Lecture1

Plant disease epidemiology – Meaning and importance, difference between simple andcompound interest diseases – Factors affecting plant disease epidemics – host, pathogen,environmentand timefactor

Edpidemiologyorepiphytologyisthestudyoftheoutbreakofdisease,itscourse,intensity, cause and effects and the various factors governing it. Based on the occurrence andgeographicaldistribution theyare classified asfollows:

EndemicorEnphytotic

When a disease is more or less constantly occurring year after year in a moderate tosevereforminacountryorlocalitythenitiscalledasendemicdisease.eg:wartdiseaseofpotato(Synchytriumendobioticum)isendemicinDarjeeling,citruscanker(Xanthomonasaxonopodispv citri)in Asiaand sorghumrust (Pucciniapurpurea).

EpidemicorEpiphytotic

It is a sudden outbreak of a disease periodically over a widespread area in a devastatinglysevere form causing severe losses or complete destruction. This is constantly present in a localitybut it assumes severe form only on occasions. This is because of the occurrence of favorableenvironment responsiblefor the rapid development of disease. eg: wheat stem rust (Pucciniagraministritici)andpowderymildew(Erysiphegraminisvortritici),lateblightofpotato(phytophthora infestans), red rot of sugar cane(Colletotrichum falcatum), downy mildew ofgrapevine(Plasmophora viticola) and rice blast (Pyriculariaoryzae).

Certaindisease areendemicinoneareaandbecomeepidemicinanotherarea. Eg: CitruscankerisendemicinAsiabutepidemicintheintroducedplace,Florida(U.S.A).Thedownymildew of corn isaendemicdiseaseinIndia but becameepidemic in thePhilippines.

Pandemic

When an epidemic disease spreads over continents or subcontinents and involves massmortality it is considered as pandemic. The outbreak of black stem rust of wheat in India during1947is best exampleforapandemicdisease.

Sporadic

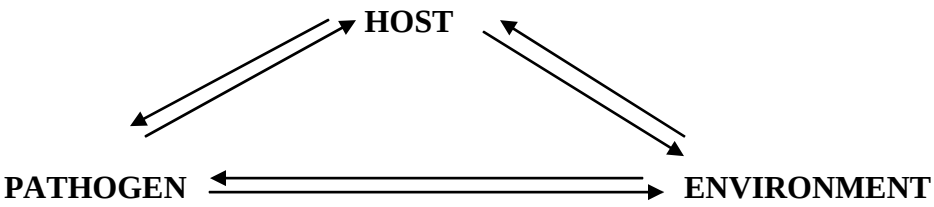
Diseaseswhichoccuratirregular intervalsoverlimitedareasorlocationsare calledsporadic.Theyoccurrelativelyinfewinstances.Eg:Fusariumwiltofcotton(Fusarium

oxysporumfsp.vasiinfectum)grainsmutofsorghum(Sporisoriumsorghi)andloosesmutofwheat(Ustilago nuda).

Anepidemicmaycausewidespreadandmassdestructionofcropinashorttimeormaypersistforlongperiods dependingupon thethreefollowingfactors responsibleforthe disease:

1. Host
2. Pathogenand
3. Environment

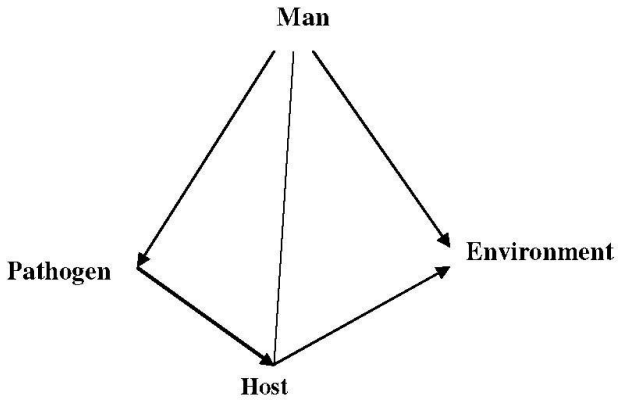
Environmentflowchart



Pathogen

A course of epidemic in nature differs with the nature of the host, the pathogen and theenvironment. In arecanut the Koleroga fungus, *Phytophthora arecae* become destructive duringmonsoon period (July-Sep) and wanes away with rising temperatures and dry conditions. Theabove disease once again become destructive during rainy season. This type of epidemic isknown as seasonal epidemic or annual epidemic. Outbreak of *Phytophthora* wilt of betelvineoccurs during rainy season in South India. In temperate zone peach leaf curl and apple scabfollowthesimilar course.

Epidemicscausedasaresultofintroductionofnewpathogensinthelocalityhithertofree from them, appear in two phases viz., destructive phase and innocent phase (due to biologicequilibrium reached between new comer pathogen and the original inhabitant). The well knownepidemics of late blight of potato in Europe and blast disease of rice in South East Asia, powderymildewanddownymildewofgrapevineinEurope,leafrustofcoffeeinSriLankaandanthracnose of grapevine inIndia are examplesof this category.In the above diseases thepathogensafter taking heavytoll of thecrops havesettled down.



Factorsgoverningepidemicor essentialconditionsforanepidemic

Adiseaseissometimessporadicandassumesepidemicproportionsunderspecialcircumstances. The essential conditions for an epiphytotic or the factors governing epidemics canbegroupedunder thethreeheads.

1. Natureofhost
2. Natureof thepathogen and
3. Environment

Anepidemiccanonlyresultfromthecumulativeeffectsofallthethreefactorsmentioned above, acting simultaneously. Few pathogens are capable of assuming epiphytoticconditions while others are sporadic. The former group consists of late blight of potato, blast ofrice,downymildewdiseases andrust diseases.

Host	**Pathogen**	**Environment**
Susceptibilityofthe host	Introductionofanew Pathogen	Temperature
Aggregationand distribution ofsusceptiblehosts	Presenceofaggressives trainofthe pathogen	Moistureand humidity
Introductionofnew hosts	Highbirth rateofthe Pathogen	Rainfall
Introductionof	Lowdeathrate ofthepathogen	Lightand

newcollateralor alternatepathogen host		shade
	EasyandrapiddispersalWind ofthepathogenAdaptabilityofthepathogen	Wind

A. HostFactors

1. Susceptibilityofthehost

Plants have ability to combat disease which manifests itself as susceptibility or resistance.Plants are predisposed to the attack depending on their nature, environment and stage of growth.Presence of susceptible varieties in an area may act as one of the causes of epidemic. Forexample, late maturing varieties of groundnut are more susceptible to early leaf spot (*Cercosporaarachidicola)* and late leaf spot*(Phaeoisariopsis)* than the early maturing varieties. Similarlylate maturing varieties of wheat are susceptible to loose smut*(Ustilago nuda tritici)* than theearly maturing varieties. Early sown sugarcane varieties of sugarcane are more susceptible to leafrustin Deccan canals in Bombayareathan the latesownvarieties.

Wheatplantbecomessusceptibletoblackrust*(Pucciniagraministritici)*atthebootstage but is resistant whenyoung. Susceptibility of rice plants to blast disease (Pyriculariaoryzae*)* increases with application of heavy doses of nitrogenous fertilizers. Cottons plants aresusceptible to *Fusarium* wilt (*F.oxysporum f.sp. vasinfectum)* at soil temperatures of 26 to 28°C,brinjal to *Verticillium* wilt *Verticillium dahliae* at 20°C. But crop plants are resistant to thesesoil-borne diseases at relatively lower or higher temperatures. Under the above conditions, thepathogenmultipliesfaster,causeinfectionandeffectivelyusesitspropagulesforquicksecondaryspreadcausingepidemic.

