prepared freshly every time as commercial formulations are not usually available. Moreover the fungicides which are unstable and loose the efficacy in storage are usually prepared freshly and applied to the crops. Some of the fungicides which are most commonly prepared are discussed.

Boreaux Mixture

In 1882, Millardet in France (Bordeaux University) accidently observed the efficacy of the copper sulphate against the downy mildew of grapes caused by *Plasmopara viticola.* When copper sulphate was mixed with lime suspension, it effectively checked the disease incidence. The mixture of copper sulphate and lime was named as “Bouillie Bordelaise” (Bordeaux Mixture). The original formula developed by Millardet contains 5 lbs of CuSO4 + 5lbs of lime + 50 gallons of water. The chemistry of Bordeaux mixture is complex and the suggested reaction is:

$$CuSO4 + Ca(OH)2 \; Cu(OH)2 + CaSO4$$

The ultimate mixture contains a gelatinous precipitate of copper hydroxide and calcium sulphate, which is usually sky blue in colour. Cupric hrdroxide is the active principle and is toxic to fungal spores.

In metric system, to prepare one percent Bordeaux mixture the following procedure is adopted:

One kg of copper sulphate is powdered and dissolved in 50 litres of water. Similarly, 1 kg of lime is powdered and dissolved in another 50 litres of water. Then copper sulphate solution is slowly added to lime solution with constant stirring or alternatively, both the solutions may be poured simultaneously to a third contained and mixed well.

The ratio of copper sulphate to lime solution determines the pH of the mixture. The mixture prepared in the above said ratio gives neutral or alkaline mixture. If the quality of the used is inferior, the mixture may become acidic. If the mixture is acidic, it contains free copper which is highly phytotoxic resulting in scorching of the plants. Therefore, it is highly essential to test the presence of free copper in the mixture before applied. There are several methods to test the neutrality of the mixture, which are indicated below:

(i) Field Test: Dip a well polished knife or a sickle in the mixture for few minutes. If reddish deposit appears on the knife/sickle, it indicates the acidic nature of the mixture.

(ii) Litmus paper test: The colour of blue litmus paper must not change when dipped in the mixture.

(iii) pH paper test : If the paper is dipped in the mixture, it should show neutral pH.

(iv) Chemical test: Acid a few drops of the mixture into a test tube containing 5 ml of 10% potassium ferrocyanide. If red precipitate appears, it indicates the acidic nature of the mixture.

If the prepared mixture is in the acidic range, it can be brought to neutral or near alkaline condition by adding some more lime solution into the mixture.

Bordeaux mixture preparation is cumbersome and the following precautions are needed during preparation and application.

(i) The solution should be prepared in earthen or wooden or plastic vessels. Avoid using metal containers for the preparation, as it is corrosive to metallic vessels.

(ii) Always copper sulphate solution should be added to the lime solution, reverse the addition leads to precipitation of copper and resulted suspension is least toxic.

(iii) Bordeaux mixture should be prepared fresh every time before spraying. In case, the mixture has to be stored for a short time or a day, jaggery can be added at the rate of 100kg/100 litres of the mixture.

(iv)Bordeaux mixture is sometimes phytotoxic to apples, peaches, rice varieties like IR8 and maize varieties like Ganga Hybrid 3.

Bordeaux paste

Bordeaux Paste consists of same constituents as that of Bordeaux mixture, but it is in the form of a paste as the quantity of water used is too little. It is nothing but 10 per cent Bordeaux mixture and is prepared by mixing 1 kg of copper sulphate and 1 kg of lime in 10 litres of water. The method of mixing solution is similar to that of Bordeaux mixture. It is a wound dresser and used to protect the wounded portions, cut ends of trees etc., against the infection by fungal pathogens.

Burgundy mixture

It is prepared in the same way as Bordeaux mixture, except the lime is substituted by sodium carbonate. So it is called as ‘Soda Bordeaux’. It was developed Burgundy (France) in 1887 by Mason. The usual formula contains 1 kg of copper sulphate and 1 kg of sodium carbonate in 100 litres of water. It is a good substitute for Bordeaux mixture and used in copper-sensitive crops.

Cheshunt compound

It is compound usually prepared by mixing 2 parts of copper sulphate and 11 parts of ammonium carbonate. This formula was suggested by Bewley in the year 1921. The two salts are well powdered, mixed thoroughly and stored in a air tight container for 24 hours before being used. The ripened mixture is used by dissolving it in water at the rate of 3 g/litre. The mixture is dissolved initially in a little hot water and volume is made up with cold water and used for spraying.

Chaubattia Paste

Chaubattia paste is another wound dressing fungicide developed by Singh in 1942 at Government Fruit Research Station, Chaubattia in the Almora district of Uttar Pradesh. It is usually prepared in glass containers or chinaware pot, by mixing 800g of copper carbonate and 800g of red lead in litre of raw linseed oil or lanolin. This paste is usually applied to pruned parts of apple, pear and peaches to control several diseases. The paste has the added advantage that it is not easily washed away by rain water.

Lime Sulphur

It is a product obtained by the combination of lime with sulphur and chemically it is a mixture of calcium thiosulphate and calcium polysulphides. When the lime sulphur is sprayed on plants, a major portion of the polysulphide is convenrted into free sulphur and this is really act against the fungal pathogens. It is prepared by boiling 9kg of rock lime and 6.75 kg of sulphur in 225 litres of water. The mixture is heated in an open pan for one hour and allowed to settle for several hours. The clear supernatant is filtered and it is called as lime sulphur or calcium polysulphide. It is a good substitute for sulphur. Commercial formulations of lime sulphur are now available in some foreign countries but not in India.

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APPLICATIONS OF FUNGICIDE

Proper selection of a fungicide and its application at the correct dose and the proper time are highly essential for the management of plant diseases. The basic requirement of an application method is that it delivers the fungicide to the site where the active compound will prevent the fungus damaging the plant. This is mostly achieved by spray, fog, smoke, aerosol, mist, dust, or granules applied to the growing plant or by seed or soil treatment. In addition, some trees and shrubs can be protected by injection of fungicide liquid into the trunk or by brushing wounds with fungicide paints or slurries. In the case of sprays, mists, aerosols and fogs, the fungicide is in of droplets of water of another fluid. In the case of smokers, the solid particles of the fungicide are carried by the air. In the case of dusts and granules, the fungicide is straightly mixed with an inert carrier, impregnated into it coated on the particles, which are applied mechanically.

The object of spraying or dusting is to cover the entire susceptible surface of host with a thin covering of a suitable concentration of the fungicide before the pathogen has come into contact with the host. However, these practices may not effectively eradicate the inoculum present on the surface of the seeds or deep-seated in the seed. So, the application of chemicals as seed dressing is highly essential. In addition, soil harbours several pathogens which cause root diseases in several crop plants. So treatment of soil with chemicals is also highly useful in reducing the inoculum load present in the soil. The fungicidal application varies according to the nature of the host part diseased and nature of survival and spread of the pathogen. The method which are commonly adopted in the application of the fungicides are discussed.

1. SEED DRESSING

The seed treatment with fungicides is highly essential because a large number of fungal pathogens are carried on or in the seed. In addition, when the seed is sown, it is also vulnerable to attack by many common soil-borne pathogens, leading to either seed rot, seeding mortality or produce diseases at a later stage. Seed treatment is probably the effective and economic method of disease control and is being advocated as a regular practice in crop protection against soil and seed-borne pathogens. Seed treatment is therapeutic when it kills pathogens that infect embroys, cotyledons or endosperms under the seed coat, eradicative when it kills pathogens that contaminate seed surfaces and protective when it prevents penetration of soil-borne pathogens into the seedling. There are various types of seed treatment and broadly they may be divided into three categories (a) Mechanical, (b) Chemical and (c) Physical.

A. Mechanical method

Some pathogen when attack the seeds, there may be alteration in size, shape and weight of seeds by which it is possible to detect the infected seeds and separate them from the healthy ones.

In the case of ergot diseases of cumbu, rye and sorghum, the fungal sclerotia are usually larger in size and lighter than healthy grains. So by sieving or flotation, the infected grains may be easily separated. Such mechanical separation eleminates the infected grains may be easily separated. Such mechanical separation eliminates the infected materials to a larger extent. This method is also highly useful to separate infected grains in the case of 'tundu' disease of wheat.

Eg. Removal of ergot in cumbu seeds.

Dissolve 2kg of common salt in 10 litres of water (20% solution). Drop the seeds into the salt solution and stir well. Remove the ergot affected seeds and sclerotia which float on the surface. Wash the seeds in fresh water 2 or 3 times to remove the salts on the seeds. Dry the seeds in shade and use for sowing.

B. Chemical methods

Using fungicides on seed is one of the most efficient and economical methods of chemical disease control. On the basis of their tenacity and action, the seed dressing chemicals may be grouped as (i) Seed disinfectant, which disinfect the seed but may not remain active for a long period after the seed has been sown and (ii) Seed protectants, which disinfect the seed surface and stick to the seed surface for sometime after the seed has been sown, thus giving temporary protection to the young seedlings against soil-borne fungi. Now, the systemic fungicides are impregnated into the seeds to eliminate the deep-seated infection in the seeds. The seed dressing chemicals may be applied by (i) Dry treatment (ii) Wet treatment and (iii) Slurry.

. **(i) Dry Seed Treatment**

In this method, the fungicide adheres in a fine from on the surface of the seeds. A calculated quantity of fungicide is applied and mixed with seed using machinary specially designed for the purpose. The fungicides may be treated with the seeds of small lots using simple Rotary seed Dresser (Seed treating drum) or of large seed lots at seed processing plants using Grain treating machines. Normally in field level, dry seed treatment is carried out in dry rotary seed treating drums which ensure proper coating of the chemical on the surface of seeds.

In addition, the dry dressing method is also used int pulses, cotton and oil seeds with the antagonistic fungus like *Trichoderma vitide* by mixing the formulation at the rate of 4g/kg of the seed.

Eg. Dry seed treatment in paddy.

Mix a required amount of fungicide with required quantity of seeds in a seed treating drum or polythene lined gunny bags, so as to provide uniform coating of the fungicide over the seeds. Treat the seeds atleast 24 hours prior to soaking for sprouting. Any one of the following chemical may be used for treatment at the rate of 2g/kg : Thiram or Captan or Carboxin or Tricyclazole.

(ii) Wet seed treatment

This method involves preparing fungicide suspension in water, often at field rates and then dipping the seeds or seedlings or propagative materials for a specified time. the seeds cannot be stored and the treatment has to be done before sowing. This treatment is usually applied for treating vegetatively propagative materials like cuttings, tubers, corms, setts rhizomes, bulbs etc., which are not amenable to dry or slurry treatment.

a. Seed dip / Seed soaking

For certain crops, seed soaking is essential. Seeds treated by these methods have to be properly dried after treatment. The fungicide adheres as a thin film over the seed surface which gives protection against invasion by soil-borne pathogens.

Eg. Seed dip treatment in paddy.

Prepare the fungicidal solution by mixing any of the fungicides viz., carbendazim or pyroquilon or tricyclazole at the rate of 2g/litre of water and soak the seeds in the solution for 2 hrs. Drain the solution and keep the seeds for sprouting.

Eg. Seed dip treatment in Wheat.

Prepare 0.2% of carboxin (2g/litre of water) and soak the seeds for 6 hours. Drain the solution and dry the seeds properly before sowing. This effectively eliminates the loose smut pathogen, *Ustilago nuda tritici.*

b. Seedling dip / root dip

The seedlings of vegetables and fruits are normally dipped in 0.25% copper oxychloride or 0.1% carbendazin solution for 5 minutes to protect against seedling blight and rots.

c. Rhizome dip

The rhizomes of cardamom, ginger and turmeric are treated with 0.1% emisan solution for 20 minutes to eliminate rot causing pathogen present in the soil.

d. Sett dip / Sucker dip

The setts of sugarcane and tapioca are dipped in 0.1% emisan solution for 30 minutes. The suckers of pine apple may also be treated by this method to protect from soil-borne diseases.

(iii) Slurry treatment (Seed pelleting)

In this method, chemical is applied in the form of a thin paste (active material is dissolved in small quantity of water). The required quantity of the fungicide slurry is mixed with the specified quantity of the seed so that during the process of treatment slurry gets deposited on the surface of seeds in the form of a thin paste which later dries up.

Almost all the seed processing units have slurry treaters. In these, slurry treaters, the requisite quantity of fungicides slurry is mixed with specified quantity of seed before the seed lot is bagged. The slurry treatment is more efficient than the rotary seed dressers.

Eg. Seed pelleting in ragi.

Mix 2.5g of carbendazim in 40 ml of water and add 0.5g of gum to the fungicidal solution. Add 2 kg of seeds to this solution and mix thoroughly to ensure a uniform coating of the fungicide over the seed. Dry the seeds under the shade. Treat the seeds 24 hrs prior to sowing.

(iv) Special method of seed treatment

Eg. Acid - delinting in cotton

This is follows in cotton to kill the seed-borne fungi and bacteria. The seeds are treated with concentrated sulphuric acid @ 100 ml/kg of seed for 2-3 minutes. The seeds are then washed 2 or 3 times thoroughly with cold water and shade dried. After drying, they are again treated with captan or thiram @ 4g/kg before sowing.

C. Physical methods

Some of the seed treating procedures do not involve the use of fungicides, the phycical agents like hot water or hot air or steam is used to eliminate the seed-borne infection. These methods are successfully used in controlling certan internally seed-borne disease like loose smut of Wheat and systemically infected diseases caused by virus and MLOs. Some of the commonly followed physical methods are discussed.

(i) Hot water treatment (HWT)

The seeds are soaked in cold water at 20-30^{O}C for 5 hrs to induce the dormant mycelium to grow. Then the seeds are immersed in hot water at 50-54^{O}C for 10 minutes to kill the mycelium. It is very effectively used to eliminate loose smut of wheat. The setts of sugarcane can be treated at 50^{O}C for 2 hrs to eliminate grassy shoot pathogen.

The main drawback in the hot water treatment is that the seeds may be killed or loose its germinability, if the period of treatment exceeds the specified time. So this method is replaced by other physical methods like Hot air and Aerated steam treatment wherein the seeds are exposed only to hot air/aerated steam.

(ii) Hot air treatment (HAT)

Sugarcane setts are treated with hot air at 50^{O}C for 2 hrs to eliminate mosaic virus.

