Chemical methods – study of different groups of fungicides.
Methods of application of fungicides

Fungicides – definition

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.

Characters of an ideal fungicide

1. It should have low phytotoxicity
2. It should have lonf shelf life
3. Stability during dilution
4. It should be less toxic to human being, cattle, earth worms , microorganisms etc.
5. It should be a broad spectrum in its action
6. Fungicide preparation should be ready for use
7. It should have compatibility with other agrochemicals
8. It must be cheaper one
9. It should be available in different formulations
10. It should be easily transportable

Classification of Fungicides

Fungicides can be broadly grouped based on their (i) mode of action (ii) general use and (iii) chemical composition.

I. Based on mode of action

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 : Eg. Bordeaux mixture, copper oxy (for growing plants) chloride, Capton, PCNB, thiram etc.
4. Foliage and blossom : Eg. Capton, ferbam, zineb, protectants 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, quinines 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.

Groups of Fungicides – Copper Fungicides, Sulphur Fungicides and Mercury Fungicides

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.

I. Copper sulphate preparations

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 $CuSO_4$ + 5lbs of lime + 50 gallons of water. The chemistry of Bordeaux mixture is complex and the suggested reaction is:

$CuSO_4 + Ca(OH)_2 \rightarrow Cu(OH)_2 + CaSO_4$

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 percent 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.

II. Copper carbonate preparation

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.

III. Copper carbonate preparation

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.

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

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 6.75Kg of sulphur in 225 litres of water.	Lime Sulphur is effective against powdery mildews as a protective fungicide.
Organic Sulphur	Hexathane 75% WP,	It is used to protect

(Dithiocarbamates) a. Monoalkyl	Dithane Z-78, Funjeb, Lonocol, Parzate C,	foliage 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.	Ziram 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 & tomato, and also against rusts of beans etc.
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 foliage 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.	It is used for seed treatment both as dry powder or as a slurry. It is a protective fungicide also suitable for 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.*

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 and in 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		It is used for treating potato tubers and propagative materials of other root crops
1. Mercuric chloride	Merfusan, Mersil	
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	Agallol, Aretan, Emisan,	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
Methoxy ethyl mercury Chloride	Ceresan wet (India)	
Phenyl mercury chloride	Ceresan Dry (India), Ceresol, Leytosan.	

Ethyl Mercury Chloride Tolyl mercury acetate	Ceresan (USA) Agrosan GN.	

Heterocyclic Nitrogen Compounds, Quinones and Miscellaneous Fungicides

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,	It has a narrow specrum of

	Glyodin, Glyoxide Dry, Glyodex 30% liquid and 70% WP.	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 (Sodiumpdimethylamino benzenediazosulphonate	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		It has a specific action

fungicide Ediphenphos (Edifenphos) (O-ethyl-SS-diphenyldithiophosphate)	Hinosan 50% EC and 2% D.	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 (TPTHTiphenyl 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 (TPTATriphenyl 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 It is effective against Cercospora leaf spot of

3. Fentin Chloride (TPTC- Triphenyl tin chloride)	Brestanol 45% WP, Tinmate.	sugarbeet and paddy blast

Systemic Fungicides and Antibiotics

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. Bavistin 50 WP, MBC, Dersol, B.Sten 50, Zoom, Tagstin, Agrozim,	It is a protective and eradicative fungicide with systemic activity, effective against a wide range of fungi

2. Carbendazim (MBC) (Methyl -2-benzimidazole carbamate)	Jkenstin.	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 postharvest sprays of dips for the control of storage rots of fruits and vegetables. 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

2. Thiophanate - methyl (1,2 bis (3 methoxycarbonyl-2-thioureido) benzene.)	Topsin-M70 WP, Cercobin-M 70 WP, Envovit-methyl, Mildothane.	*Venturia* spp., on apple and pear crops, powdery mildews, *Botrytis* and *Sclerotinia* spp. On various crops. 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.

IV.Morpholines

Common Name	**Trade Name**	**Diseases Controlled**
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 *Mycosphaerella, Exobasidium*

V. Pyrimidines, Pyridines, Piperidines and Imidazole

Common Name	**Trade Name**	**Diseases Controlled**
1. Triadimefon (1-(4-chlorophenoxy)-3, 3-dimethyl-1-(1-2-triazol-1yl) 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 Terrazole 30% WP, Terrazole 95% WP,	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 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

2. Cyclafuramid (N-cyclohexyl-2,5-dimethyl firamide) **VIII.Benzanilide derivative** 1. Mebenil (2-methyl benzanilide)		dressing fungicide against loose smut of wheat and barley. 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. 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.*

IX. Organo phosphorous compounds

Common Name	**Trade Name**	**Diseases Controlled**
1. Pyrazophos (2-0-0-	Afugan, Curamil, WP,	It is used to control

Diethylthionophosphoryl) -5- methyl-6-carbethoxy pyrazolo-(1- 5a)pyrimidine)	Missile EC.	powdery mildews of cereals, vegetables, fruits and ornamentals.
2. Iprobenphos (IBP) (S-benyzl-0-0-bisisopropylphosphorothiate)	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.
XI. Phenol derivative 1. Choloroneb (1-4-dichloro-2,5-dimethoxy benzene)	Demonsan 65 WP, Tersan SP, Turf fungicide	It is also active against storage diseases of fruits. 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 disease

XIII. Other systemic fungicides

Common Name	**Trade Name**	**Diseases Controlled**
1. Metalaxyl (methyl-DLN-(2,6-dimethylphenyl-N-)2-methoxyacetyl	Apron 35 SD, Ridomil Ridomil MZ 72 WP (8% Metalaxyl + 64% Mancozeb) Beam, Bim Alliette 80 WP	It is a systemic fungicide and highly effective for specific use as seed dressing against fungal pathogens of the order Peronosporales.
2. Metalaxyl + 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)		It is a specific fungicide used against paddy blast fungus, *P. oryzae*
4. FosetylAI. (Aluminium - Trisaluminium		It is a very specific Fungicide for Oomycetous fungi, especially against *Pythium* and *Phytophthora*

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 seedling 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.*

Methods of allocation of fungicides – Precautions and safety measures while handling fungicides

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 hostwith 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 treatment

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 soilborne 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 machinery 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 in 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 sets 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 soilborne 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.

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 of pathogens. 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.

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-AI 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.

VI. Special method of applications

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.