2. Aggregationanddistributionof susceptiblehosts

Abundance of susceptible hosts in an area is one of the major causes of the spread ofepidemics. Continuous cultivation of susceptible variety or varieties in an area, that too in a largecontiguous area help in the build up of inoculum and improve the chances of epidemics. Underthe above conditions the pathogen increases the rate of multiplication of its propagules andrepeatsthediseasecyclesinashortspan.WheatcultivationareaintheU.S.AandCanadaand

rice cultivation area in East Asian countries are exposed to a greater danger of epidemics bywheatblackrust and riceblast respectively.

Destructive epidemic of early and late leaf spots of groundnut in Bombay area (Gujaratand Maharashtra States) during 1912-1913 was mainly the result of cultivation of local varietiesin a larger area. Panama wilt (*Fusarium oxysporum* f.sp. v*asinfectum)* susceptible table variety,'Son' in banana was responsible for the destructive epidemic in parts of Bombay area (GujaratandMaharashtra)during1936–1940Countrywidecultivationofredrot(*Colletotrichumfalcatum*) susceptible sugarcane varieties (local varieties like *Pundya, Khajuria* etc.,) practicallymadetheircultivation impossiblein Bombayarea.

3. Introductionofnewhost(s)

Disease proneness in the host is induced by environment and other factors. The host isliable to vigorous attack and successful infection by the pathogen. A resistant or moderatelyresistantvarietymaybecomesusceptibleorhighlysusceptible.Asusceptiblevarietymaybecome highly susceptible when conditions favouring proneness are existing and cause severedamage. Under the above conditions the pathogen multiplies faster, cause infection and producesmore propagules for secondary spread. Introduction of an exotic cotton variety (C4 (Cambodia)causedoutbreakofbacterialblight(*Xanthomonasaxonopodis*pv.*malvacearum)*andgrey mildew*(Septoacylindriumgossypii)*inlocalvariety,Deviraj,grownin MaharashtraareainIndia.

4. Introductionofnew collateraloralternatehosts

Alternatehostsarethoseplantsonwhichtheheteroeciouspathogenspasspartoftheirlife cycles. Similarly, collateral hosts are some wild plants in which the pathogen survives whenprimary host is not available. Both alternate and collateral hosts are important in building up theprimaryinoculum to the next crop. Theydeterminethe courseand intensityof an epidemic.

Grasshosts(collateralhosts)of*Sclerosporasacchari,S.philippinensis(*downymildews), *Pyricularia oryzae* (rice blast), *Ustilago scitaminea* (sugarcane smut) may produceabundant inoculum which aid in building up of epidemics. Outbreak of heteroecious blister rustofpine*(Cronartiumribicola)*inEuropeandtheU.S.Ahappenedduetoimportorintroductionof*Pinus strobus* from theUSA.

B. PathogenicFactors

1. Introductionofnewpathogen

Some pathogens, epidemic in certain area, may become quite aggressive and outbreak asepidemicwhenintroducedtonewarea.Forexamplelateblightofpotatocausedby*Phytophthora infestans* was epidemic in South America. This disease became epidemic when theinfected tubers were introduced in Europe (in 1843-45). Fire blight (*Erwinia amylovora* in NorthAmerica is endemic. Fire blight spread to Pacific coast fruit-growing areas of the U.S.A in 1884and subsequently it reached Canada. It reached New Zealand in 1919 and it appeared in Englandin 1957. The mode of introduction had been through fruit boxes. Coffee rust (*Hemileia vastatrix)*is indigenous in Ethiopia, where *Coffea arabica* is native. The disease spread to Sri Lanka in1869, India in 1870, Sumatra in 1876, Java in 1878 and the Philippines in 1889. It also spreadfrom Kenya to the Congo by 1918 and reached the Cameroons. From 1950 onwards, it spread tothereminder ofWest Africa.

The mode of long distance transport of H. *vastatrix* is wind. Spores have been trapped atup to 1000 m above sea level up to 150 m from infected sites. Dutch elm diseases *(Ceratocystisulmi*) first reported in 1919 in Holland, spread throughout Europe and reached Great Britain in1927.Itwas introducedtothe easternUnitedStates onelm logsimportedfrom Europe.

2. Presenceof aggressivestrain ofthepathogen

All the strains of a pathogen are not aggressive. Only the aggressive strains are capable ofcausing infectious diseases which spread as epidemic. They are characterised by rapid cycle ofinfection and causing successful infection in new hosts. Rapid cycle of infection is essential forsuccessful infection and it happens only by aggressive strain of the pathogen. e.g., *Pucciniagraministritici*(wheatblackrust)inIndia,striperust,buntandloosesmutofwheatinthe U.S.A. and Europe. The possibility of outbreakof epidemics increases with the number ofphysiologicforms orpathogenicstrains ofthe pathogen presentin alocality.

3. Highbirthrateof thepathogen

Pathogen with high reproductive capacity and capable of rapid dissemination over wideareas mostly cause epidemics. The fungal members causing powdery mildews, downy mildews,rusts, blasts, blights etc., produce enormous amount of spores. These spores are easily dispersedbyusingwaterorinsectsandcauseinfectionstonewplants.Thehighdegreeoffecundityand

theenormousamountsofinoculumproducedbysomecommonplantpathogensaregivenintable.

Fecundityratesof plantpathogens

Sl. No	Pathogen	Extentoffecundity
	Wheatstemrust*(Pucciniagraminis tritici)*	Twentyfive trillion uredospores in one hectareofwheatcrops.
2	Wheatstemrust*(Pucciniagraminis tritici)*	64,000millionaeciosporesfromaecialcups in a singlebarberrybush
3	Cedarrustofapple	Twobillion teliosporesin asinglegall.
4.	Acornplantinfectedwithdowny mildew	225million sporangia inonenight
5.	A. grapevine infected by downy mildew	32,000sporangiapersq.cm
6.	Buntofwheat	6to12millionsmutsporesinasinglekernel
7.	Smutofcorn	125,000billionsmutsporesinonehectare
8.	Chestnutblight	150,000,000spores in a singlesporehorn
9.	*Fomesapplanatus*	5,460billion spores in a singlefruiting body

4. Lowdeathrate

Epiphytotics may also be caused by low death rate diseases. These diseases are caused byagents of systemic nature which are protected by plant tissues. As they are protected by planttissues the chances of high mortality is reduced to the minimum. In these diseases the chiefsourceforaccumulationofinoculumforepiphytoticsisthediseasedplantorganusedforvegetativep ropagation(corms,setts,tubers,etc,).Herethebuildupofepidemicsiscomparatively low compared to high birth rate diseases. When a particular area is planted andcovered with diseased planting material the chances of occurrence of epiphytotics are very high.e.g.,virus and phytoplasma diseases incrops propagated through vegetativeplantparts.