(iii) Aerated steam therapy (AST)

Sugarcane setts are also exposed to aerated steam at 50^{O}C for 3 hrs to eliminate mosaic virus.

(iv) Moist hot air treatment (MHAT)

This method is effectively used in sugarcane to eliminate grassy shoot disease. Initially the setts are exposed to hot air at 54^{O}C for 8 hrs, then exposed to aerated steam at 50^{O}C for 1 hr and finally to moist hot air at 54^{O}C for 2 hours.

(v) Solar heat treatment (SHT)

A simplest treatment has been devised in India to eliminate the pathogen of loose smut of wheat. Previously the hot water treatment was followed to eliminate loose smut. As the termal death point of the fungus and the embry are very close. The extensive care should be taken to avoid killing of the embryo. Luthra in 1953 devised a method to eliminate the deep seated infection of *ustilago nuda.* The method is popularly known as solar heat or solar energy treatment.

Luthras solar energy treatment: The seeds are soaked in cold water for 4 hours in the forenoon on a bright summer day followed by spreading and drying the seeds in hot sun for four hours in the afternoon. Then, the seeds are again treated with carboxin or carbendazin at 2g/kg and stored. This method is highly useful for treating large quantities of the seed lots.

II. SOIL TREATMENT

It is well known that soil harbours a large number of plant pathogens and the primary sources of many plant pathogens happens to be in soil where dead organic matter supports active or dormant stages ofpathogens. In addition, seed treatment does not afford sufficient protection against seedling diseases and a treatment of soil around the seed is necessary to protect them. Soil treatment is largely curativ in nature as it mainly aims at killing the pathogens in soil and making the soil ‘safe’ for the growth of the plant.

A. Physical methods

(i) Soil Solarization

Soil solarization is generally used for controlling soil-borne pathogens like *Pythium, Verticillium, Rhizoctonia, Fusarium* etc. and nematodes in small areas like nurseries. Irrigate the nursery bed to moisten the soil to a depth of 10cm. Cover the bed after 2 days with thin transparent polythylene sheets for 4-6 weeks and then irrigate the beds once in a week. The purpose of irrigation is to increase the thermal sensitivity of resting structures of fungi and to improve heat conduction.

(ii) Steam Sterilization

Steam is passed through perforated pipes at a depth of 15 cm to sterilize the upper layers of soil. It is mostly practised under glass house and green house conditions.

(iii) Hot air Sterilization

Hot air is also passed through pipelines to sterilize the soils in the nursery areas.

(iv) Hot water treatment

It is mainly done in pot culture studies to kill the fungi and nematodes. The pots containing soil are immersed in boiling water at $98^{O}C$ for 5 minutes or drenching boiling water @ 20 litres/ Sq.m.

B. Chemical methods

Chemical treatments of the soil is comparatively simple, especially when the soil is fallow as the chemical is volatile and disappears quickly either by volatilization or decomposition. Soil treating chemicals should be non-injurious to the plants in the soil adjacent to the area where treatment has been carried out because there may be standing crop in adjacent fields. The soil treatment methods involving the use of chemicals are (i) Soil drenching, (ii) broadcasting, (iii) furrow application, (iv) fumigation and (v) chemigation.

(i) Soil drenching

This method is followed for followed for controlling damping off and root rot infections at the ground level. Requisite quantity of fungicide suspension is applied per unit area so that the fungicide reaches to a depth of atleast 10-15 cm.

Eg. Emisan, PCNB, Carbendazim, Copper fungicides, etc.

(ii) Broadcasting

It is followed in granular fungicides wherein the pellets are broadcasted near the plant.

(iii) Furrow application

It is done specifically in the control of some diseases where the direct application of the fungicides on the plant surface results in phytotoxic. It is specifically practiced in the control of powdery mildew of tobacco where the sulphur dust is applied in the furrows.

(iv) Fumigation

Volatile toxicants (fumigants) such as methyl bromide, chloropicrin, formaldehyde and vapam are the best chemical sterilants for soil to kill fungi and nematodes as they penetrate the soil efficiently. Fumigations are normally done in nursery areas and in glass houses. The fumigant is applied to the soil and covered by thin polythene sheets for 5-7 days and removed. For example, Formaldehyde is applied at 400 ml/100 Sq. m. The treated soil was irrigated and used 1 or 2 weeks later. Vapam is normally sprinkled on the soil surface and covered. Volatile liquid fumigants are also injected to a depth of 15-20 cm, using sub-soil injectors.

(v) Chemigation

In this method, the fungicides are directly mixed in the irrigation water. It is normally adopted using sprinkler or drip irrigation system.

III. FOLIAR APPLICATION

A. Spraying

This is the most commonly followed method. Spraying of fungicides is done on leaves, stems and fruits. Wettable powders are most commonly used for preparing spray solutions. The most common diluent or carrier is water. The dispersion of the spray is usually achieved by its passage under pressure through nozzle of the sprayer.

The amount of spray solution required for a hectare will depend on the nature of crops to be treated. For trees and shrubs more amount of spray solution is required than in the case of ground crops. Depending on the volume of fluid used for coverage, the sprays are categorised into high volume, medium volume, low volume, very high volume and ultra low volume.

The different equipments used for spray application are: Foot-operated sprayer, rocking sprayer, knapsack sprayer, motorised knapsack sprayer (Power sprayer), tractor mounted sprayer, mist blower and aircraft or helicopter (aerial spray).

B. Dusting

Dusts are applied to all aerial parts of a plant as an alternative to spraying. Dry powders are used for covering host surface. Generally, dusting is practicable in calm weather and a better protective action is obtained if the dust is applied when the plant surface is wet with dew or rain drops.

The equipments employed for the dusting operation are: Bellow duster, rotary duster, motorised knapsack duster and aircraft (aerial application).

IV. POST-HARVEST APPLICATION

Fruits and vegetables are largely damaged after harvest by fungi and bacteria. Many chemicals have been used as spray or dip or fumigation. Post harvest fungicides are most frequently applied as aqueous suspensions or solutions. Dip application has the advantage of totally submerging the commodity so that maximum opportunity for penetration to the infection sites. Systemic fungicides, particularly thiabendazole, benomyl, carbendazim, metalaxyl, fosety-Al have been found to be very effective against storage diseases. In addition, dithiocarbamates and antibiotics are also applied to control the post-harvest diseases. Wrapping the harvested products with fungicide impregnated wax paper is the latest method available.

V. PAINTING (SWABBING)

This is practiced normally in most of the ornamentals and fruit trees after pruning. The fungicidal solution/paste is painted on the cut ends to prevent the entry of pathogens. Sometimes, the swabbing is done after removing the diseased portion of the plants.

Eg. Swabbing of Bordeaux paste in stem bleeding disease of coconut.

VI. SPECIAL METHODS

1. Trunk Application / Trunk Injection

It is normally adopted in coconut gardens to control Thanjavur wilt caused by Ganoderma lucidum.

In the infected plant, a downward hole is made to a depth of 3-4” at an angle of 450C at the height of 3’ from the ground level with the help of an auger. The solution containing 2g of Aureofungin soil and 1 g of copper sulphate in 100 ml of water is taken in a saline bottle and the bottle is tied with the tree. The hose is inserted into the hole and the stopper is adjusted to allow the solution in drops. After the treatment, the hole is covered with clay.

2. Root Feeding

Root feeding is also adopted for the control of Thanjavur wilt of coconut instead of trunk application. The root region is exposed; actively growing young root is selected and given a slanting cut at the tip. The root is inserted into a polythene bag containing 100 ml of the fungicidal solution. The mouth of the bag is tied tightly with the root.

3. Pseudostem Injection

This method is very effective in controlling the aphid vector *(Pentalonia nigronervosa)* of bunchy top of bannana. The banana injector is used for injecting the insecticide.

Banana injector is nothing but an Aspee baby sprayer of 500 ml capacity. In which, the nozzle is replaced by leurlock system and aspirator needle No. 16. The tip of the needle is closed and two small holes are made in opposite direction. It is for free flow of fluid and the lock system prevents the needle from dropping from the sprayer.

One ml of monocrotophos mixed with water at 1:4 ratio is injected into the pseudostem of 3 months old crop and repeated twice at monthly intervals.

The same injector can also be used to kill the bunchy top infected plants by injecting 2 ml of 2, 4-D (Femoxone) mixed in water at 1:8 ratio.

4. Corn Injection

It is an effective method used to control Panama will of banana caused by *Fusarium oxysporum* f. sp. *cubense.*

Capsule applicator is used for this purpose. It is nothing but an iron rod of 7 mm thickness to which a handle is attached at one end. The length of the rod is 45 cm and an iron plate is fixed at a distance of 7 cm from the tip.

The corm is exposed by removing the soil and a hole is made at 45) angle to a depth of 5 cm. One or two gelatin capsules containing 50-60 mg of carbendazim is pushed in slowly and covered with soil. Instead of capsule, 3 ml of 2% carbendazim solution can also be injected into the hole.

5. Paring and Pralinage

It is used to control *Fusarium* wilt and burrowing nematode (*Radopholus similis)* of banana. The roots as well as a small portion of corm is removed or chopped off with a sharp knife and the sucker is dipped in 0.1% carbendazim solution for 5 minutes. Then, the sucker is dipped in clay slurry and furadan granules are sprinkled over the corm @ 40 g/corm

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EVALUATON OF FUNGICIDES

Several techniques for evaluating chemical fungicide have been described from time to time by different workers. Modifications of the already described techniques have also been suggested. Whereas, it is difficult to pinpoint the best method of evaluation for a certain chemical, much would depend upon what is the objective for which a certain material is to be evaluated. Though various techniques have been described by workers, it is possible to consider a few which would serve the need of laboratory screening of most of the chemicals. Some such techniques have been described in this chapter.

A. Laboratory Methods

1. Spore germination assay

The fungal spore suspension and fungicide solution of desired concentration are prepared separately and mixed on cavity slides. The slides are kept in moist chamber for 6-8 hr and the numbers of spores germinated are recorded and per cent germination is worked out.

Different concentrations (100, 500, I 000 ppm) of test fungicide are prepared. Spore suspension of the test fungus is also prepared (50,000 spores/ ml). Two drops each from fungicidal solution and spore suspension are pipetted on the cavity slide and incubated at 24-25'C in a moist chamber for 6-8 hour. Germination count is taken at different intervals (6, 12, 24 hr.). Sterile distilled water, instead of fungicidal solution, serves as control.

Dosage response or toxicity curve is prepared. The per cent inhibition of spore germination is plotted against the concentration of the fungicide. The common unit for comparison is the LD50 value, the dose that inhibits germination of 50 per cent spores.

2. Poisoned food technique

The principle involved in this technique is to poison the nutrient with a fungicide and then allowing a test fungus to grow on the medium. In this technique, either a solid (agar) or a liquid medium can be used.

(i) Solid (agar) medium

Potato dextrose agar (PDA) medium is prepared in flasks sterilized. Different concentrations of fungicide (100, 250, 500, 1 000 ppm) are prepared by mixing with medium with constant stirring. The medium is then poured into sterilized petriplate and allowed to solidify. A disc of 7 mm diameter of test fungus grown on a solid medium is cut with the help of a sterilized cork borer and placed aseptically in the centre of the petriplate containing medium and the plates are incubated at room temperature for 7 days. The culture discs grown under the same conditions on PDA without the test fungicide

serve as control. The diameter of the fungal colony is measured at 24 hr intervals

(ii) Liquid medium

Richard's medium without agar is prepared and sterilized. Different concentrations of fungicidal solution are prepared as in previous method. A disc of 7 mm diameter of fungal growth on solid medium is removed with a sterile cork borer and transferred to the medium. The flasks are incubated at room temperature for 7days.The mycelial mat is removed by filtration and the dry weight is determined. The fungal discs grown in the medium without fungicide solution serve as control.

3. Inhibition zone technique

Spore suspension of the fungus is prepared from 7 day old culture with sterile distilled water. Different concentrations of fungicide are prepared. Twenty ml of PDA medium is seeded with 3 ml of spore suspension (1 x 106 spores / ml) and allowed to solidity. The petridishes are frozen to condense water. Paper discs are dipped separately it) known concentration of fungicide solution and placed at the centre of the seeded medium. The plates are incubated at 28-30'C for 24-48 hours. The inhibition zone of the fungal growth around the treated disc is measured. The paper discs dipped in the sterile water serve ascheck.

4. Evaluation of systemic fungicides

Translocation of fungicides in plants is conveniently described as apoplastic, symplastic or ambimobile. Apoplastic fungicide is characterised by being transported in the direction of the transpiration stream with long distance transport occurring in the xylum (upward). Symplastic fungicides are characterised by being transported in the direction of assimilate movement with long distance transport occurring in the phloem (downward). Some fungicides can be transported by both system and are termed as ambimobile.

(i) Upward translocation (Apoplastic)

The upward translocation of systemic f ungicides can be studied by the Root dip technique.

Different concentrations of fungicide are prepared in sterile water. The roots of the seedlings are washed free of soil in sterile water and immersed in the known concentration of a fungicidal solution kept in a conical flask or test tube for 2 hours. The flask is covered with a black paper to prevent the roots from turning green. The top portions of the seedlings are then taken in bits and bioassayed by placing in seededagarfollowinginhibitionzonetechnique. Theseedlingsdipped in sterile water serve as check.

(ii) Downward translocation (Symplastic)

Different concentrations of fungicidal solution are prepared. The seedlings with 4-5 leaves are sprayed with the test solution, separately and

seedlings are incubated at room temperature for 24 hours. The plant parts are then cut separately as leaf, stem and root and placed on seeded agar medium following inhibition zone method. At the end of incubation period, the inhibition zone is recorded. The seedlings sprayed with sterile water serve as check.

5. Evaluation of soil fungicides

In this method, discs cut form fungal cultures grown on nutrient medium are placed in fungicide treated soil. After an incubation period, the discs are removed and washed free of soil and viability of the fungus is determined by culturing the discs on a nutrient medium.

Air dried soil is sterilized in an autoclave for one hour at the pressure of 1. 1 kg/cm. The sterilized soil is placed in a glass jar to a height of one inch. A fungal disc of 1 0 mm diameter is removed from the outer margin of PDS culture and placed on the soil and then covered again with sterilized soil. Five ml of fungicidal solution of known concentration is poured on the soil surface with a pipette and incubated at 25^0 C for 24 hours. The discs placed in sterilized soils with out fungicides solution serve as check. At the end of the incubation period, the disc is removed and washed free of soil. Disc is placed on agar medium and checked for growth. This growth is compared with the disc removed from the sterilized soil with out fungicide.

B. Field Method

In this method, the fungicides are directly applied on the plants in the field and efficacy is worked out based on the disease incidence. The plants in the field are labelled in groups and are sprayed separately with different concentrations of the fungicide. The disease intensity is recorded after a specified time interval, using a standard disease score chart with 0-9 grades. Per cent Disease Index (PDI) is worked out using a standard formula to know the efficacy of the fungicides. The same method is also practicable in glass house of grading the disease intensity and calculating PDI are discussed in detail in the next chapter.

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PLANT DISEASE ASSESSMENT

The assessment of the amount of disease on a plant, more importantly on a crop, is essential in any quantitative epidemiological study. Disease assessment also forms the fundamental basis of many other aspects of plant pathology. Assessment data are essential to breeders, fungicide manufacturers, economists, government agencies and academics in their various evaluations of resistance, treatment efficacy and resource priorities.

With such diverse investigational objectives, the precision of the assessment methods and the quality of data collected will vary accordingly. Inevitable, as large areas may be involved, sampling will be carried out, a compromise being necessary between what ideally should be done and what it is practical and economical to do.

Most importantly, assessment of a particular disease in an individual crop over several years can provide indicators to elucidate the factors governing its incidence and severity. This information can also used to devise forecasting systems.

Methods of Assessment

1. Assessment in terms of percentage

This method is applicable for those diseases which complete death of plants (eg. damping off, root rot , wilt, etc.). This also followed in systemic diseases (eg. Virus and MLO diseases, etc.) and in the diseases leading to total destruction of infected organs (eg. Smut, green ear, etc.) The per cent disease incidence is calculated using the following formula,

$$\text{Per cent disease Incidence} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

2. Assessment using disease grades

This method is useful to assess the foliar diseases like downy mildew, powdery mildew, leaf spot, leaf blight, canker, rust, etc. A of disease with area affected or per cent grains affected, indicating the grades anging from 0 to 9. The Plants are observed individually and severity percentages are arrived and the numerical rating is given as 0, 1, 3, 5, 7 or 9 as shown below. Normally, 50 or 100 plants or leaves are observed and individual rating is given.

Eg. Paddy - Blast *(Pyricularia oryzae)*

Grade	
0	No visible symptoms
1	< 1% leaf area affected
3	1-10% leaf area affected

5 11-25% leaf area affected
7 26-50% leaf area affected
9 >50% leaf area affected

Eg. Sorghum-rust *(puccinia purpurea)*

Grade
0 No visible symptoms
1 < 1% leaf area affected with pustules growth
3 1 -1 0% leaf area affected with pustules
5 11-25% leaf area affected with pustules
7 26-50% leaf area affected with pustules
9 >50% leaf area affected with pustules

Eg. Cumbu-Ergot *(Claviceps fusiformis)*

Grade
0 Earheads free from infection
1 < 1% grains in earhead repalaced by sclerotia
3 1-10% grains in earhead replaced by sclerotia
5 11-25% grains in earhead replaced by sclerotia
7 26-50% grains in earhead replaced by sclerotia
9 >50% grains in earhead replaced by sclerotia

Eg. Grapes-Downy mildew *(Plsmopara viticola*)
Bhendi-POwdery mildew *(Erysiphe cichoracearum)*

Grade
0 No visible symptems
1 <1% leaf area with mildew growth
3 1-10% leaf area with mildew growth
5 II -25% leaf area with mildew growth
7 26-50% leaf area with mildew growth7
9 >50% leaf area with mildew growth and severe infection on fruits

The sampling unit and sample size will vary according to the type of experiment, nature of host and disease involved. In the case of foliar diseases where the assessment of all the plants in a plot or a field is not possible, 1per cent representive population is selected at random for assessment. In the case of tree crops, five trees are selected at random and 20 representative leaf or fruit sample are assessed at random. In each tree using the standard disease score chart. The percent disease index is worked out using the following formula.

$$PDI = \frac{\text{Sum of individual rattings}}{\text{Total number of plants}} \times \frac{100}{\text{maxmiuam disease grade/leaveas observed}}$$

The assesssment of the disease intensity and evaluating yield loss are important factors with regard to a plant disease in a particular crop. This is

important to growers to warrant the trouble due to a disease and to take up control measures. Therefore, knowledge about nature of disease, its intensity and enconomic importance is necessary to forecast a disease.

EPIDEMIOLOGY

Epidemiology is a study of outbreak and spread of diseases in a population. Epiphytology or epidemioloy of plant diseases is essentially a study of the rate of multiplication of a pathogen which deteffnines its capacity to spread a disease in a plant population.

The buidup of a epiphytotic is actually the manifestation of a balance between two opposing forces. On one side are the growth character and pathogenic potentialities of the pathogen and on the other side are the forces that counteract these capabilities of the pathogen. Environment plays a very decisive role in epiphytotics.

Compound Interest and Simple Interest Diseases

The term compound interest and simple interest for explaining the rate of increase of pathogens irt populations during the crop season was introduced by van der Plank in 1963. The term Compound Interest diseases refer to those diseases in which the incubation period and sporulation period of the pathogen is short. Thus, there are many generations of the pathogen in the life of the crop if pathogens spreading by means of air disseminating propaguies, such as rusts of cereals and late blight of potato.

Simple Interest diseases are those in which there is only one generation of the pathogen in the life of the crop. The primary inoculum is seed or soil borne and secondary infection rarely occurs during the season e.g., Diseases caused by soil borne fungi such as wilts and root rots and seed and soil borne smuts such as loose smut of wheat, covered smut of barley, sorghum, etc.

Measuring Disease Growth Rate The factors that affect the cause of an epidemic can be put under three headings.

(i) Original amount of inoculum

(ii) Rate of progress of the disease in the population.

(iii) Time during which the disease can progress.

The establishment of an epiphytotic require following conditions

(i) Distance of susceptible plants from the source of primary incoculum

(i i) Abundance and distribution of susceptible hosts
(iii) Disease processes in the host due to environments
(iv) Presence of suitable alternate or collateral hosts
(v) Presence of aggressive isolate of the pathogen
vi) High birth rate of the pathogen
(vii) Low death rate
(viii) Easy and rapid dispersal of the pathogen
(ix) Adaptability of the pathogen
(x) Optimum weather

However the epiphytotic does not remain forever in a population. After development, a stage is reached when it shows a decline by itself. The causes for the above are as follows:

(i) The saturation of the pathogen in a host population

(ii) Reduction in aggressiveness of the pathogen.

The above conditions for the development and decline of epiphytotics can be expressed by the following equation.

Disease severity = lnoculum potential x Disease potential

Spore Trapping: Principles and Methodology

Dispersal, dissemination or spread of pathogenic propagules, from the site of production, is pivotal in epidemiology, for causing primary or secondary infection, i.e., successful disease progress the pi-opagules must move. This may on their own, to very limited extent, or ti-iay be mediated through various agencies, viz., Air (Wind), water, insects or nematodes, etc., without dispersal there will not be epidemic. Dispersal of plant pathogens, an area of immense importance, had not been well attended or ignored by the scientists, following are some of the limitation in study of dispersal phenomenon:

1. Disperal involves dimensions of time and space
2. Experiments under controlled conditions not possible
3. Results of field experiments are not comparable
4. Removal and deposition of propagules require knowledge of physics
5. lnvolvement of mathematical and computer models

The process of spore dispersal involved three phases:

1. LIBERATION OR REMOVAL OF SPORES FROM PARENTAL TISSUE

This may be an active- process, involving biological or other form of energy or a passive phenomenon. There is lot of variation in amount of force

required for removal of spores *(Helminthosporium maidis* 0.018 dynes-generated by a wind of 5 m/sec) while the spores of *Erysiphe graminis* takes fraction of this force for detachment

The maximum wind speed required to detach/remove a fungal spore from parental tissue is known as critical wind speed. If we see the structure of boundary layer of air just above the leaf surface, where fungal spores are produced. We find that normal wind speed goes on reducing as we go nearer to leaf surface. It has been found that if normal wind speed is 25 m/ sec, the wind speed at the leaf surface will be reduced to 5 m/ sec. This high speed (5 m/sec) is achieved for a fraction of time (10^{-3} Fe 10^{-4} sec) due to GUSTS: which are transitional or intermittent high speed winds for a very short time. The roughness of leaf surface and the 'speed breakers' in crop canopy are some of ttio, 'actors which are responsible for creations of Guts-

2. TRANSPORTATION OR FLIGHT OF SPORES

Once the spores are detached or remove from parental tissue and cross the boundary layer the come in air and move/soil with wind like any other suspended particle. The convection Currents take ttiet'n to different heights in atmosphere and the wind speed alongwith wind direction determine their destination. More the height spores gain, more is the distance they travel.

3. DEPOSITION OR SETTING OF SPORES

Spores suspended in atmosphere and moving with air gradually settle down. Twoprocessareimportaiit:

(i) Sedimentation due to Gravity

The characters of spores *viz*. weight, shape and size are important determinants in the process of sedimentation.

(ii) Impaction due to inertia

The spores moving with air may strike some surface and may strick to it. Mass of the spore and wind speed determines the efficiency of impaction.

METHODOLOGY OF SPORE TRAPPING

The materials (spore traps) or the methodology of spore trapping depends on the objectives of the worker:

(i) Biology of the pathogen
(ii) Spore dispersal gradients
(iii) For infection forecasting
(iv) Disease management

CHOICE OF SAMPLER

1. Microscopic glass slides or Cyclindrical rods

Surface is made sticky by putting tapes or grease. Useful for collecting information on arrival of spores in an area. Quantitative estimation not feasible. The number of spore collected is very low and difficult to locate under microscope.

2. Hirst Spore trap

Hirst (1 952) designed and fabricated, air is sucked in a chamber and strikes a Drum wrapped with celophone tape. The spores in air stick to greased surface of tape. Give continuous count of spores in 24 hrs.

3. Anderson Cascade spore sampler

It separates nortnat and large spores with the help of perforated discs through which air passes in a chamber. Petriplates with nutrient agar are used to collect spores.

4. Bourdillon Slit sampler

Air is sucked in a chamber by vaccum pump. The air enters through a slit and strikes the rotating petridisc containing agar medium which retains the spores. Concentration of viable spores ran be determined by counting the germinating spores.

5. Rotorod Spore Traps

They are very handy traps. The trapping arms (H or U shaped) move/rotate at very high speed by a electric motor. The leading edge of arms are made sticky to catch spores from air.

6. Burkard's 7 day volumetric spore trap

It is more recent model of spore trap available. It records the spores in air on 7 day basis on a celophane strip wrapped on a drum rotating inside a chamber. The air is drawn by a pump.

TYPES OF STUDIES CARRIED OUT BY SPORE TRAPPING

1. Periodicity of spore release

Fungal genera differ in time of spore production the conditions required for their liberation and dispersal are also different. The number of a specific type of spore is not same throughout the day.

Periodic observation on spore count present in air can give idea about time of their maximum release or Periodicity of spore release.

2. Vertical distribution of spores

Spores may be produced or released at different height from soil level. So spore concentration in any field will differ in different heights. This can be measured by trapping spores at different height in field.

3. Horizontal dispersal of spores

The source of inoculum (spores) may be point, time, area or volume. The spores thus produced move with air in its direction. Thus dispersal gradients are created. The numberof spores are maximum at the source and are reduced as we move away from source. The dispersal gradient is steeper if we are moving against the wind direction.

SPORE TRAPPING UNDER CONTROLLED CONDITIONS

Rothamsted Experimental Station (U.K.) has a very unique facility where the wind of a desired speed or Rain of desired amount can be generated inside Raintower-wind tunnel complex and spores can be trapped at different distance from the source (infected plant), kept on a platform inside the complex. The temperature and humidity of wind blowing inside can also be regulated with the help of devices attached to the complex. The factors that can be studied are.

1. Effect of varying wind speeds
2. Effect of Rain rates
3. Effect of both wind and rain combined together.

Spore trapping is an useful function for understanding epidemology of a disease as well as behaviour- of the pathogen. This can help in developing various models either on dispersal or on (Epidemiology of a disease, which will ultimately help in management of disease. Spore trapping is a very important component of aerobiology.

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PLANT DISEASE SURVEY

Disease survey is one of the main aspects in the disease management studies. The plants disease survey is very useful (1) to know the prevalence of disease in a crop in a particular area, (ii) to study the damages caused by a particular disease and assess the economic importance of the disease, (iii) to correlate the disease incidence with the weather factors, vegetation and soil factors, (iv) to give suitable forecasting to the farmers about the outbreak of file disease and (v) to device suitable control measure in advance by cultural and chemical means.

In Tamil Nadu, a well organised Pest Surveillance Programme is functioning throughout the state. The officials of the Department of Agriculture and Department of Horticulture and Plantation crops are doing the survey in collaboration with the scientists of Tamil Nadu Agricultural University and they have sent weekly pest/disease surveillance report to the University Analysis and compilation. The pest/disease surveillance report should also accompany the details on the daily weather factors, viz., maximum temperature, minimum temperature, relative humidity, wind velocity, rainfall, rainy days, etc.

METHODS OF SURVEY

(i) Fixed plot survey

Select two villages and fix two fields per village. Select five sampling plots per field of one acre and it should be three metres away from the bunds. The size of the sample plot should be 1 Sq, m. Select 20 plants or leaves perplot and observe forthe disease intensity using the standard disease score chart having 0-9 grades. Work Out the percent disease index(PDI)usingthestandardformula. Survey the field every week and prepare the report.

(ii) Roving survey

Select four villages and in each village, fix two fields. Observe and score 1 00 plants or leaves in each field by walking across, starting from south west comer to North East corner. Work out the PDI using the standard formula. Survey the fields every week and prepare the report.

DISEASE SURVEILLANCE REPORTS

(i) White Report

It contains the disease/pest surveillance detail in a particular block/division/district for a week.

(ii) Yellow Card

It should be sent when the disease/pest occurrence attained half the level of Economic Threshold Level (ETL).

(iii) Red Card

It should be sent when the disease/pest occurrence exceeded the Economic Threshold Level.

The weekly data on disease incidence along with the weather parameters collected from fixed plot and roving surveys are reported to the Joint Director of Agriculture in each district. These data collected from the farmers'fields and research centres in the district are pooled and interpreted jointly by the plant protection scientists of the university and Deputy Director of Agriculture (Plant Protection) every week and the action to be taken is decided. After analysing the weekly survey reports and the data on the weather factors, the message on the severity level of disease and control measures to be adopted are disseminated to the farmers through mass media. So surveillance and monitoring methods must be continuously adopted to trace the diseases, their movement and spread with a view to prevent the epidemics.