5. Easyandrapiddispersalof thepathogen

The ability of the pathogen to cause epidemic depends both on the high birth rate anddispersal. The propagules of the pathogen produced should be dispersed for development of anepidemic. It may happen by external agencies like wind, water, insects, mites and nematodes.Fungal spores /conidia are minute and lightand resistant toadverse conditions. Fungal sporesare mostly disseminated by wind. Bacteria are mostly disseminated by water or insects.Virusand phytoplasma diseases are mostly transmitted by insects, mites or nematodes. Epidemics aredetermined by the velocity of wind, direction of wind, moisture, relative humidity, temperature,presenceand number of vectors and theirrateof reproduction.

6. Adaptabilityofthepathogen

Pathogens have the capacity to adapt to adverse conditions. Fungi produce different typesof spores like oospores, ascospores and smut spores (chlamydospores) which help in tiding overadverse conditions. Bacteria survive in diseased plant parts. Viruses and phytoplasmas live incollateralhosts or insectvectorsin theabsenceof the suitable crop hosts.

C. EnvironmentalFactors

The environmental conditions such as temperature, relative humidity, rainfall, durationand intensity of light, etc. play very important role in causing epidemics. These are actually thedeciding factors and influence almost all the stages of disease cycle. Favourable environmentalconditionsareneededforsporulation,liberationofspores,disseminationofpathogen,germination,infection and establishment of pathogen in the host.

Forexample,persistentoptimumtemperatureandmoistureareneededforsporegermination and entry of germ tube in the host. Similarly optimum temperature, moisture, lightand specific nutrition is required for the development of the disease and sporulation of pathogen.Compoundinterestdiseasesandsimpleinterestdiseases Thetermscompoundinterestandsimple interest are for explaining rate of increase of pathogen. These terms were introduced byVanderPlankin1963inthebook 'PlantDiseases-EpidemicsandControl'.Basedonthemodeofmultiplication ofpathogen, thediseasesare classified oftwo types:

1. Simpleinterestdiseases
2. Compoundinterestdiseases

1. Simpleinterestdiseases

In simple interest diseases the increase is mathematically analogous to simple interest inmoney.There is only one generation ofthe pathogen in the life of the crop.The primaryinoculum is seed-borne or soil-borne. The secondary infection rarely occurs during the cropseason. That is, the pathogens do not spread from plant to plant in one growing season. Simpleinterest diseases are caused by seed-or soil-borne smuts, like loose smut of wheat, covered smutof barley and soil borne fungi which attack roots, like wilt *(Fusarium oxysporum)* and root rot*(Rhizoctonia*spp.) diseases.

Most of the smuts infect the seedlings, grow along with the growth of the plant andproduce spores in the inflorescence on maturity of the crop. There is no secondary spread fromthe smutted heads. These smut diseases are mostly systemic in nature. They do not producepropagules external to the host during the active season of the crop. Dispersal of propagules ofthesefungi is restricted byexisting climaticand bioticconditions.

2. Compoundinterestdiseases

Incompoundinterestdiseasestherateofincreaseismathematicallyanalogoustocompound interest in money. The pathogen produces enormous amount of spores at a very rapidrate.Thesesporesaredisseminatedrapidlybywindandinfecttheotherplants.Boththeinoculation and sporulation period are short so that the pathogen spreads from plant to plantduring the same growing season. New crop of spores is produced, disseminated and the cycle isrepeated fast. Thus more generations of the pathogen are produced in the life of a crop. e.g., lateblight of potato, powdery mildews and rust diseases. If we consider wheat stem rust caused by*Puccinia graminis tritici* as an example, the fungus produces uredospores in very large numbers(50,000to 4,00,000 uredospores peruredosorus).

These spores are spread by wind and infect other plants. Each of the freshly infectedwheatplantproducesuredopustuleswithin5to7daysat24°C.Thuswithinaweekofappearance of the first pustule in the crop several thousand new pustules are formed which couldrepeat the process within a week. If the climatic conditions of about 24°C temperature andrelative humidityremainforonlyfewweeks, theentirecrop isseverelyaffected bythe disease.

Courseofepidemic

Thecourseof epidemicfollows two distinct phasesviz.,

i. Progressivelydestructivephaseand

ii. thedeclinephase

i. Progressivelydestructivephase

Some epidemics develop slowly (tardive) while others develop rapidly. Slow epidemics(or epiphytotics) usually occur among population caused by systemic pathogens. The pathogenmultiplies slowly following the characters of simple interest disease. They belong to low deathratecategoryandhavelessincubationperiodandsporulationperiod.However,therapidepiphytotics aregreatlyinfluenced byenvironmental factors.

ii. Declinephase

During early stage, an epidemic spreads vigorously causing diseases in new hosts. Afterdevelopment of a saturation stage it shows a decline by itself. No epidemics may be due to non-availability of suscepts non-availability of susceptible stages of the crop, unfavourable weatherconditions and reduction in aggressiveness of the pathogens. Generally the hosts are prone to thedisease at a specific developing stage. Once this stage is crossed in a plant it's proneness toinfections is reduced or completely lost. Under the conditions the epidemic declines. The declinein the epidemic may also be due to unfavourable weather conditions for disease development. Asa result future spread of the disease will be checked and the epidemic will decline. Wheat crop inNorthernIndiausuallygets theattack ofrusts in Januaryto March.

Epidemics develop during these months. Although the plant remains prone to attackafterwards also, further development of the disease is checked because of rise in temperaturewhichisfavourableforthepathogen.Duetotheabovementionedandothercauses,theaggressiveness of the pathogen may be reduced. When all susceptible individuals are destroyedby the pathogen, it may try to parasitize the remaining resistant individuals of the same species.Intheseadverseconditions,thepathogenmayloseitspowerofsuccessfulinfection,itsreproductionmayslow down and the pathogen becomes less aggressive.

Slowandrapidepiphytotics

The form of epidemic is decided by the nature of the pathogen, host and the weather.Epidemic may develop slowly and is called ' tardive'. Epidemic which develops rapidly is called'explosive'.In between theseintermediateformsofepidemicmayoccur.

i. Slowepiphytotics

Slow epiphytotics occur among perennial (tree) populations. Infected host survives forseveralyearsbeforedying.Mostofthecharactersofasimpleinterestdiseasearefoundinslow

epiphytotics.Thecausalagentismostlysystemic.Thepathogenmultipliesslowly.Theirmovement from plant to plant is much slower. They are low death rate pathogen. In slowepiphytotics,crop sanitation isthe best method. e.g.,Swollen shoot of cocoa.

Thisdiseasespreadsvery slowly fromtreetotreeandstilllessfrom onegardentoanother garden. For instance, the incidence of 31 % swollen shoot increased to 75 % over aperiod of 2.5 years. As stated by Van der Plank (1959) the rate of multiplication of a systemicdisease of trees is about ten fold a year whereas it is 10,000 fold in respect of herbaceous plantsandit is of higher ratesforlocal lesionpathogens e.g.,lateblightof potato, wheatstem rust,etc.,

ii. Rapidepiphytotics

Rapid epiphytotics occur among annual crops. It is caused by non-systemic pathogenswith high birth rate. Several generations of the pathogen is produced within a short time.

Rapidepiphytoticsarelargelygovernedbyenvironmentalfactorscomparedtoslowepiphytotics.Disease increase is rapid and the disease rises to a beak in short time and then show sharp declinewhentheweatherturnsunfavourableorwhenthehostbecomesresistantduetomaturityorddueto restricted dispersal of propagules of pathogen. e.g.,apple scab. This type of epiphytotic iscontrolledbyprotectivespraying or dusting with chemicals.

Lecture02

PlantDiseaseForcasting–Meaning,advantages,methodsinforecastingandexamples

DiseaseForecasting

Forecasting of plant diseases means predicting for the occurrence of plant disease in aspecified area ahead of time, so that suitable control measures can be undertaken in advance toavoid losses. Disease forecasts are predictions of probable outbreaks or increase in intensity ofdisease. It involves well organized team work and expenditure of time, energy and money. It isused as an aid to the timely application of chemicals. Among the first spray warning services tobe established for growers, were the grapevine downy mildew forecasting schemes in France,Germany andItaly in the 1920s. Disease forecasting methods are available for the followingplantdiseases.

Sl. No	**Plantdisease**	**Countries**
1.	Grapevine downymildew	Australia,France,Germany,Greece,Italy,Romania, Spain,USSR,Yugoslavia
2.	Cucurbitdownymildew	U.S.A.
3.	Potatolateblight	Australia,Brazil,Finland,France,Germany,Greece, Japan,theNetherlands, Norway,Peru, U.K,the U.S.S.R.
4.	Tobaccobluemould	Canada,U.S.A.
5.	Appleand pearscab	Australia,Canada, Netherlands,NewZealand, U.S.A.
6.	Sugarbeetrootrot (*Aphanomyces*sp.)	U.S.A
7.	Wheatbrown(Leaf)rust	U.S.A.
8.	Corn bacterial wilt (*Erwiniastewartii*)	U.S.A
9.	Sugarbeetcurlytop	U.S.A.

Information'sneededfordiseaseforecasting

Forecastingdiseasesisapartofappliedepidemiology.Hence,knowledgeofepidemiology (development of disease under the influence of factors associated with the host,pathogen) is necessary for accurate forecasting. The factors of epidemic and its componentsshouldbeknown in advancebeforeforecasting is done.

Theinformationsrequiredforforecasting are:

1. HostFactors

a. Prevalenceofsusceptiblevarieties inthegiven locality

b. Response of host at different stages of the growth to the activity of pathogen e.g. Somediseasesarefound duringseedling stages whileothers attack grownup plants and

c. Density and distribution of the host in a given locality. Dense populations of susceptiblevariety invite quick spread of an epidemic. Growing susceptible varieties in scattered locationsandthat too in alimited areaareless proneto epiphytotic.

2. Pathogenfactors

a. Amountofprimary(initial)inoculum intheair,soilor plantingmaterial

b. Dispersalofinoculum

c. Sporegermination

d. Infection

e. Incubationperiod

f. Sporulationon theinfected host

g. Re-dispersal/Disseminationofspores

h. Perennatingstages

i. Inoculumpotentialanddensityin theseed,soilandair

3. Environmentalfactors

a. Temperature

b. Humidity

c. Lightintensity

d. Windvelocity

Requirementsorconditionsfordiseaseforecasting

There are five main requirements which must be satisfied before a useful and successfuldiseaseforecast is made.

1. The disease must cause economically significant damage in terms of yield loss or quality.Damageassessmentisessentialtodevelopstrategyforcontrollingadisease.e.g.,Annualestimation of yield loss caused by barley powdery mildew (*Erysiphe polygoni*) in England andWales had ranged from 6 to 13 %. Potato late blight can cause a yield loss of 28% if the diseasereaches the 75% stage by mid- August. Diseases like apple scaband potato common scabreduces the quality of the produce lower the value of the harvested crop and cause considerablefinancialloss to thegrowers.

2. Controlmeasuresmustbeavailable ataneconomicallyacceptablecost.

3. The disease must vary each season in the timing of the first infections and its subsequent rateofprogress.Ifit does not,thereis no needforforecasting.

4. The criteria or model used inmaking a predictionmustbe based on soundinvestigationalwork carried out in the laboratory and in the field and tested over a number of years to establishitsaccuracyandapplicabilityin all thelocations whereits use isenvisaged.

5. Growers must have sufficient man power and equipments to apply control measures whendisease warning is given. Long-term warnings or predictions are more useful than short-termwarningorpredictions.

Methodsof diseaseforecasting

Disease forecasting requires field observations on the pathogen characters, collection ofweather data, variety of the crop and certain investigations and their correlations. Usually thefollowingmethods areemployed in diseaseforecasting.

1. Forecastingbasedonprimaryinoculums

Presence of primary inoculum, its density and viability are determined in the air, soil orplanting material. Occurrence of viable spores or propagules in the air can be assessed by usingdifferentairtrappingdevices(sporetraps).Inthecaseofsoil-bornediseasestheprimaryinoculumin the soil can bedetermined bymonoculturemethod.

Presenceofloosesmutofwheat,ergotofpearlmilletandviraldiseasesofpotatocanbedetectedintheseedlotsatrandombydifferentseedtestingmethods.Seedtestingmethodscanbe used to determine potential disease incidence and enable decision to be made on the need forchemicalseedtreatment.Theextentofmanyvirusdiseasesisdependentontheseverityoftheprecedingwinterwhichaffectsthesizeofvectorpopulationinthegrowingseason.e.g.,Sugarbeetyellows virus.

2. Forecastingbasedonweatherconditions

Weather conditions *viz*.,temperature, relative humidity, rainfall, light, wind velocity etc.,during the crop season and during the inter crop season are measured. Weather conditions abovethecrop andat thesoil surfacearealso recorded.

3. Forecastingbasedoncorrelativeinformation

Weather dataof severalyearsare collected andcorrelatedwiththe intensity ofthediseases. The data are compared and then the forecasting of the disease is done. Forecastingcriteria developed from comparisons of disease observation with standard meteorological datahave been provided for diseases like *Septoria* leaf blotch of wheat, fire blight of apple and barleypowderymildew.

4. Useof computerfordiseaseforecasting

In some advanced countries forecasting of disease is made by the use of computers. Thissystem gives the results quickly. One such computer based programmes in the USA is known as‘Blitecast’ for potato late blight. Examples of well developed forecasting systems are givenbelow.

a. Earlyandlateleaf spotsof groundnut

A technique has been developed forforecasting early and late leaf spots of groundnut inthe U.S.A. When the groundnut foliage remains wet for a period greater than or equal to 10 h andthe minimum temperature is 21°C or higher for two consecutive days or nights, the diseasedevelopmentis forecasted.

A computer programme has been developed in the USA. This is accurate and is widelyused in the USA. The data on hours for day with relative humidity (RH) of 95% and above andminimum temperature (T) during the RH observations for the period, for the previous 5 days arefed to the computer. Calculations are rounded to whole numbers. The T/RH index for each of thefive days is calculated e.g., when hours of the RH 95% equal 10 and the minimum temperatureduring the period equals 21.1°C the T/RH index is 2.0 .The T/RH indices for days 4 and 5 aresummed. If the total index exceeds 4 disease is forecasted. If the index is 3 or less no disease isforecasted.

b. Lateblightofpotato

IntheUSAaforecastingprogrammehasbeendevelopedforlateblightofpotato(*Phytophthora infestans*). The initial appearance of late blight is forecasted 7 to 14 days after theoccurrence of 10 consecutive blight favourable days. A day is considered to be blight favourablewhen the 5 day average temperature is 25.5°C and the total rainfall for the last 10 days is morethan 3.0 cm. A computerized version (Blitecast) has also been developed in the U.S.A forforecasting potato late blight. Blitecast is written in Fortran IV. When a farmer desires blight cast(blitecast)hetelephonestheblightcastoperatorandreportsthemostrecentlyrecordedenvironmental data. The operator calls for the blight cast programmes in the computer *viz*.,typewriter terminal and feeds the new data into the computer. Within a fraction of second thecomputer analyses the data and series of a forecast and spray recommendations to the operatorwhorelays it to thefarmer.