PLANT QUARANTINE

The term 'Quarantine' literally means a 40 day period. This once referred to the period of detention for ships arriving from countries where epidemic diseases like bubonic plague, cholera and yellow fever were present. Lateron,the term'Quarantine"came to be used for the d and the practices connected with it, irrespective of the period. 'Plant Quarantine' is the use of exclusion or other regulatory actions as a control strategy against the entry of exotic new pests and pathogens along man-made pathway into a new area.

Often a new post, disease or wead has accidentally entered a country where it did not exist before and has multiplied, spread and caused enormous damage to the crops of that country. The most devastating disease in coffee, coffee rust *(Hemileia vastatrix)* was introduces to India from Sri Lanka in 1876. Late Blight *(Phytophthora infestans)* of potato was introduced into India in 1883 from Europe. Rubber powdery mildew *(Oidium* sp.) was introduced from Malaysia in 1938, causing great concern in Kerala. Fire blight *(Erwinia* of pear and other pomes was introduced from England in 1940. Bunchy top of banana was introduced from Sri Lanka in 1940 to South India. Black rot of crucifers *(Xanthomonas campestris)* believed to have been introduced to India with seeds imported from Holland, and other European countries after World War II. Wart disease *(Synchytrium endobioticum)* of potato was noticed in Darjeeling district of West Bengal since 1953, having been introduced with seed potatoes from Hollarid.

Plant Quarantine Regulation in India

In India, two categories of regulatory measures are in operation for controlling posts, diseases and weeds. In the first category, regulatory measures are aimed to prevent the introduction of exotic pests and diseases into the country or their spread from one state or union territory to another. The second pertains to suppression or prevention of spread of pests and diseases in localized areas with a state or union territory. The foffner derives its authority from the Destructive insects and pests (DIP) Act 1914 of the Central Government and the latter from Agricultural Pest and Diseases Acts of the various states.

Quarantine stations have been established in airports (Bombay, New Delhi, Madras, Calcutta, Amristar, Tiruchi and Trivandrum). Seaports (Bombay, Madras, Calcutta, Cochin, Tuticorin, Vishakapatnam, Rameswaram and Bhavnagar), land frontiers of AftaiiWagha border (Amristar, Kallimpong etc.) and in railway stations at Attari and Amristar.

Plants and plant products to pass through these quarantines should be accompanied by a Phytosanitory Certificate, as per international convention, issued by the competent authority of the exporting countries. All these products will be inspected and fumigated if at these quarantine stations if necessary. To export the plant products from Inida, state plant pathologists have been empowered to issue phytosanitary certificates.

Embargo

Some of the plant materials have been totally banned for import into India irrespective of any certificate. Potatoes cannot be imported to India from any wart disease *(Synchytrium endobioticum)* and/or golden nematode infested areas. Sugarcane cuttings from Australia, Fiji and Philippines cannot be imported. Import of cocoa from Africa and Sri Lanka is totally banned. Rubber nd seeds from South America and West Indies and Sunflower seeds from Argentina and Peru are totally banned.

Domestic Quarantine

Within India, domestic quarantine has been established. To prevent the spread of Bunchy top of banana, an Act has been promulgated which prevent the movement of suckers, stems and materials of banana plant used for packing and wrapping from the states of Assam, Kerala, West Bengal and Orissa to other states. To prevent the spread of b nana mosaic, movement of banana suckers from Gujarat and Maharashtra to other parts of India is prohibited. Potato wart *(Synchytrfium endobioticum)* is prevalent in Darjeeling district of West Bengal to other states is prohibited.

SEED HEALTH TESTING

Seeds carry several destructive pathogens that often take a heavy toll by causing severe diseases on crops raised from them. Disease agents may be carried externally or intemally. Disease agents carried with seeds may be fungi (e.g. loose smut of wheat, brown spot of rice, smut of sorghum) or bacteria (e.g. black leg of cabbage, blackarm of coffon) or virus (e.g. bean mosaic, lettuce mosaic) or even nematodes (e.g. earcgcide of wheat, paddy white tip). So seed health testing is very essential to obtain the information on the the seed lot.

Methods of testing seeds for the presence of pathogens are of four main types. The seeds may be (i) directly examined, (ii) examined after incubation, (iii) plated on agar so that the pathogens grown out into colonies and (iv) subjected to tehniques which allow the use of modern serological developments viz., ELISA, SSEM and IF.

I. DIRECT EXAMINATION

This is useful in preliminary screening studies to avoid the heavily infected seed stocks. It reveals the presence or absence of pathogens, but do not give any indication about the viability of the pathogens.

(a) Dry Seed Examination

This method gives the information on physical purity of the seed lot. It is suitable to detect the sclerotia, galls, smut balls, discolouration, malformation, resting hypha, fruiting bodies of fungi (oospores, smut spores, pycnidia, perithecia) and bacterial masses. A sample of 400 seed (in replication of 1 00 seed each) may be drawn and examined care" for the presence of discoloured, malformed and diseases affected seeds. The number is recorded and the percentage is worked out on the number basis.

(b) Seed Washing Technique

This is useful in testing surface-borne, contaminating fungi like smuts, bunts, downy mildews, powdery mildews, rusts, etc. Two gram seed sample is taken in a test tube and mixed well by adding 2 ml of sterile water, for 5 to 10 minutes. The supernatant is taken and centrifuged at 2000 rpm for 1 0 minutes. The supernatant solution is observed for the fungal structures under a microscope.

II. INCUBATION METHOD

(a) Blotter Method

In this method, the seeds are placed on moistened blotters (three layers of filter paper in a petridish form a blotter). Generally 400 seeds are drawn for this test, with replication of 100 seeds each. Twenty five seeds are placed in blotters at equal distance. The blotters are incubated for 7 days

under alternating cycle of Near Ultra Violet (NUV) light (12 hr.) and darkness (12 hr.) at 20^0C. Then the fungal growth developed on the seeds are examined and identified under Sterioscopic microscope.

(b) Freezing Method

It is a modified blotter method wherein the blotters are incubated at 20^0C for 2 days, then at -20^0C for a day and again at 20^0C for 5-7 days.

(c) 2, 4-D Blotter Method

In this method, the seeds are placed on blotters added with 0. 1 -0.2% 2, 4-D solution and incubated at 22^0C for 7 days.

III. AGAR PLATE TECHNIQUE

In this method, the seeds are treated with 1% Sodium hypochlorite solution (to prevent the growth of saprophytic fungo for 5 - 10 minutes. Then, the seeds are placed on potato dextrose agar medium or malt extract agar medium and incubated at 20±2^0C for 7 days. The plates are examined periodically for the fungal growth.

IV. SEROLOGICAL AND OTHER METHODS

These are used mainly to detect seed-bome bacteria, viruses and mycoplasma but ter-hniques are also rapidly developing for fungi.

The methods used are listed below.

(i) Enzyme Linked Immuno-Sorbant Assay (ELISA)

The conventional serological techniques cannot be used for many viruses because of limitations such as low virus concentrations, unsuitable particle morphology or the presence of plant extracts of virus inactivators or inhibitors. These are largely, overcome by the use of micro plate method of ELISA. Polyclonal and more recently monoclonal antibodies have been used forthedetection and'identification of viruses. In this case, a substrate that genera duces a cotorimetric reaction upon hydrolysis by an enzyme is used to provide a means for qualitative and quantitative measurement of viral antigen.

(ii) Enzyme Linked Fluorescent Assay (ELFA)

It involves the utilisation of florescent substrate such as 4Methyl umbelliferyl phosphate (.MUP) to enhance the sensitivity of ELISA technique.

The other techniques used are Serologically Specific Electron Microscopy (SSEM) and Immuno-Fluorescence method (IF).

(V). INDICATOR PLANT METHOD

This is especially useful for bacteria and viruses. The seed extracts are prepared and inoculated on indicator plants. The virus/ bacterium is identified on thesymptom development.

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CROSS PROTECTION IN PLANTS

A plant already infected by a strain of a given virus generally offers resistance to the infection of another strain of the same virus. This kind of resistance seen in plants is called, cross protection. This phenomenon is well established in citrus tristiza virus causing quick decline disease.

In Tamil Nadu, tiisteza is reported to be severe in acid lime gardens. This is transmitted by black citrus aphids *(Toxoptera citricidus).* The occurrence of mild and severe strains has been reported in tristeza virus. So, it is possible to inoculate the mild strain to the young acid lime seedlings grown in isolated nurseries. This will confer protection against the severe virulent strain.

Symptoms of severe strain

The infected trees in general do not show the seasonal new flushes orgrowth. The leaves show chlorosis along the main and lateral veins with a large number of vein. DefoUation from tip downwards and show dieback symptoms and tvags remain barren. Sudden death of some trees may occur within a few months following infection but some may produce sparse foliage and bear fewer small fruits of infor quality. The severe strain also produce stem pitting symptom. This is characterised by small or long depressions or grooves in the wood of the branches and trunk.

Symptoms of mild strain

(a) On the leaves only few flecks are seen

(b) Less number of pits develops which are smaller in size than the severe strain affected stem. The trees infected with mild strains may survive for more than 30 years with chlorotic leaves, but their productivity is considerably reduced. These trees are used as source of mild strains.

Pre-immunization technique

The grafting method followed in this technique is Patch budding. Four to five months old seedlings are normally selected for grafting. Scion material (bark piece of 5 x 2 mm size) should be collected from the trees with the symptoms of mild strain. The scions should be stored in a cool box to prevent desiccation and grafted on the seedlings, usually within hrs after collection.

In the seedlings to be cross protected, a bark piece of 5 *x 2* mm size is removed and bark patch collected from the mild strain source is inserted and covered with a Polythene p. The graft union is examined after 15 days of inoculation. If the union remains green it indicates the successful establishment of the grafting. This observation confirms the entry of mild strain of the virus into the plant system. Such seedlings can confer appreciable resistance against a virulent strain. The resistance due to pre-

immunization may be due to the fact that mild strain occupies the whole plant system and prevents subsequent infection by the severe strain.

In addition to virus disease, the same cross protection phenonmenon has been well established in some of the bacteria diseases. If a plant is first infected with a mild or avirulent strain of a bacterium, the plant frequently escapes disease from other strains that could cause more severe symptoms. Avirulent strain of *Agrobacterium tumafaciens* protects the crop from severe infection by virulent strain of *A.tumafacions.* The same mechanism is also established in fire blight disease of apple caused by *Erwinia amylovora*- In addition, heatkilled cells of *Pseudomonas tabaci* protected the tobacco from disease infection by a virulent strain.

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DIAGNOSIS OF PLANT VIRAL DISEASES

The infection of virus in a plant can be identified by the methods of serology and chemical means.

CHEMODIAGNOSIS

It is a technique of identification of plant virus diseases using certain chemicals. Chemical methods to identify certain plant virus diseases have been well established.

(i) Terazolium chloride test

This method is specially followed for detection of banana bunchy top virus and cassava mosaic virus. Thin section are taken from the mid rib or petiole of the leaf and soaked in 5 ml of 1% 2, 3, 5 triphenyl totrazolium for 30-60 minutes in a test tube. The sections are then removed and observed for" co4oumtion. If the sections turn to brick red colour, indicates the infection of virus in the plant sample. If the sections remain green, indicates the healthy nature of the plants. This helps in selection of disease free planting materials.

(ii) Iodine test

This is used to identify Rice Tungro Infection. Iodine solution is prepared by dissolving 2 g of Iodine and 6 g of Potassium iodide in 100 ml of water.

The iodine solution is taken in a test tube and 1 0 cm long leaf tip is dipped in the solution for 15 minutes (Collect the leaf samples before 6 am in the morning). Then, the leaf tip is taken out and washed thoroughly with water and examined. Tungro virus affected leaves show dark reddish brown streaks, while the healthy leaves retain their green colour.

A solution containing 1 0 ml of tincture iodine in 140 ml of water ran also be used for this test. In this case, leaf samples should be dipped for 1 hour.

SERODIAGNOSIS (SEROLOGY)

The study of relation between an antigen and an antibody is called serology.

All serological assays depend on the interaction between an antigen and an antiserum. The antigen is usually allien proteins like that of virus particles can induce the production of specific proteinaceous antibodies (immunoglobulins) in certain cells of lymphatic tissues of animals. The cleared blood serum of the animal containing antibody is called antiserum.

Antiserum is prepared by injecting purified virus suspension intravenously or intramuscularly or both, into rabbits or guinea pigs or mice. Normally, 2-4 injections are given at 3 weekly intervals. The blood is drawn

from the animal by bleeding at weekly interval. The blood serum is purified by centrifugation and stored at -18^{0}C in a refrigerator or deep freeze. An antigen will react only with a particular antibody which is specific for it and this deteffnines the serological reaction. Several sensitive seralogical techniques have been developed to detect the virus infection in the plant samples.

(i) Slide agglutination test

In this method, equal quantities of antiserum (antibody) and antigen (plant sample) are placed in the depression of a cavity slide and incubated at 25^{0}C for 90 minutes. Then, the slides are observed at 15 minutes interval. If the precipitate is seen in the test sample, indicates the presence of virus in the sample. The precipitant is formed due to specific binding of the virus protein (antigen) with antibodies and are visible to the naked eye.

(ii) Tube precipitin test

Glass capillary tubes of IO cm long and 0.5 to 1.0 diameter are used forthis assay. The glass tube is dipped in antiserum and sucked upto a height of 2 cm. Then, the tube is dipped in the clarified plant sample and the sap is sucked upto 2 cm height. Then, both the solutions are mixed by letting the liquid to run from one end to other. The capillary tubes are then fixed to the glass slide by cellophane tape. Thetubes are observed at periodical intervals for the formation of precipitate. The precipitates are formed when antigen and antibodies are related, indicating the positive reaction of presence of specific virus in the plant sample.

iii) Ouchteriony's double diffusion test

Two percent agar medium is prepared and sterilized. Wells are formed in a sterile petridish by keeping small pieces of 5 mm diameter glass tube at equal distances (5 mm apart) and pouring agar medium. The antiserum is placed in the central well and the plant saps to be tested are placed in the surrounding wells. The petridishes are incubated at 37^{0}C for IO hours. F ation of the precipitin lines (bands) can be detected after 2-4 days by observing under stereoscopic microscope. Theantigenic components and antibodies move towards each otherthrough agar medium and form bands when they are related, indicating the presence of virus infection in the plant sample.