The entire operation can be completed during standard three minutes telephone call. Thesystem makes one of the four recommendations viz., no spray, late blight warning, 7 days sprayschedule or 5 days spray schedule. The last 5 days spray schedule is issued only during severeblightweather.InWestGermany,'Phytoprog'istheprogrammeused.Itisbasedonmeasurements of temperature, relative humidity and rainfall. Phytoprog provides a negativeprognose(an indicationofwhenthe usualroutinesprayapplication shouldbedispensed with).

c. Blisterblightoftea

A system for predicting epidemics of blister blight of tea (*Exobasidium vexans*) has beendeveloped based on the number of spores in the air in the tea plantation and the duration ofsurface wetness on the leaves. The duration of sunshine is negatively correlated with the durationof surface wetness. The following prediction equation has been developed. Y = 1.8324 + 0.8439X1 + 0.9665 X2 – 0.1031 X3where, X1 = log % infection t2X2 = log % infection t2 – loginfection t1Y = log of the number of spores in the air and t1 – t2 three weeksX3 = mean dailysunshinefora7 days period preceding t2

d. Southerncornleafblight

'Epimay'isasystemforforecastingSoutherncornleafblight(*Bipolarismaydis*)basedonconceptual model.

e. Riceblast

In India, forecasting rice blast (*Pyricularia ozyzae*) is done by correlative informationmethod. It is predicted on the basis of minimum night temperature 20 to 26°C in association withhigh relative humidity of 90% or above. Computer based forecasting system has also beendevelopedfor riceblast inIndia.

f. Wheatstemrust

Forecasting wheat stem rust epidemic is done by analysing therain samples which giveprecise data for inoculum present in the air. Moreover several wind trajectors are also prepared tosurvey the air-borne primary inoculums and its deposition. It has been observed that primaryinoculumcomes fromSouthIndia, tothe plains ofCentral and NorthIndia.

g. Brownstripedownymildew ofcorn

The forecasting of brown stripe downy mildew of corn (*Sclerophthora raysise* var. *zeae*)which is restricted to India is done on the basis of average rainfall 100 to 200 cm or moreaccompanied by low temperature (25°C or less). Spore trappingTechniques of acquisition ofbiological data for consecutive forecasting models are important. Spore traps have been widelyusedinto completediseasewithweather conditions. Sporetrappingisusefulforunderstandingepidemiologyofadiseaseandbehaviourofthepathogens.Thishelpsindeveloping models on dispersal of pathogens or on epidemiology of the disease and to formulatemethods of management. Methodology of spore trapping depends on the following objectives oftheworker.

1. Biologyofthepathogen
2. Forinfectionforecasting
3. Sporedispersal gradients
4. Managementofthedisease

In epidemics of air-borne plant diseases the number of spores of the pathogen landing on theplant which depends on the number of spores in the atmosphere above the crop is an importantfactor for the quantitative sampling of the atmosphere (number of spores per unit volume ofair).For trapping and estimating these studies different types of traps are used. The followingsporetraps areusuallyemployed in trapping offungal spores.

Cylindrical rods or microscopic glass slides: It helps to gather data on the spore arrival in alocality. In this, the surface of microscopic slide is smeared with grease and made sticky. In themethod,quantitative estimation isnot possible asnumberof sporescollected is verylow.

1. Hirst'svolumetricsporetrap (Hirst1952)

In this instrument, air is sucked into at a controlled rate and impinged on to a glass slidemoved by a clockwork mechanism past the orifice. It gives continuous count of spores in 24 h.Thenumberof spores per unit volume ofairat anygiven time can thus becalculated.

2. Rotorodsampleror rotorodsporetrap(SuttonandJones1976)

It comprises of a 'U' shaped rod attached at its mid point to the shaft of a small batteryoperatedelectricmotor.Inthisequipmentthesurfaceoftherodiscoveredwithavaselinestripof transparent cellophanes to catch spores which can be taken off and mounted on a glass slide.Fromthe areaof thestripand the speedof rotation, thevolume ofairsamples can be calculated.

3. Andersoncascadesporesampler

ItisadevicewherePetriplateswith nutrientagar areusedtocollectthespores.

4. Bourdillonslitsampler

AirissuckedinachamberbyvacuumpumpwhichstrikestherotatingPetridishcontaining agar medium. The agar medium retains the spores sucked in the air. Concentration ofviablespores is calculated aftercounting germinated spores in themedium.

5. Burkard's7dayvolumetricsporetrap

This device records spores in the air drawn by a pump on 7 days basis on a cellophanestripwrapped onadrumrotating inside achamber.

6. Jetsporetrap

In the above sampling methods, the viability of the spores cannot be determined. Toovercome this, living plants have been used as spore traps. A jet spore trap in which spores areimpacted in an air jet into a column of still air, through which they fall, to settle on leaf segmentsexposed at the base of the chamber. In this trap, suitable cultivars of host plants can be employedtodeterminenumberof viablespores.

Lecture03

Remotesensing–Meaning,scope,objectives,advantages

Remote sensing carries many different connotations to different individuals, ranging fromphotography to large satellite platforms. Each day we are provided many frames of remotesensing information through our eyes, which we use to make visual assessments of an object.Thesescenesprovideaninformationsourceaboutobjectsfromwhichwejudgecertaincharacteristics, e.g., size, condition, or change. The local TV weather report uses remote sensingof clouds to show the passage of storms. Plant pathologists have used remote sensing tools for anumber ofyears and were among the first to use color infrared photography to assess thepresence of disease in trees. The application of remote sensing via airborne cameras provided ananswer to a question that would not have been possible through ground surveys. In many aspectswe have progressed rapidly to our current state of knowledge about the utility of remote sensing.The intent of this address is to arouse the interest of individuals in discovering how remotesensingcould be appliedto plant pathologicalproblems oftodayandtomorrow.

RegionsofTheSpectrum

Thespectrumofelectromagneticradiationrangesfromthefromshort,highenergywavelengths to the long radio waves. As a receptor, the human eye only measures a relativelysmall portion of the spectrum in the visible wavelengths from 0.4 to 0.7 gtm. Remote sensinginstruments, on the other hand, have utilized wavelengths extending in the microwave region foravarietyofapplications.Forthisdiscussion,wewillconfinethewavelengthstotheregionfrom 0.4 to 14 /im. The region from 0.4 to 5 /Mm can be represented as the reflected wavelengths.Reflectionisthatphenomenoninwhichanimpingingbeamofradiationofaparticularwave length is reflected back away from the object without any change. This can be contrasted toemittance,whichistheemittingofradiantenergyataparticularwavelengthduetothetemperature of an object. Surfaces at the temperature of the earth (300' K) emit mostly in 10-124m waveband, while thesun at 6000^{0}K emits in the 0.5 pm region. Both reflectance andemittance provide information that can be utilized in applying remote sensing to agriculturalproblems.

ReflectionfromLeaves

Reflection from individual leaves is not constant across the wavelengths from 0.4 to 2.5ym.Leaveshavealowreflectanceinthevisible(0.4-0.7/m),ahighreflectanceinthenear-

infrared (0.7-1.2 Mm), and a low reflectance in the middle and far infrared (1.2 *Mm)* wavebands.This variation in leaf reflectance has allowed for the differentiation of leaves from soil, whichtendsto show little variation inreflectanceacross thesewavelengths.

Reflectance from leaves is species dependent and sometimes cultivar dependent. Theprimary variation among species is in the visible reflectance and is due to species or leaf age.Reflectance tends to increase in individual leaves as the leaf matures; however, the changes arewavelength dependent. These changes are due to changes in intracellular water content andchlorophyll content. Lesions and reduction in chlorophyll content created by a disease also causean increase in reflectance. Water stress by reducing the internal water content increases thereflectance from an individual leaf. Information gathered from individual leaves provides a basicset of information about the mechanism of the changes occurring within a plant; however, to beofpractical application it must beextended to a canopyorfield level.

ReflectionfromCanopies and Fields

Composites of leaves or canopies exhibit the same reflective properties of individualleaves; however, there are a series of variables that now must be considered.Leaf orientation,i.e., the arrangement of leaves on the stem and orientation to the sun, provides a source ofvariation when viewing a canopy compared with an individual leaf. Also, all leaves are notexposed to the same level of incoming radiant energy and often do not reflect back to the sky dueto distortions in the leaf surface. Leaf surfaces often act as polarizing filters and reflect back toportions of the sky that are not always detected by viewing the canopy only the vertical direction.However, the information contained in bidirectional and polarized reflectance has yet to be fullyexploitedintheevaluationofcanopyresponsetostress.Leaffluorescenceisanotherattributethat has been observed in all plants and can be related to the efficiency of the photosyntheticprocess. It is possible that leaf fluorescence could be used to assess the impact of diseases on thephysiologicalstatusoftheplant.Thistechniquehasonlybeenusedonindividualleaves;however, it could be extended to canopies through the use of laser-induced fluorescence. Thisprocedure will have to be adapted to plant canopies but may become a powerful and usefulresearchtool.

Canopies of plants are grown in fields with varying soil, and soil also has some uniquereflective properties. The variation across wavelengths is less for soil than for leaves; however,thereflectancechangesinresponsetomodificationsinthesurface.Theadditionoforganic

matter as residue on the surface reduces the reflectance. Soils vary in reflectance due to mineralcompositionandweatheringoftheminerals.However,acrossthevisibleandnear-infraredwavelengthsthereflectancefromsoilremainsrelativelyconstantwithinagivensoiltype.Changesinwatercontentintheupper2mmcausethelargestvariationinreflectance.Waterhasa low reflectance and the addition of a water film around the soil aggregate causes an increasedabsorption of the incident radiation. As a soil is wetted there is a darkening in the color, whichlightens as the soil dries. This variation in the reflectance from soils due to changing soil wateradds, complexity to the reflectance from canopies, particularly when there is less than completeground cover by the plant, i.e., exposed soils when viewed from above the plant. Since there is achangingamountofplantmaterialbothintheaddingofnewleavesorthesenescenceoftheolderleaves,thereisacontinuallychangingscenetobeviewed.Thischallengemustbefacedand understood if we are to develop the tools that allow us to assess the effect of a disease or anyotherstresson theplant.

Instruments available for the measurement of reflected radiation adaptable to remotesensing range from the portable spectro-radiometer, which measures all wavelengths between 0.4and 1.1 /tm to radiometers with multiple channels set for discrete wave- bands. Instruments withindividual channels mimic the wavebands available on the current satellites. A rapidly emergingtechnology that has yet to be applied is the use of multiple waveband video cameras. This systemoffers a capability not possible with other radiometers, in that the data are readily available forviewing without intense signal processing and manipulation. Video camera systems may provideapractical tool fordiseaseassessment.

VegetativeIndices

Tousetheinformationcontainedinthereflectanceacrosswavelengths,severalvegetative indices have been proposed and evaluated. These indices are based primarily on theratioordifferencebetweenthereflectanceinthenear-infraredandredwavelengths.Theapproachesrangefromsimpleratiosofnear-infrared/-red)/(near-infrared+red)]ismoreappropriately related to the interception of photosynthetically active radiation. To account for thesoil background the perpendicular vegetative index was developed to account for a changing soilbackground due to sur- face soil water content changes. There have been several other indicesdevelopedto describehow thechanging reflectiveproper-tieschange with growth ofthe plant.

Observed changes in the vegetative index, in particular, the ratio vegetative index and thenormalized vegetative index have shown unique seasonal patterns. The patterns of both indicesshow an increase with the developing canopy and a hysteresis effect during senescence becauseplant material remains standing in the field, which has different reflective properties than the soilin the background. Over fields of seemingly uniform conditions there is considerable variation inthe observed signal whether the data are collected with hand-held, boom-mounted, or aircraft-mounted systems. The variation is typically 10% of the field mean. However, the change inspatial variability may be one of the methods that could be effectively used to monitor thechanges that occur within fields as a result of disease. Most diseases do not infect a whole fielduniformly and thus could induce a change in the field pattern. Even on a single sample event thismethod could provide valuable information given a priori knowledge about the expected level offieldvariability.

EmittedRadiation

All objects that have a temperature emit radiation according to Planck's Law. Soil andplant canopies emit energy, and given the temperatures found on the earth's surface, range in the10-14 **bm** waveband. Temperature of a plant canopy can be described by the temperature ofindividual leaves, the temperature of foliage, or the temperature of the canopy that includes thesoil. Leaf temperatures that have been measured relative to the ccurrence of Verticillum wilt orbrown rot of soybeans *(Phialo- phora gregata* Gans) have been measured with attached leafthermocouples.OthermeasurementsofVerticillumwilthavebeenmadewithinfraredthermometers . Each method has provided a unique relationship of describing the change in leaftemperaturerelative to thepresenceofadisease.

EnergyExchangeProcesses

Temperatures of the leaf, foliage, or canopy are a result of the energy exchange process.The observed temperatures are a result of the partitioning between the sensible and latent heatexchanges and therefore are a balance between the energy impinging on the leaf or foliage andthewateravailableforevaporation.Simplystatedthen,asurfacewithafreewatersurfacewillbe as cool as possible given the meteorological conditions while one without water will be thewarmest possible under a given set of conditions. It is this relationship that has allowed foliagetemperature to be effectively used in the estimation of transpiretion from canopies. Also, anyfactorthatdisruptsthiswaterflowtotheleaf,e.g.,vasculardiseases,rootdiseases,ordiseases

that disrupt the stomatal action, will cause the foliage temperature to be higher than that observedinhealthyfoliage.Wehavebeensuccessfulinusingfoliageandcanopytemperatureinevapotranspiration models for a variety of crops. In well-irrigated crop canopies, the variationacross a field is relatively uniform and the variation increases with increasing soil water deficits.As with the reflected radiation, the change in field variability may be useful in defining thecharacteristicsofagivenfield.