(iv) ELISA (Enzyme Linked - Immuno Sorbant Assay)

In this technique, antibody is first linked with an enzyme like alkaline phosphatase. The antigen (virus) is then mixed with the antibody solution. The substract (usually p-nitrophynyl phosphate for alkaline phosphatase) is d bythe enzyme action and bright yellow colour appears. The colouration can be measured In a Spectrophotometer. This test is highly reliable and sensitive in detecting viruses that occur in very low concentration in plant samples.

(a) Direct ELISA

Double antibody Sandwich (DAS) form of ELISA is the more commonly used technique for detecting the antigen (Virus). In this method antibody specific for the antigen is coated on the surface weft of polystyrene microlitre plates (ELISA plates) to saturate the binding sites on plates. In the second step, excess antibodies are washed and antigen or sample to be tested is added to the wells and allowed to react with the bound antibodies. Any antigen in the sample will bind to the antibody and any unbound substances can be removed by washing the wells. An enzyme conjugate is then added, which is a conjugate molecule with an enzyme (alkaline phosphatase) linked to the same antibody as that coated on the well surface. This binds the remaining sites of the bound antigen, making the sandwich. Excess enzyme conjugate is then washed away and an enzyme substrate is added. The substrate is usually colourless but develops a yellow colour when acted upon by the enzyme. The amount of colour produced during a given time interval is directly proportional to the quantities of antigen present and can be measured in a spectrophotometer.

b. Indirect ELISA

This method is also found to be equally effective or more sensitivethandiredELISAandhaveborderspecificity. Inthismethod, the antibodies, which react with the virus antigens already trapped by the coated antibodies are not labelled with the enzyme as in the case of standard double sandwich method. The wells can be coated with purified virus or gamma globulines obtained from an animal species different from the one in which the detecting antibodish been produced. Then the binding of viral antigen with the antibodies is detached indirectly by employing enzyme-labelled Fc specific antibodies (commercially available). Then the substrate is added to find out the relation between the antigen and antibody for observing the colouration of the substrate.

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MYCOHERBICIDES

Weeds continue to cause major problem in agriculture throughout the world and reducing yield and quality of crops by competing forwater, nutrients and sun light essential for vigorus growth. In the past decades herbicides have dramatically increased yield in many cases. However, the toxic nature of chemicals, their harmful effects on plants and organism and their ever increasing costs are compelling alternative methods which could be specific to target plants and environmentally safe. Among the methods available as if today, biological control offers promise and is gaining recognition.

Fungal pathogens are considered to be the only group of microorganism with potential for classical biological control of weeds. agents or living products control specific weeds in agriculture as effectively as chemicals. Also when these agents are once established they could a to survive on the weeds year after year over long periods and provide Prot to be applied every time, season after season and year after year. These organisms have been defined as mycoherbicides. Natural endemic might be rendered completely destructive to its weed host by applying a massive dose at later stage of weed growth. Many fungal herbicides have been developed the most popularly used mycoherbicides in countries like USA and China.

Application Strategy

a. Classical strategy

One time spraying of the pathogen. The pathogen is expected to survive from year to year and providing long term control or population reductions with out additional re-introduction.

Eg. *Puccinia chondrillina controls Chondrilla juncea* (weed).

b. Inundative strategy

Application of pathogen year by year. Here the pathogen is applied to specific areas in predetermined volumes and dosages that achieve control of target weed within an allofted time and before econamic losses are incurred.

Eg. Colletotrichum gloeosporioides f. sp. *aeschynomene* controls *Aeschynomene virginica*

Different formulations available In the market

The mycoherbicide ‘Collego’ has been used commercially since 1982 in Arkansas to control Northern jointvetch *(Aeschynomene virginica)* a leguminous weed in rice *(Oryze sativa)* fields. It is marketed as a dry formulation consisting of 15% viable, dry conidia of *Colletotrichum gloeosporioides* f. sp. *aeschynomene* and 85% inert ingredients. Each

formation batch is assayed or packaged to contain 7.54 x 10 4 viable conidia per bag, the amount required for treatinefd of 4.05 hectares at the rate of 93.5 ha -'. This amounts to 1.8 x 1 0 "viable spores m '2. The pathogen infects but does not adequately control, a closely related species, Indian jointvetch *(Aeschynomene indica) a* serious localized weed in the gulf coast rice production area of Louisiana and Texas.

Mycoherbicide 'Devine' has been used commercially since 1981 in Florida citrus (Rutaceae).groves to control milkweed vine, *Morrenia odorata*. It is marketed as a wet formulation of chlamydospores of *Phytophthora palmivora with* a shelf life of six weeks in cold storage. It is applied at the rate of $8x10^4$ chlamydospores m^{-2} to the surface of moist soil under citrus tree. A safety zone of 1.6 km must be maintained between site of application and planting of several susceptible vegetable crops and ornamental plants. It is feasible to distribute and market this relatively liable product because of the limited marketing area. No damage to non,target or citrus have been noted in the seven years since first commercial use of this mycoherbicide despite mild infection of citrus in. controlled environments with high inoculum (200 x field rates).

The persimmon vilt fungus, Acrimo*nium diospyri,* is not commercially available but is routinely used as a mycoherbicide to control Persimmon trees *(Diospyrous virginiane)* in Rangeland in South Central Oklohama. It has been used since 1960 to control trees upto 10 cm in diameter. All trees in a grove may be killed wftwn three years following hand inoculation of 80% or more of the trees with a conidial suspension of the fungus.

Velgo is a potential mycoherbicide for velvet leaf (*Abutilon theophrasti)* control in corn *(Zea mays)* and soybeans *(Glycine max)* in the U.S. Corn Belt and southern Ontario, Canada. It is a strain of *C. coccoides.* Commercialization is anticipated in 3 to 5 years as a combination trea with rates of several chemical herbicides that well not control velvet leaf alone. The fungus atom at the rate of I x 10^9 spores m^{-2} kills 46% of the plants inoculated at the two or three leaf stage. Lack of complete kill is due to premature shedding of Ile"w and of now leaves. The host range of this isolate'of *C. coccoides* Is restricted to cow isolates, and although It Infects sevomt other plants, it does not cause significant damage to them.

Luboa 2 is a selected strain of *C. coccoides* f. sp. *cuscttae* that is used as a mycoherbicide in the People's Republic of China to control dodder *(Cuscute chinensis and Cuscuts australis)* parasitic on broad cast planted soya beans. It has been used since its discovery in 1963 for practical control of this parasitic weed. Spore concentrations of 2 x 10^7 spore's ml are applied with a hand sprayer until run off. Best results are obtained when spraying is done at I0.00 to 17.00 h on days when humidity Is high, usually in late July to early August. Luboa 2 Is an improved strain necessiated by loss of virulence in Luboa 1. \Aruience is positively correlated with spore size greater use is expected when new foffnulations with longer shelf life are available.

Biomal Is a potential mycoherbicide for control of round leaved mallow *(Malva pusilla)* in wheat *(Trificum aestivum)* and lentils *(Lens culinads)* in the provinces of Manitoba and Saskatchewan, Canada and the northern tier of wheat producing states in the United States. It is a selected strain of *Colletotrichum gloeosporioides* f. sp. *malvae.* It is applied in spore suspension containing of 2 x 1 0^9 at the rates of $5x10^2$ 1 ha $^{-2}$. This amounts to $6x10^7$ viable spores in m^{-2}. The pathogen infects, but doesn't adequately control, velvet leaf, a serious malvaceous weed widely distributed in corn and soybeans.

Casst is a potential mycoherbicide for control of sickel pot *(Cassia* obtusifolia) and coffee senna *(Cassia accidentalis)* in soybeans and peanuts *(Arachis* hypogea) in the Southern States of the United States. It is a strain of the *Altemaria crassiae* and is applied at the rate of 1. 1 kg ha -1 In 76.71 of water with an oil-based adjuvant. The spore concentration in the spray tank is 7.5 x 10^4 spores ml^{-1} amounting to application of 1.4 x 10^{-6} spores m^{-2}. Spores are currently produced on solid substrates with some modification of the procedure.

A potential microherbicide for control of Bathrust burr (spiny cocklebur or spray clotbur =*Xanthium spinosum)* has been developed in New South Waives, Australia, with a strain of *Colletottichum orbiculare* that is indigenous in the area where the weed is an economic problem, Small scale field tests with the pathogen indicate that it kills large weed plants in heavily inoculated. The pathogen does not kill common cocklebur *(Xanthium pennsylvanicum)* when spray inoculated, but if infected into young stems it causes death. The fungus is known as a pathogen of species in the family cucurbitaceae.

Another host pathogen interaction that has been exaimned in detail for mycorherbicide potential is *Cercospora rodmanii* on Waterhyacinth *(Eichhornia crassipes).* Mycelium of this leaf spot inducing pathogen was grown for 3 weeks on potato dextrose broth containing 5% yeast extract, blended and applied at the rate of 1.1 gm wt weight m^{-2}. After inoculation of the plants grown in of supplemented water disease stress caused a significant reduction in the net rate of leaf production. However, success of this biocontrol strategy was limited by a low rate of plant kill and the ability of the host to compensate for disease low by rapid leaf production.

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BIOLOGICAL CONTROL

Biological control is defined as the reduction of inoculum density or disease producing activities of a Pathogen or Parasite in its active or dormant stage by one or more organisms accomplished naturally or through manipulation of the environment, host or by introduction of one or more antagonists.

Biological control is n but control of plant diseases using living microorganisms. Root rot disease *(Macrophomina phaseolina)* is a major disease in pulses, oilseeds, cofton, etc., and the most common method of control is using fungicides. But the chemical methods are uneconomical and law effective, as seed treatment with chemical may give protection only in the early stages of crop growth 2 weeks. In addition, it is harmful to the beneficial microorganisms in soil and creates residual problems. So, the biological control can be very efficasy used for the root rot disease management as the biological agent multiply in soil and offer protection throughout the crop growth. The four main mechanisms involved in the biocontrol are (i) the biological agent (antagonist), may parasite the other organism, (ii) antagonist may secrete metabolites (antibiotics) harmful to the pathogens (Antibiosis) (iii) antagonist may compete with the pathogens for nutrients or space (Competition) and (iv) may cause death of the parasite by producing enzymes (Lysis).

Parasitism & Lysis

The biocontrol against parasitizes the pathogen by coiling around the hyphae, e.g., *Trichoderma* viride; various bacteria and fungi secrete hydrolytic about the degradation of cell wall of pathogens.

e.g. (i) *Bacillus* sp. causes hyphal lysis of *Gaeumanornyces* graminis

(ii) The chitnolytic enzymes of *Serratia marcescens* caused cell wall lysis of *Scierotium rolfsii.*

(iii) *Trichoderma* sp. produces chitinases and β-1,3 glucanases which lyses the cell wall of *Rhizoctonia solani.*

Antibiosis

The antibiotic compounds secreted by the biocontrol agent suppress the growth of the pathogen.

e.g. Phenazine-l-carboxylic acid produced by *P fluorescens* plays an important role in suppressing the take all disease of wheat.

Competition

The biocontrol bacteria and fungi compete for food and essential elements with the pathogen thereby displacing and suppressing the growth of pathogen.

e.g. (i) the competition for nutrients between *Pythium aphanidermatum, P ultimum* and bacteria suppress the damping off disease in cucumbers.

(ii) Fluorescent siderophores (iron chelaters) such as pseudobactinis & *pyoverdins* produced by P *fluorescons* chelates iron available in the soil, thereby depriving the pathogen of Its Fe requirements.

A. TRICHODERMA VIRIDE

The fungus, *Tfichoderma vitide* is one such biocontrol agent, mainly used for the control of root rot diseases of pulses and oil seeds in Tamil Nadu. A mass production technology for *T.viride* has been developed by Tamil Nadu Agricultural University, Coimbatore.

Systematic Position

	Asexual **(conidial)**	**Sexual (sscospore)**
Sub division	: Deuteromycotina	Ascomycotina
Class	: Hypomycetes	Pyremomycetes
Order	: Moniliales	Sphaeriales
Family	: Moniliaceae	Hypocreaceae
Genus	: Trichoderma	Hypocrea

Isolation of *Trichoderms* from soil

Trichoderma is isolated from the soil by using *Trichoderma* selective medium developed by Elad and Chet (I 983).

Collect soil samples from the field, mix well and make it into fine particles. Soil samples should be collected in root zone at 5-1 5 cm depth and from rhizosphere wherever possible.

Ten gram of soil sample is taken, and suspended in 100 ml of sterile distilled water and stirred well to get I : IO dilution.

Transfer one ml from this to 9 ml of sterile water in a test tube to get 1: 100 dilution.

Make serial dilutions by transferring one ml of suspension to subsequent tubes to get dilution of 1: 1 0,000.

Transfer one ml of the desired soil suspension to sterile petriplates. Pour 15 ml of melted and cooled *Trichoderma* selective medium in the same petriplates.

Rotate the plate gently and allow to solidify, incubate at room temperature for 5-7 days and observe for the development of fungal colonies. Trichoderma colonies will be white initially and turn to green. Count the number of colonies developing in individual plates. Transfer the individual colonies to potato de)drose agar slants.

TESTING METHOD

Dual Culture Technique

It consists of growing the test organism and the pathogenic organism on the same plate. This ran be done by the following procedure.

Transfer 15-20 ml of melted and cooled PDA to sterilised petridishes. Allow it to solidify. Transfer 8 mm disc of test organism to one end of the petriplate.

In the opposite end, 8 mm disc of the pathogenic culture is transferred in the same petriplate (if the antagonistic micro-organism is slow growing it should be plated in the previous day itself). Incubate the plate at room temperature. Observe the development of inhibition zone. Observe under microscope where both the test organism and the pathogen come in contact.

MASS PRODUCTION

Molasses yeast medium (Molasses 30g + yeast 5g + water 1000ml) is prepared in conical flasks and sterilized at 1.1 kg/CM^2 for 20 minutes. *T.viride* culture is inoculated by taking a fungal disc from 10 day old culture and incubated for 10 days. This serves as mother culture.

Molasses yeast medium is prepared in a fermenter and sterilized. Then, the mother culture is added to the fermenter @ 1.5 litre/50 litres of medium and incubated at room temperature for 10 days.