CropStressIndices

To improve the efficiency of using foliage temperatures, several crop water stress indiceshavebeenproposedandevaluatedsincethemiddle1970s.Thesebecamepossibleatthistimedue to the leaf area index, while the normalized difference [(near-infrared development of theaccurate, portable, hand-held infrared thermo- meter. At first, the comparison was made betweenthe foliage and air temperature (Tf - Ta**),** since this form was the integral part of the energyexchange process. It was found that although the Tf - Ta differences were related to crop yieldinduced by water stress, the relationships were site dependent. Further development and studyrevealed that other environmental variables were needed to fully interpret foliage temperaturesanddeveloplesssite-specific relationships.Theprimary variableswerenetradiation,windspeed, and vapor pressure deficit. These stress indices have been based on the energy exchangeprinciples between the foliage and the surrounding atmosphere. Any factor that affects the rate ofwater movement to the leaf has an impact on the foliage temperature. For example, the additionofhighsaltcontentirrigationeveninlargeamountscausesthefoliagetemperaturestobewarmerthan thoseplantsirrigated with thesamevolumeofsalt-freewater.

Recent research has identified that plants have biochemical. temperature optima thatdefinetheoptimatemperatureforplantgrowth.Combiningfoliagetemperaturewiththesepredeterminedoptimatemperaturesprovidesanother descriptionofplantstress.Ithasbeenfound that plants with maximum growth in a particular environment have the minimum amountoftimeoutsideofthispredeterminedthermalrange.Forcotton,thisrangewasdeter,minedtobe 23-30 C and for wheat 18-25 C. This range has been defined as the thermal kinetic windowand is basedon the biochemical efficiency ofa particular plant. The utilityof this stress indexhas yet to be fully evaluated; however, it offers a method of linking the plant response to anobservedparameter. Eg:foliagetemperature.

Other methods that can be used are to calculate the canopy resistance to water vaporexchange. It is known that many diseases affect the stomatal resistance and the combinationenergybalanceandobservedfoliagetemperatureprovideamethodofestimatingcanopyresistance. These techniques, however, are yet to be applied to any measure of disease. They mayoffer the potential of quantifying the degree of stress or level of infection in ways that have notbeenpossible before.

The instruments available for measuring the foliage temperature range from hand-heldportableunits,tofixed,battery-poweredsystemstoairborneorsatellitethermalscannerssystems. The coverage is obtained, e.g., NOAA or GOES satellites. Smaller areas are coveredwith systems that provide less frequent coverage, e.g.,**LANDSAT** or **SPOT.** The variationwithin a scene of data obtained with an airborne or satellite system will not permit the reliabledetection of the onset of a disease. The handheld or fixed units on the ground may be useful in aresearchsettingtodetermine the casualrelationshipsandthe developmentof a monitoringprogram where a problem is suspected. Each of these instruments require some training to mostproperlycollect and interpret thedata.

TemporalandSpatialVariation

Boththetemporalandspatialattributesofremotesensingtechniquesdetectuniquefeatures about the surface being ob- served. Satellites that provide repeated coverage of the earthhave allowed assessments to be made of the changes that have occurred over a period of monthsor years. The same factors apply when applying remote sensing to the monitoring of agriculturalfields, forests, and native or managed grasslands. The value of repeatedcoverage has providedforaunique glimpse at theecosystem that wearetrying tomonitor.

Temporal variations can be large because the system to which we are applying may bechanging due to the normal progression of growth. However, we know what patterns to expectand deviations away from that pattern provide an investigative tool. Likewise, changes in thespatialpatternsmaysignalapotentialproblemwithinagivenfieldorecosystem.Theinterpretationoft hetemporalandspatialpatternwillrequiresomeexperiencebutmayprovideanindication ofaproblem not possiblebeforethis information wasmade available.

IntegratingRemoteSensing IntoPlantPathology

There are two avenues in which remote sensing information, either reflected or emittedradiation,canbeincorporatedintodiseasemonitoring.Thetwoapproachesinvolveeitherdirect

or indirect methods of evaluating the disease occurrence and extent. Given the number of factorsthat cause variation in both the reflected and emitted radiation signals it is unlikely that the directmonitoringmethodwillbeuseful.Boththeindirectanddirectmethodsrequireapriorіknowledgeth at acondition mayexist.

Given this knowledge then, one may use a direct monitoring program to measure theextentofadisease.eg:*Phytophthora*spp.onsoyabeansor*Fusarium*spponbeans,whichcausea reduction in leaf area. The spatial sampling capability provides an assessment not possible withground monitoring.

The indirect method would involve interpretation of deviations from the expected caseeither in temporal or spatial patterns. For example, an increase in foliage temperature in a fieldwithanadequatesoilwatersupplywouldsignalapotentialproblemthatcouldinvokeamonitoringef fort.Anunexplainedchangeinleafareaorwiltingresultinginachangeinreflectance could signal a problem before complete infestation. The utilization of both indirectand direct methods will require imagination and dedication to the problem by a number ofresearchers.

Lecture04

General principles of plant diseases management – Importance, general Principles – Avoidance,exclusion,eradication, protectionandtherapy, immunization

Information on etiology, symptoms, pathogenesis and epidemiology of plant diseases areintellectually interesting and scientifically justified but most important of all they are useful astheyhelpinformulationofmethodsdevelopedforsuccessfulmanagementofdiseaseandthereby increasingthe quantity andimproving the quality of plant andplant products. Practicesofdiseasemanagementvaryconsiderablyfromonediseasetoanotherdependinguponthetypeo f pathogen, the host and the biotic and abiotic factors involved. Contrary to management ofhuman and animal diseases where every individual is attended, the plants are generally treated aspopulationsand measures used as preventiverather than curative.

Methods for plant diseases control were first classified by Whetzel (1929) into exclusion,eradication,protectionandimmunization.Furtheradvancesinplantpathologyleadingtodev elopment of newer methods. Two more principles - avoidance and therapy were created(NAS,1968)

Avoidance

It involves avoiding disease by planting at time when, or in areas where inoculums isabsent or ineffective due to environmental conditions. The major aim is to enable the host toavoid contact with the pathogen or to ensure that the susceptible stage of the plant does notcoincide with favourable conditions for the pathogen. The main practices under avoidance arechoice of geographical area, selection of the field, choice of sowing/ planting time, selection ofseedandplantingmaterial,shortduration/diseaseescapingvarietiesandmodificationofagronomic/c ulturalpractices.Thepotatocultivationathighaltitudeisrelativelyfreefromviruses; as prevailing environmental conditions do not permit the buildup of vector populations.Similarly, early planting of potato or wheat, in indo Gangetic plains may escape late blight orstemrust damagerespectively.

Exclusion

It means preventing the inoculums from entering or establishing in a field or area where itdoes not exist. Seed certification, crop inspection, eradication of inoculums and / or insectvectors,andquarantinemeasuresaresomeofthe meansofpreventing the spread forpathogens.

Eradication

The process of reducing, inactivating, eliminating or destroying inoculums at the source,either from a region or from an individual plant in which it is already established is termed aseradication. Eradication involves eliminating the pathogen from infested areas; the magnitude ofthe operation involved may vary considerably. On eof the most extensive eradication operationscarried out so far was to get rid of the citrus canker (xanthomonas axonopodis)in the USA during1927- 35. As many as 4 million citrus trees were cut and burnt at a cost of about 2.5 milliondollars to eradicate the pathogen. The practices invariably employed to achieve eradication ofinoculumsincludeeradicationofalternateand/orcollateralhosts,croprotations,fieldsanitations,heat orchemical treatmentsof plantmaterials orsoil, biologicalcontrol etc.