The fungal biomass and broth are mixed with talc powder at 1:2 ratio. The mixture is air dried and mixed with carboxy methyl cellulose (CMC) @ 5g / kg of the product. It is packed in Polythene covers and used within 4 months.

QUALITY CONTROL SPECIFICATIONS

1. Fresh product should contain not less than 28 X 10^6 CfU / g
2. After 120 days of storage at room temperature, the population should be 10 x IO^6 cfu / g.
3. Maximum storage period using talc as carrier is 120 days.
4. Size of the carrier (talc) should be 500 microns.
5. Product should be packed in white Polythene bags.
6. Moisture content of the final product should not be more than 20%.

Seed Treatment

The talc-based *T.viride* formulation is used as a dry seed treatment @ 4 g/kg and the treated as can be sown immediately. This treatment has several advantages. *T.viride is* than the conventional fungicides compatible with biofertilizers like *Rhizobium and Azospirillum,* non-toxic to human and other living organisms and in the crop yield appreciably. However, fungicide treatment should not be ad with the biocontrol agent.

B. BACILLUS SUBTILIS

This bacterium is widely used for the control of soil-bome plant pathogens like *Macrophomina phaseolina, Rhizoctonia solani, Fusarium* spp. etc. This treatment also considerably improves the plant growth and yield.

Bacillus subtilis is a rod shaped, thermophilic gram positive, aerobic bacterium. Roots may be formed in chains. It is 5-6 mm in length and 2-3 mm in width. It forms endospores during adverse conditions.

Isolation

One gram of soil sample is mixed with 9 ml sterilized nutrient broth in a test tube. This has to be kept on a boiling waterbath at 80^0C for 10 minutes. Then it is kept for incubation at root temperature for 24-48 hrs. From this serial dilution is prepared upto 10-6 dilution. Dilution 10^{-5} and 10^{-6} are plated In Nutrient Agar and incubated for 24-48 hrs. *B. subtilis* colonies will be rough, opaque with irregular margins.

Staining for Identification

Bacterial smear is prepared with 24 hours old culture, air dried and heat fixed. The slide is flooeded with crystal violet for 60 seconds and then washed with tap water. Then, the slide is flooded with Grams iodine mordant for 60 seconds and washed with tap water. It is then the smear is counterstrained with safranin for seconds, washed with tap water, blot dried and observed under microscope. *Bacillus subtilis* appeared violet since it,is gram positive.

Biochemical tests for Identification

The following biochemical tests are carried out for identification.

1. Starch hydrolysis
2. Catalase test
3. Nitrate reduction test
4. Acid and gas production test

Bacillus subtilis is amylase positive catalase positive, nitrate positive, acid positive and gas negative.

Mass multiplication

Nutrient broth (Peptone 5g, beef extract 3g, sodium chloride 3g in 1 litre of distilled water, pH7) is prepared and sterilized at 1.1 kg/ CM^2 pressure for 20 minutes. One loopful of *B. subtilis* is inoculated and incubated for 24 hours. This serves as mother culture. One litre of mother culture is transferred to 100 litres of sterilized nutrient broth in a fermenter and the bacterial growth is harvested after 72 hrs. Then it is mixed with 250 kg of sterilized peat soil amended with 37 kg Calcium carbonate, dried in shade and packed in Polythene bags. This product can be stored upto 6 months.

Seed treatment

Six hundred gram of Peat-based culture is required for one hectare. The culture is gently mixed with 200 MI of cooled rice gruel and then mixed with seeds and dried in shade. The seeds should be sown with in 24 hrs. (Precautions: Iron rods or sticks should not be used for mixing and treated seeds should not be dried in sun).

C. PSEUDOMONAS FLUORESCENS

This is another bacterium effectively used in controlling sheath blight and blast of paddy, wilt diseases of redgram, and banana.

Pseudomonas fluorescens is a gram negative, rod shaped nonspore forming bacteria which may be mono or lopotrichous or non motile. It produces greenish, fluorescent and water soluble pigment, pyoverdin.

The direct influence of pseudomonas on plant growth is mediated either by release of auxin-like substances or through improved uptake of nutrients in the environment. The indirect promotion of plant growth is achieved when fluorescent *Pseudomonas* decreases or prevents the deleterious influence of phytopathogens.

Isolation

One gram of rhizosphere soil sample is mixed in 100 ml of sterilewaterto give 1:100dilution. From this serial dilutions upto 10^{-7} level are made by repeatedly transferring 1 ml of 1:I00 dilution to 9 ml sterile water stants 10^{-5}, 10^{-6} and 10^{-7} dilutions are plated in kings B Agar medium and incubated for 24-48 hours. P *ftuorescens* appears as smooth, slimy, circular translucent colonies.

Staining for Identification

As that of *Bacillus subtilis.*

P fluorescens does not take up the secondary stain.

Biochemical tests for characterization

The following biochemical tests are carried out for characterizing *P. fluorescens.*

(i) Cyanogenesis
(ii) Chrome Azurol assay
(iii) 'P'solubilization
(iv) IAA production
(v) Antibiotic assay

Mass production

P. fluorescens is multiplied in sterilized Kings 'B' broth for 48 hours. The pH of the substrate (Peat soil or talc powder) is adjusted to 7 by adding calcium carbonate @150 g / kg. The substrate is then sterilized at 1.1 kg/cm^2 pressure for 30 minutes for two successive days. Four hundred ml of *P. fluorescens* suspension is added to 1 kg of substrate containing 5 g of carboxy methyl cellulose and mixed well.The formulation is packed in Polythene covers and can be stored for one month.

Quality Control

1. Fresh product should contain 2.5 x I 0" cfu / g
2. After 3 months of storage at room temperature, the population should be 8-9 x 10^7 CfU / g.
3. Storage period is 3-4 months
4. Minimum population load for use is 1.0 x $I0^8$ cfu / g.
5. Product should be packed in white Polythene bags.
6. Moisture content of the product should not be more than 20% in the final product.
7. Population per ml of the broth is 9 ± 2 x 1 0^8cfu / g.

METHODS OF APPLICATION

Crop: Paddy -blast, sheath blight

1. Seed Treatment

Mix paddy seeds with the formulation at the rate of 10 g per kg ofseedsandsoaktheseedsinwaterforovemight. Decant the excess water and allow to sprout the seeds for 24 hrs and then sow.

2. Seedling root dipping

Apply 2.5 kg of the formulation to the water stagnated in an area of 25 sq.m. The seedlings, after pulling out from the nursery can be left in the stagnating water containing the bacteria. A minimum period of 30 minutes is necessary for soaking the roots and prolonged soaking will enhance the efficacy.

3. Soil application

Apply the product @ 2.5 kg / ha after 30 days of transplanting (This product should be mixed with 50 kg of well decomposed FYM / sand and then applied).

4. Foilar application

Spray the product at 0.2% concentration (1 kg/ha) commencing from 45 days after transplanting at 10 days interval for 3 times depending on disease intensity. If there is no disease incidence, a single spray is sufficient.

Crop: Groundnut, Gingelly, Sunflower, Redgram, Greengram, Blackgram - root rot and wilt

Seed treatment : 10 g /kg of seeds

Soil application : Apply 2.5 kg/ha. mixed with 50 kg of well decomposed FYM / sand at 30 days after sowing.

Crop : Banana - Fusarium wilt

Suckertreatment : 10 g/sucker

Capsule application : 50 mg / capsule / sucker.
Apply once in 3 months from 3 months after planting

Soil application : 2.5 kg / ha + 50 kg FYM / sand
Apply once at the time of planting and repeat it once In 3 months.

Biological Control Agents

Antagonist	Pathogen controlled

Fungi

Trichoderma viride	*Macrophomina phaseolina, Pythium spp Sclerotium rolfsii*
T.harzianum	*Fusarium oxysporum f.sp.vasinfectum F.o.* f.sp- *melonis, R.solani*
T.harnatum	*Pythium spp. R.solani*
Verticillium leccani	*Uromyces dianthi*
Gliocladium virens	*R.solani*
Laefisaria arvalis	*Sclerotinia sclerotiarum, R. solani Pythium* spp.

Bacteria and Actinomycetes

Pseudomonas fluorescens	*P ultimum, P. aphanidermatum, R.solani F.o.*.f.sp. udum. Fo. f. sp. *cubense, F.o* f. sp- *ciceri*
Bacillus subtilis	*F.o*. f.sp. *dianthi. M,phaseolina, R.solani, S.rolfsii*
B. thuringiensis	*Hemileia vastatrix*
Streptomyces griseoviridis	*Altenaria brassicola, R. solani. Fo*f.sp. *dianthi*

Formulations of biocoittrol fungi effective against plant pathogens

Pelletes

Gliocladium	*Pythium, Rhizoctonia / ornamentals*
GlioGladium, Trichoderma	*Rhizoctonia / cotton*
Gliocladitim	*Sclerotium / beans*
Talaromyces	*Verticillium /potato*

Bulk materials, grains

Gliocladium	*Rhizoctonia / peanuts*
Gliocladium	*Sclerotium / beans*
Rhizoctonia	*Rhizoctonia / sugarbeets*
Sporidesmium	*Sclerotinia / lettuce*

Trichoderma	*Rhizoctionia, Pythium, etc, vegetable, field crops.*
Trichoderrna	*Rhizoctonia / cotton*
Dusts, powders	
Gliocladium	*Sclerotium / beans*
Gliocladium, Trichoderma	*Rhizoctonia / potato*
Pythium,	*Rhizoctonia /carrots, beets, etc*
Talaromyces	*Verticillium / potato*
.	
Trichoderrna	*Verticillium / mushrooms*
Trichoderma	*Pythium /peas*
Gels, fluid drill	
Trichoderma	*Rhizoctonia /radish*
Laetisaria	*Rhizoctonia /peppers*
Trichoderma	*Sclerotium /apple seedlings*
Spores	
Talaromyces	*Verticillium / eggplant*

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DISEASE MANAGEMENT BY BOTANICALS

Plant products play an important role in evolving an ecologically sound and environmentally acceptable disease management system. Plant products have been found to have fungicidal, bactericidal and antiviral properties. It is well established that about 346 plant products have fungicidal properties, 92 have bactericidal and 90 have antiviral properties. This clearly indicates that the plant kingdom is a vast storehouse of chemicals that can check several plant pathogens. As many of them have more than one type of activity there is a less chance for development of resistance and moreover, the plant products are saferto non-target organisms.

NEEM PRODUCTS

Among the plant products, the neem derivatives are reported to be effective in controlling several diseases. The neem tree *(Azadirachta indica),* popularly called as china berry, crackjack, Nim, Indian lilac, margosa and paradise tree, contains several active principles in various parts. The important active principles are Azadirachtin, Nimbin, Nimbidin, Nimbinene, Nimbridic acid and Azadirone which have aiitifungal and insecticidal properties.

(i) Neem Seed Kernel Extract (NSKE)

It is prepared by soaking 5 kg of powdered neem seed kernel (in a gunny bag) in 100 litres of water for 8 hours. The gunny bag is then removed afterthorough shaking. Then, 100 ml of teepol is mixed thoroughly, before spraying. The quantity of extract required for a liectare is 500 litres,

(ii) Neem oil solution

One hundred nil of teepol is mixed first with 100 litres of waterThen, 3 litres of neem oil is slowly added to this solution with constant shaking. The milky solution formed is ready for spray. The spray volume is 500 litres/ha.

(iii) Neem cake extract

Ten kg of powdered neem cake in a gunny bag is soaked in 100 litres of water for 8 hours. The gunny bagis removed after thorough shaking. Then, 100 ml of sticker is added and mixed well. The quantity of spray fluid required is 500 litres / ha.

(iv) Neem cake

Powdered neem cake is directly applied to the field at the time of last ploughing. The quantity applied is 150 kg/ha.

Diseases controlled by neem products

(a) Paddy: Tungro (virus) (Vector: *Nophotettix virescens)*

Neem cake is applied at 150 kg/ha as basal dose. In addition, 3% neem oil or 5% NSKE @) 500 l/ ha can be sprayed. If one jassid is noticed in a plant. Three sprays have to be given at 15 days interval.

(b) Paddy : Sheath rot *(Acrocyfindrium oryzae)*

Five per cent NSKE or 3% neem oil can be sprayed @ 500 lit/ ha at the time of grain emergence.

(c) Paddy: Blast *(Pyricularia oryzae)*

Spraying 5% neem oil is effective

(d) Paddy: Sheath blight *(Rhizoctonia solani)*

Application of 150 Kg of neem cake/ha

(e) Groundnut : Rust *(Puccinia arachidis)*

Application of 3% neem oil @ 500 lit/ha. The first spray should be given immediately on noticing the symptom and second 15 days later.

(f) Groundnut : Foot rot *(Sclerotium rolfsii)* Application of 1 % neem oil is effective.

(g) Coconut: Wilt *(Ganoderma lucidum)*

Application of 5 kg of neem cake/ tree/ year during the rainy season.

(h) Black gram: Powdery mildew *(Erysiphe polygoni)*

Two sprays with 3% neem oil or 5% NSKE, starting first spray at the initiation of the disease and second 15 days later are effective.

(i) Black gram: Root rot *(Macrophomina phaseolina)* Application of neem cake @ 150 kg/ha

(j) Black gram: Yeliow mosaic (Virus)

Application of 3% neem oil is effective.

(k) **Soybean:** Root rot *(M. phaseolina)* Application of neem cake @ 150 kg/ha.

OTHER PLANT PRODUCTS

In addition to the neem products, products from several other plant species are also found to be effective in disease management. The leaf extract of tuisi *(Ocimum sanctum)* is found effective against *Helminthosporium oryzae* (paddy brown spot). The leaf and pollen extracts of vilvam *(Aegle marmolos)* effectively reduced early blight of tomato *(Altenaria solani)* and blight of onion *(A. porri). A. solani* is also effectively checked by flower extract

of periwinkle *(Catheranthus roseus)* and bulb extract of garlic *(Allium sativum).* Rice discolouration caused by *Drechslera oryzae* is effectively reduced by leaf extract of mint *(Mentha piperita).* The bulb extract of garlic is also effective in reducing leaf blight of finger millet *(H. nodulosum)* and blast of paddy *(Pyricularia oryzae).* The root exudates of kolinji and rhizome extract of banana are effectively used against *Ganoderma lucidum, the* pathogen of Thanjavur wilt of coconut. The seed oil of pinnai *(Calophyllum inophyllum)* is effective against *Puccinia arachidis* causing groundnut rust. Leaf extract of nochi *(Vitex negundo)* effectively reduced, Rice Tungro viruses by checking the vector, Nephotettix *virescens.*

ANTI VIRAL PRINCIPLE (AVP)

Plants are also known to contain some compounds which are inhibitory to virus. They are called Anti-Viral Principles (AVP) or AntiViral Factors (AVF). The leaf extracts of sorghum, coconut, bougainvillea, *Prosopis juliflora and Cyanodon dactylon* are known to contain virus inhibiting principles.

Preparation of AVP extract

Dried coconut or sorghum leaves are cut and powdered. Twenty kg of leaf powder is mixed with 50 litres of water and heated at 60^0C for one hour. It is filtered and volume is made upto 200 litres. This gives 10 per cent extract. Five hundred litres of extract is required to cover one hectare.

The 10 per cent AVP extract is very effective in controlling groundnut ring mosaic virus (bud necrosis). Two sprays are to be given at ten and twenty days after sowing. Similarly of percent leaf extracts of *P. juliflora* and C. *dactylon* effectively reduced the tomato spotted wilt virus in tomato. The leaf extracts are known to contain some proteinaceous substances which induce virus inhibition in the plants.

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BIOTECHNOLOGY IN PLANT DISEASE MANAGEMENT

In modern terms “biotechnology’ is defined as the manipulation, genetic modification and multiplication of living organisms through novel technologies, such as tissue culture and genetic engineering, resulting in the production of improved or new organisms and products that can be used in a variety of ways.

Genetic engineering is the technology by which it is possible to isolate particular gene from one organism, insert them into the genome of another organism and make them to express at right time. Cells of plants can be cultured in special nutrient medium and whole plants can be regenerated from cultured cells. This technique of growing plants in *vitro* is called “Tissue culture”.

In calli derived from infected tissues not all cells uniformly carry the pathogen. Only 40% of the single cells mechanically separated from TMV - infected tobacco callus contained the virus. The two possible reasons for the escape of some cells of a systemically infected callus from virus infection are -. a) virus replication is unable to keep pace with cell proliferation, and b) some cells acquire resistance to virus infection through mutagenesis. Cells resistant to virus at back may even exist in the parent tissue together with susceptible ones.

Several disease resistant plants have been evolved using somoclonal variation. Out of 370 tomato plants regenerated from calluses six showed resistant to TMV. Similarly, late blilght *(Phytophthora infestans)* - resistant potato plants and bacterial blight of rice resistant calli have been evolved.

The pathogen produced secondary metabolites can be used to screen calluses for evolving disease resistant plants. Toxins will kill the calluses, but the mutant toxin resistant calluses will survive. The regenerated toxin resistant calluses yielded disease resistant plants. Brown spot pathogen *(Helminthosporium oryzae)* produced a host specific toxin for which resistant plants have been successfully developed. Similariy, *Helminthosporium maydlis* - toxin resistant maize plants, *Phytophthora infestans* - resistant tobacco plants, *H. sacchari* resistant sugarcane plants have been evolved.

Somaclonal variation refers to the tissue culture derived variation- Plants regenerated from somatic cells, using tissue culture. are not genetically uniform but display significant genetic variability. This variability is very high when compared to spontaneous mutation. Somacional variation has been deryionstrated in a large number of plant species (wheat, rice, oats, maize, tobacco, potato, sugarcane, brassica, etc.) for various traits such as resistance to fungal, viral and bacterial diseases. The procedure involves growing of cell cultures for several cycles on nutrient medium without any selective agent, followed by regeneration of plants. The regenerants and their progenies are screened for disease resistance.

Embryo rescue and protoplast fusion techniques are important to obtain hybrids among incompatible species and introgression of alien genes for disease resistance. In number of cases, useful genetic variability in the cultivated germplasm for resistance to diseases is either limited or lacking. Under such situations, wild germsplasm seems to be a reservoir of useful genes for disease resistance. In the incorporation of alien genes, several crossability barriers are encountered. In many cases, the hybrid embryo aborts. However, the excised hybrid embryos when cultured on nutrient medium ran be grown to plantlets. To incorporate alien genes from divergent sources, embryo rescue appears to be promising.

Tissue culture in conduction with recombinant DNA technology is becoming increasingly important to insert foreign genes and produce transgenic plants. Forsuccessful infection of virus particles, the coat protein should be removed from viral RNA. If the host is made to synthesize coat proteins in large amount, naked viral RNA formation will be negligible. The host coat protein will encapsulate the RNA of the virus and prevent its multiplication. This will result in reduction and delay in symptom development. Eg. Transgenic tobacco plants expressing the tobacco mosaic virus coat protein protected the plants against this virus.

The expression of the viral genome in transgenic plants also conferred resistance to virus infection. These regions include portion of the viral replicas as well as, antisense RNA to coat protein. Transgenic tobacco plants transformed with a DNA copy of the satellite RNA of cucumber mosaic virus (CMV) were shown to produce large amounts of satellite RNA following inoculation with CMV and symptom development was greatly reduced.

Proteins with the ability to inhibit the growth of fungi *in vitro* are abundantly present in plants. Constitutive expression of these genes in transgenic plants may render these plants to fungus resistant. Transgenic tobacco plants constitutively expressing bean chitinase have been shown to display enhanced resistance to *Rhizoctonia solani*.

Recently, tobacco plants expressing a ribosome inactivating protein (RIP) from barely showed resistance to *R. solani.* The RiPs do not inactivate self ribosomes and show activity towards ribosomes of distantly related species including those from fungi. The constitutive expression of the groundnut stilbene synthase gene in transgenic tobacco plants results in the synthesis of resveratrol (phytoalexin) and the transgenic plants show resistance to *Botrytis cinerea.*

Transgenic tobacco plants expressing acetyltransferase which detoxifies the tabtoxin, show resistance to *Pseudomonas syringae* pv. *tabaci.* More recently, chitinase gene from *Manduca sexta,* tobacco horn worm, has been cloned into *P.fluorescens* to increase their antagonistic potential against R.solani.

Meristem or shoot tip culture

Meristem and shoot tip culture are used to eliminate virus from infected germplasm. It has long been observed that the rapidly growing meristems of plants are usually free of viruses, or at least have much lower concentration of viruses than non-meristem cells. This situation has been exploited forthe production of virus-free plants by meristem culture. It is commanly used in cassava, potato, sweet potato and ornamental plants.

"Virus-free" the term has been loosely used in literature. Plants infected with more than one type of virus and also may carry some unknown viruses. Thus, a plant can be claimed as free of only those virusesforwhichspecifictestshavegivennegativeresults- owever, the term "virus-free" is still retained by horticulturists for its commercial value.

Pathogen attack does not always lead to death of the plant. Many viruses may not even show visible symptoms. However, the presence of viruses in the plants, can reduce the yield and quality of crops. It is well known that the distribution of viruses in plants is uneven. In infected plants, the apical meristems are generally either free or carry a very low concentration of the viruses. In the older tissues, the titre of the viruses increases with increasing distance from the meristem tips.

Five main possibilities have been suggested to explain the mechanisms underlying the 'resistance'of meristems to viruses.

(i) Exclusion of the viruses from the meristems by lack of suitable vascular or plasmodesmatal connections.

(ii) Competition for key metabolites by the rapidly dividing meristem cells.

(iii) The production of substances in meristem cells that result in breakdown of the virus.

(iv) Deficiency in some key components of the machinery of virus replication, and

(v) Presence of inhibitors of virus replication.

Factors affecting virus eradication

Factors such as culture medium explant size and culture storage influence the virus eradication. In addition, heat treatment before or during culture significantly influences the efficiency of this technique. The physiological stage of the explants also affects virus elimination by meristem tip culture.

(i) The success in obtaining complete plants can be considerably improved by the choice of the culture medium. The major features of the culture medium to be considered are its nutrients, growth regulators and physical mature.

(II) The size of meristem tip is an important factor governing regeneration capacity of meristems and to obtain virus free plants. For example, in cassava, meristems exceeding 0.2 mm size regenerated to plantlets, but those less than 0.2 mm size developed either Gallus or callus with roots. In general, the larger the meristem, the greater is the number of regenerated plants, but the numberof virus free plant is inversely proportional to the size of meristem cultured.

(iii) For meristem - tip cultures light incubation has generally proved better than dark incubation. The optimum light intensity for initiating tip cultures of potato is 100 lux, which should be increased to 200 lux after 4 weeks. The cultures are generally stored understandard culture room temperatures (25 ± 2OC).

(iv) Meristem tips should, preferably be taken from actively growing buds. Tips taken from terminal buds gave better results than those from axillary buds.

Meristem tip culture to eliminate Cassava Mosaic Virus

Rapidly growing vegetative buds are excised, rinsed with sterile distilled water and then disinfected by immersing them in mercuric chloride solution (0.1%) for 2-3 minutes. The buds are then rinsed with several changes of sterile distilled water. Underthe microscope, 3-4 leaf primordia (0.3 to 0.6 mm in size) is removed from the bud with a sterile scalpel. The buds are then aseptically transferred to Murashige and Skoog (MS) medium in test tubes and incubated at 25 ± 2'C in light, for 45 days. The piantlets are then removed from the test tubes, washed in tab water and kept in Hoagland solution for 3-4 days for hardening. The plantlets are transferred to pots containing peat soil and verwgctdite at 3:1 ratio and kept in mist chamber for 5-7 day. The plants are then transferred to glass house for further study.

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GLOSSARY

Active ingredient - the active component of a formulated product.

Adherence - property of a fungicide to adhere or stick to a surface

Adjuvant - material added to a fungicide to improve some physical or chemical property

Adult plant resistance - resistance detectable at the post-seedling stages of development (Mature plant resistance)

Aerobic - requiring free oxygen for respiration

Aetiology (etiology) - the science of the causes of the diseases; the study of the casual factor, its nature and relations with the host

Aflatoxin - mycotoxins produced by *Aspergillus flavus*

Alternate host - one of the two hosts required by a pathogen to complete its life cycle; either of the two hosts of heterocious rust.

Agar agar - gelatine like material obtained from seaweed and used to prepare media on which microorganisms are grown and studied.

Anaerobic - living in the absence of oxygen.

Anamorph - asexual or imperfect state of a fungus.

Antagonism - a general term for counteraction between organisms or group of organisms.

Antagonist - an organism used in biological control which can decrease the capacfti of a pathogen to cause disease.

Antibiotic - a substance produced by a micro organism and able to inhibit or kill other rnicroorgane, or to destroy them.

Antibody - a substance that is produced in response to injection of a foreign substance (antigen) into a animal body, and that reacts specificall y with the foreign body. Antibodies are modified serun globulins.

Antigen - a substance, when injected into an animal body, stimulate a production of a substance (antibody) antagonistic to the substance injected.

Biotroph - an organism which is entirely dependent upon another living organism as a source of nutrients (obligate parasite).

Biotype - a sub division of a physiologic race of a fungus'. subrace; a subdivision of a species, subspecies or serotype of bacteria distinguished by some special physiological characters.

Bracket - a shelf like fruit body (basidiocarp) which extends horizontally from the substratum which is normally woody.

Broad-spectrum fungicide - a fungicide with activity against a wide range of pathogens.

Callus - A tissue arising disorganized proliferation of cells either in cultures or in nature.

Carrier - an organism harbouring a parasite without itself showing disease', the material used to convey the fungicide to its target.

Cell culture - culture of single cells or small groups of similar cells.

Chemotherapy - the treatment of disease by chemicals

Chlorosis - yellowing of usually green parts-, partial or complete absence of normal green colour.

Chromosome - one of a set of thread like bodies found in the nucleus, which are composed of nucleic acid and protein. Chromosomes carry genes ind are involved in the transmission of hereditary characteristics.

Circulative virus - a virus, which passes throuch the out wall of the vector into the haemolymph and eventually contaminates the mouth parts via saliva.

Clonal propagation - Asexual plant multiplication starting from a single individual.

Clone - A population of cells derived from a single cell by mitotic divisions. It is also commonly used to denote a population of plants derived from a single individual through vegetative propagation. Colony - (of bacteria and yeast) a mass of individuals, generally of one species, living together; (of fungi) a group of hyphae-, frequently with spores.

Colonization - the spread of the pathogen in the host tissue away from the initial site of infection and the dependence on the host for nutrients.

Compatible - (of pesticides) able to be mixed without deleterious effect.

Compound interest disease - a disease which goes through more than one cycle of infection during a growing season, analogous to a bank account giving compound interest.

Conidioma - any hyphal structure bearing conidia.

Control - to prevent or retard the development of disease.

Coverage - distribution of fungicide over a discontinuous area such as leaves of a tree.

Cultivar - a variety of a cultivated plant.

Culture - growth of a microorganism on artificial medium.

.Cyst - a sac, especially a resting spore or sporangium - like structure.

Deposit - quantity of dry fungicide deposited on unit area of material treated.

Differential variety - a variety which gives reaction which distinguishes between race - specific isolates of a pathogen.

Diluent - an inert material added to a fungicide to reduce its concentration.

Diploid - having two copies of each chromosome characteristic for the species.

Disease - harmful deviation from normal functioning of physiological processes, caused by one or more pathogenic organisms.

Disinfestation - the destruction of a pathogen on the surface of the host or in the environment surrounding the host.

Disorder - harmful deviation from normal functioning of physiological processes, arising from causes other than pathogenic organisms.

Dose, dosage - quantity of toxicant applied per unit of material treated.

Dressing (seed) - process of covering seeds with a fine coating of fungicide , the fungicide applied to seed.

Durable resistance - resistance, which remains effective to pathogens which, have highly developed variety specific pathogenicity even though varieties a-re extensively cultivated in environment favourable to disease.

Ecoclimate - climate within a plant community.

Embryogenesis - the process of embryo initiation and development

Endemic – (of a disease) - Permenently established in a defined area of a country.

Epidemic - a progressive increase in the incidence of a particular disease within defined host population; widespread temporary increase in the incidence of an infectious disease.

Epidemiology - the study of factors influencing the outbreak of disease and spread of infection.

Epiphytotic - the term used for an epidemic in plants.

Eradicant fungicide - a fungicide used to kill existing pathogen infestation, often referred to as curative fungicide; one applied to a substratum in which the fungus is already present.

Excise - to remove a piece of tissue or an organ from the parent source, such as, removing shoots from callus or separating individual shoots from a proliferating mass of shoots.

Explant - a plant organ or piece of tissue used to initiate a culture.

Exudate - liquid discharge from diseased of healthy plants ; substance passed from within plant to the outer surface or in to surrounding medium.

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Facultative parasite - an organism able to live as a saprophyte or a parasite and to be cultured on laboratory media, not obligate.

Field immune - not becoming infected by a pathogen in the field, although susceptible under experimental conditions.

Field resistance - resistance detectable under natural infection in field conditions but not detected under experimental conditions. (adult plant resistance).

Filler -a diluent in powder form

Forma specialis - a sub-division of an organism characterized from a

Fruit body - hyphal structure producing and bearing spores,

Fumigant - a chemical toxicant used in volatile form

Fumigation - disinfestation by fumes

Fungicide - a substance which kills fungal mycelium or spores

Fungicide resistance - a decrease in the sensitivity to a fungicide due to

Fungistat / Fungistatic - a substance which prevents /stops the growth with out killing it.

Fungus - a type of organism which lacks chlorophyll and conductive tissues.

Gene - one of a set of units of heredity, having a specific effect on the characteristics of an organism. Genes are composed of DNA and are arranged linearly on the chromosomes.

Heteroecious - undergoing different parasitic stages in two unlike hosts as in rust fungi.

Horizontal resistance - resistance which is evenly spread against all races of a pathogen.

Host - an organism harbouring a parasite.

Hybridization - any process by which hybrids are created,

Hyperparasitism - parasitism on another parasite.

Hyperplasia - abnormal growth associated with increased cell division.

Hypersensitivity - a rapid local reaction of plant tissue to attack by a pathogen

Hypertrophy - abnormal growth associated with cell enlargement.

Hypha - a tubular thread like filament of fungal mycelium - a basic building block of a fungus.

Hyphopodium - short mycelial branch.

Immune - exempt from infection by a given pathogen.

Imperfect fungus - a fungus which is not known to produce sexual spores.

Imperfect state (Anamorph) - the state in which asexual spores asexual spores (conidia) or no spores are produced-, the asexual period of a fungal life cycle.

In vitro - literally “in glass” now applied to any process carried out in sterile
In vivo - literally “in life”, now applied to any process occurring in a whole organism.

Incubation period - the period of time between infection and the appearance of symptoms.

Indexing - any procedure for demonstrating the presence of known viruses in suscept plants.

Indicator plant - one, which reacts to certain viruses or environmental factors with specific symptoms, used for identification of the viruses or the environmental factors.

Infect - to enter and establish a permanent or temporary parasitic relation with an organism; to enter and persist in a carrier.

Infection - the penetration of the host by a pathogen and earliest stages of development within the host.

Infection court - the initial site of contact between a patho en and the surface of the host; the place of invasion of a host by a pathogen.
Infection peg - a slender structure formed by the deposition of substances such as lignin around a thin hypha penetrating a host cell.

Infest - to over-run the surface of a plant, or to be dispersed through soil or other substrate.

Infested - attacked by animals, especially insects, soil or other substrata contaminated fungi.

Inoculate - to introduce a microorganism into an organism or into a culture medium.

Inoculum - spores or other pathogen parts which can cause disease; the substance used for inoculating.

Integrated control -the continuous application of a balanced range of disease control measures; the complementary use of biological, chemical and cultural methods to control pathogens.

Isolate - to separate a microorganism from its host or substrate and to establish it in pure culture.

Latent period - the time between infection and sporulation of the pathogen on the host; time between infection and disease symptoms, time from the start of a virus vectors feeding period until the vector is able to transmit the virus to healthy plant.

Lesion - a localized area of diseased or disordered tissue.

Life cycle / life history - the stage or stages (states) between one spore and its recurrence. There are commonly 2 stages, the imperfect with one or more spore forms, and perfect, but one or the other may not be known.

Lysis - a breaking down or dissolution of cells by enzymes.

Major gene resistance - genetic resistance to disease based on one or a few genes.

Masked virus - one carried by a plant which does not show symptoms of its presence.

Medium / culture medium - a substance or solution for the culture of microorganisms.

Meristematic - having the characteristics of a meristem.

Micro propagation - asexual or vegetative propagation of plants *in vitro.*

Monocyclic - having only one cycle of infection during a growing season (simple interest disease).

Mosaic - patchy variation of normal green colour, symptomatic of many virus diseases.

Mottle - an arrangement of indistinct light and dark green areas, and dark green areas, symptomatic of many virus diseases; arrangement of spots or confluent blotches of colour, often symptomatic of many virus diseases.

Moulds (mold) - superficial mycelium of a fungus,- a visible mycelial growth of a fungus; fungus species where the vegetative mycelium is visible often on the surface of food stuff.

Multiline - a combination of almost genetically identical breeding lines (isogenic)

Mycelium - mass of a fungal threads (Hypahe) that form the vegetative body of a fungus.

Mycology - study of fungi.

Mycorrhiza - symbiotic association of a fungus with the roots of a higher plant. mutually beneficial relationshiop between a fungus and a plant root. Ectotrophic / ecto - on the surface of the roots. Endotrophic / endo- within the root. Pseudotrophic - in which the fungus is parasitic. Tolypophagous - in which the fungus is killed and digested by the host.

Mycosis - an infection by a parasitic fungus, or a disease so caused.

Mycostatic - fungistatic.

Mycotoxins - poisonous substances produced by vertain fungi-, toxins produced by fungi which may contaminate fbodstuff.

Necrophyte - an organism living on dead material.

Necrosis - a browning or blackening of cells as they die; death of plant cells, especially when resulting in darkening of the tissues, common symptom fungus infection.

Necrotroph - an organism that causes the death of the host tissues as it grows through them such that it is always colonizing dead susbtrate.

Non persistent virus - a virus that persists in its vector for a few hours- one which remains infective within its insect vector for only a short period.

Notifiable disease - a disease, which by law, has to be reported to the appropriate authority.

Obligate parasite - an organism capable of living only as a parasite.

Parasexual cycle - a mechanism whereby recombination of hereditary properties is based on mitosis.

Parasite - an organism living on or in, and getting its food from another living organism (host) but conferring no benefit in return,

Pathogen - a parasite able to cause disease in a particular host or by range of host; an organism which causes disease.

Pathogenecity - the characteristic of being able to cause disease.

Pathogenesis - a sequence of processes in disease development from initial contact between pathogen and host to completion of syndrome.

Pathovar (pathotype) -a sub division of a species distinguished by common characters of pathogenicity, particularly in relation to host range.

Pelleting - coating seeds with inert material, often incorporating pesticides, to ensure uniform size and shape.

Perfect state (Teleomorph) - the state of the life cycle in which sexual spores are formed after nuclear fusion or by parthenogenesis.

Persistence - time for which a virus vector remains infective after leaving the virus source.

Persistent virus - a virus which persists in vector for more than 1 00 hrs and in some cases for the life of the vector; one which remains infective within its insect vector for a long period.

Perthophyte - an organism feeding on dead tissues of living hosts.

Phage (bacteriophage) - a virus which attacks bacterium.

Physiologic race - a sub specific group of parasites characterized by specialization of different cultivars of one host species.

Phytiatry - the treatment of plant diseases, especially by chemical methods.

Phytoalexin - a substance that inhibits the development of microorganism,

Phytoncide - a chemical substance produced by higher green plants which can inhibit the growth of microorganisms.

Phytosanitary certificate - a certificate of health, which accompanies plants or plant products to be exported or imported.

Phytosanitation - any measures involving the removal or destruction of infected plant material likely to form a source of re-infection by a pathogen.

Phytotoxic - toxic to plants.

Plamodium - a naked amoeboid muftinucleate mass of protoplasm.

Plasmid - a self-replicating extrachromosomal circle of DNA.

Pleomorphic - having more than one independent form or spore stage in the life cycle.

Polycyclic - having more than cycle of infection during a growing season (compound interest disease)

Polygenic resistance - genetic resistance based on many genes.

Precipitin - an antibody that causes precipitation of soluble antigens.

Propagative virus - a virus that multiplies in its vector.

Propagule - that part of an organism by which may be dispersed or reproduced.

Prophylaxis - preventive treatment against diseases.

Protectant fungicide - a fungicide which protects an organism / host against invasion by a pathogen.

Pseudothecium - a fruiting body containing asci similar in appearance to perithecium, buf produced in an aggregation of vegetative hyphae,

Pustule - a blister-like spore mass breaking through a plant epidermis.

Pycnidium - a flask shaped or spherical fungal receptacle bearing asexual spores, pycniospores.

Pycniospore - an asexual spore produced in a pycnium.

Quarantine- control of import or export of plant to prevent the spread of diseases and pests; holding of imported plant in isolation for a period to ensure their freedom from diseases and pests.

Race - a genetically and often geographically distinct mating group within a species; also a group of pathogens distinguished by their ability to infect a given set of plant varieties.

Race non-specific resistance - resistance to some races of a pathogen.

Race-specific resistance - resistance to some races of a pathogen but not to others.

Resistance factor - resistance gene or genes in a host, which have not necessarily been identified but can be used for practical purposes in gene-for-gene relationships.

Resistant - (host plant) ability to suppress or retard the activity of a pathogen; possessing qualities which prevent or retard the development of a given pathogen; (microorganism) able to withstand, completely or in some degree, the presence of a given chemical or other harmful factor.

Rhizomorph - a thread like or cord like structure made up of aggregated hyphae. Interwoven mycelial threads looking like a root or cord and sometimes attached to the stem base of the host.

Rhizoplane - the surface of the root.

Rhizosphere - the soil near a living root

Rotting - disintegration of tissues by the action of one or more microorganisms.

Rouging - removal of diseased or unwanted plants from a crop, critical examination of a crop and removal of unhealthy or otherwise unwanted plants.

Run-off - quantity of spray which runs off on unit area of plant surface.

Saprobe - saprophyte when the organism is not a plant.

Saprophyte - an organism that lives on dead and decaying material.

Sclerotium - a long-lived compacted mass of vegetatively produced hyphae.

Semi-persistent virus - a virus persists in vector for between 10 and 100 hrs.

Sensitive - (host plant) reacting with severe symptoms to infection by a given pathogen; (microorganism) succumbing to the effect of a given chemical or other harmful factor.

Sensitivity - the tendency of an organism attacked by a disease to give more or less strong symptoms.

Shoot tip / Shoot apex - terminal 0. 1 - 1.0 mm portion of a shoot comprising the meristem (0.05 - 0.1 mm) together with primordial and developing leaves and adjacent stem tissues.

Simple interest disease - a disease which goes through only one cycle of infection during a growing season analogous to a bank account giving simple interest.

Slurry - a thin, watery mixture.

Somatic - referring to vegetative or non-sexual parts or process.

Spawn - mycelium especially that used for starting mushroom culture, to put inoculum into mushroom bed or other substratum

Sporangiophore - a specialized hypha / hyphal branch bearing one or more sporangia.

Sporangium - a structure containing sporangiospores.

Spore - the reproductive unit in fungi, consisting of one or more cells, a specialized propagative or reproductive body in a fungus, reproductive cell which on germination will produce a new individual. it is analogous to the seed of a higher plant.

Spread - uniformity and completeness with which a fungicide deposit covers a continuous surface.

Spreader - a substance added to a spray to assists in its even distribution over the target.

Sterilization -the elimination of microorganisms.

Sticker - a substance added to a spray to assist in its adhesion to the target material added to a fungicide to increase tenacity.

Strain - the many meanings include: 1) a group of similar isolates, races form. 2) the descendants of a single isolation in pure culture; isolate. 3) cultivar. 4) a group of viruses has most of its antigens in common with another group.

Stroma / stromata - compact mycelial structures, with or without host tissues, in or on which spores are produced; a mass of vegetative hyphae in or on which spores are produced.

Stylet - borne virus - a virus which is borne on the stylet of its vector as a contamination.

Subculture - a culture derived from another one.

Substrate - the material on which an enzyme acts.

Substratum - the material on or in which a microorganism is living,

Suppressive soil - a soil in which a pathogen may persist, but either causes little or no damage or causes disease for a short time and then declines.

Surfactant - a surface - active material, especially a wetter or spreader used with a spray.

Suscept - organism affected or capable of being affected by a given disease.

Susceptible - subject to infection; non - immune.

Suspension culture - cells or cell aggregates cultured in liquid medium.

Symbiosis - a mutually beneficial association of two or more different kinds of organisms.

Symplast - living parts of the plant including the phloem and protoplast.

Symptom - a detectable abnormality arising from disease a visible change in a host plant as a result of pathogen infection.

Syndrome - the totality of effects produced in a plant by a disease.

Synergism - the concurrent parasitism of a host by two pathogens, in which the symptoms produced are of greater magnitude than the sum of the effects of each pathogen action alone.

Systemic fungicide - a fungicide which is absorbed into the plant through root of foliage, and translocated elsewhere in the plant.

Systemic infection - Infection occurring through out the plants

Teleomorph - sexual or perfect stage of a fungus.

Tenacity - property of a fungicide deposit to resist removal by weathering etc.

Tissue culture - commonly used as a blanket term to refer to all types of aseptic plant or animal cultures. Strictlv speaking, however, this term should include only the culture of unorganized tissue or callus.

Tolerant - (host pant) able to endure infection by a particular pathogen, with out showing severe symptoms; (microorganisms) able to withstand, completely or in some degree, the presence of a given chemical or other harmful factor; giving little reaction to the effect of other factors.

Toxicant - a toxic substance or preparation.

Translaminar activity - ability of a fungicide to move through a leaf from one surface to the other.

Variety - a sub division of a species below the level of subspecies; cultivar.

Vector - an organism, which transmits a pathogen, usually a virus.

Vegetative propagation - the sexual propagation of some part of the plant body,

Vein banding _ development of dark green bands along the veins in a virus disease.

Vein clearing - development of pale bands adjacent to veins of leaves in a virus disease.

Vertical resistance - resistance to some races of a pathogen but not to others.

Virosis - a virus disease.

Virulence - the degree or measure of pathogenicity.

Virulence factor - virulence qene or genes in a pathogen, which have not necessarily been identified but can be used for practical purposes in gene for gene relationships.

Virulent - strongly pathogenic.

Viruliferous (of a vector) carrying or containing a virus.

Virus - free - a plant certified through specified tests as being free of specified viruses.

Volunteer plant - a self sown plant.

Wetting agent / wetter - material that reduces the contact angle of a liquid on a surface.

Witches' broom -abnormal proliferation of shoots.

Yellows - a plant disease characterized by yellowing of tissue.