Protection

The protection of infection courts against the inoculums of many fast spreading infectiouspathogen,broughtbywindfromneighboringfieldsoranyotherdistantplaceofsurvival.Princi ples of avoidance, exclusion and eradication may not be sufficient to prevent the contact ofhost with pathogen, thus development of the disease is imminent. Measures are necessary toprotect host plants from invading inoculums. It can be achieved by creating toxic barrier betweenthe plant surface and the inoculums. Methods employed to achieve such results are chemicalsprays,dusts, modification ofenvironment, and modification ofhost nutrition.

Hostresistance

It utilizes in – built mechanism to resist various activities of pathogen. The infection orsubsequent damage by pathogen can be rendered ineffective through genetic manipulation or bychemotherapy.The host resistance can also be induced by use of certain biotic and abioticfactors. The discovery of Mendelian laws of inheritance and developments in plant breedingtechniques have helped in developing crop varieties resistant to specific pathogen or group pfpathogens. The classical breeding techniques include selection, mutation and hybridization. Useof biotechnological tools such as tissue culture, genetic engineering and protoplast fusion arebeingused to developresistant cultivars ofvariouseconomicallyimportantcrops.

Therapy

It is the treatment of infected host plant, which is attempted in case of economicallyimportant horticulture plants. As a principle of plant disease control, it provides an

opportunity

tocureorrejuvenatethediseasedhostplantbyuseofphysicalorchemicalagents.Thefirstfiveof

these principles are mainly preventive (prophylactic) and constitute the major components ofplant disease management. They are applied to the population of plants before infection takesplace. Therapy is a curative procedure and is applied to individuals after infection has takenplace.Under the conceptof disease managementthese principleshave beenclassifiedintofollowing fivecategories:

1. Managementofphysicalenvironment(culturalcontrol)
2. Managementof associatedmicrobiota(biologicalantagonism)
3. Managementofhostgenes(hostresistance)
4. Managementwithchemicals(Chemicalcontrol)
5. Managementwiththerapy(Physical,chemicaletc)

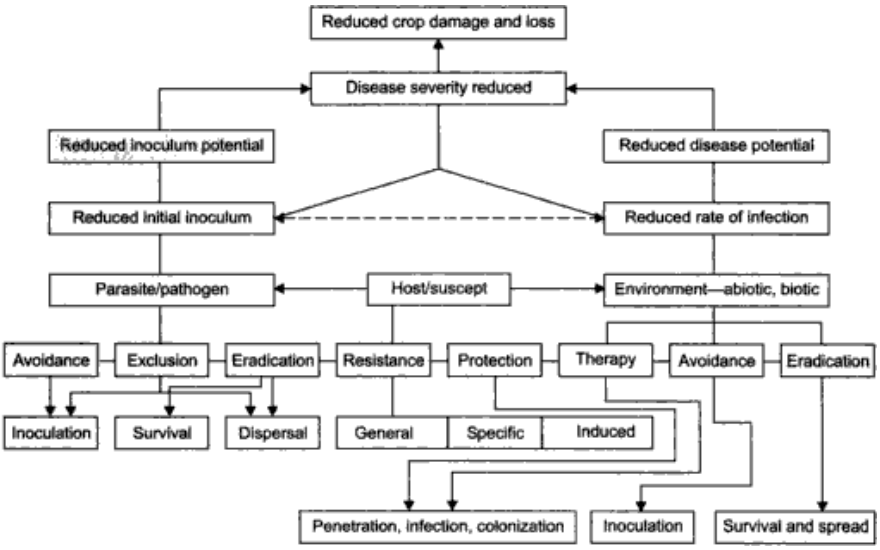
Thesixprinciplesthatcharacterizethemodernconceptofplantdiseasemanagementshouldbeviewedfrom threestandpoints

(a) Reductionintheinitial inoculumsortherateofdiseasedevelopment.

(b) Managementofthepathogenpopulation,thecureorinducedefenseofthesusceptormodifytheenvironment as it influences diseaseand

(c) Interruptionofdispersal,survival orthecourseofdiseasedevelopment.

Theseinteractionsareoriginallyproposedby Baker(1968)andRobertsandBoothroyd(1972)andsubsequentlymodified forthe readers areillustrated as below:

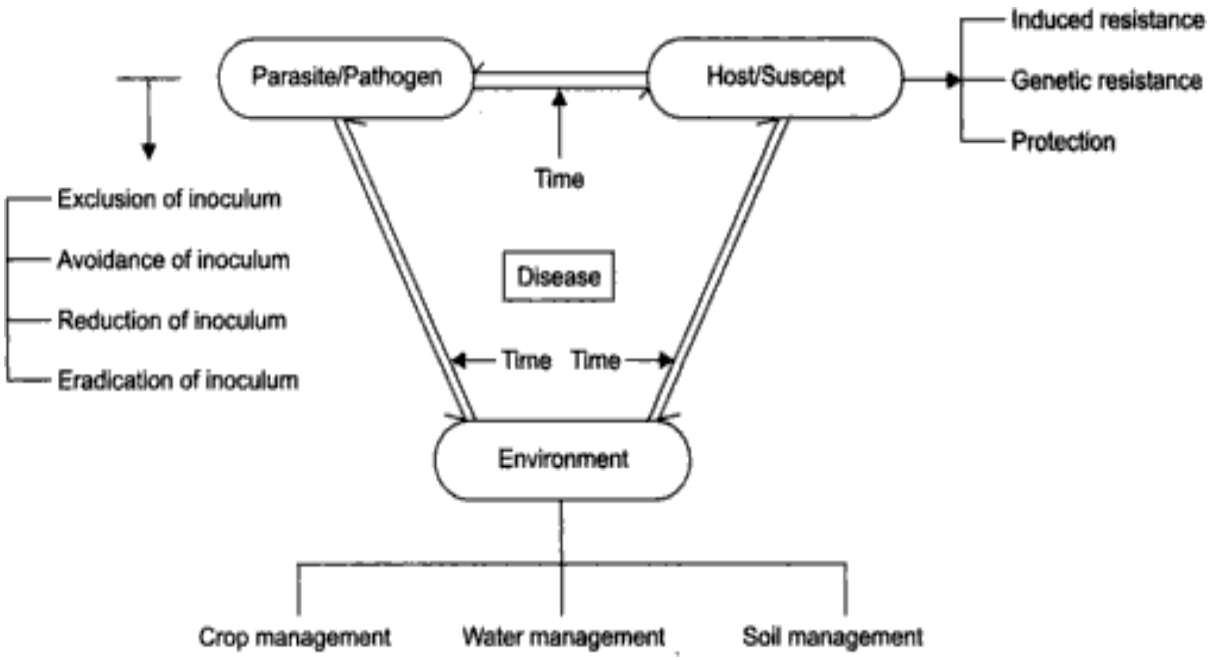


Integrateddiseasemanagement

The term Integrated pest management was originally designed for management of insectpest but it is equally applicable to plant diseases also. IPM is an ecosystem- based strategy thatfocuses on long term prevention of pests or their damage through a combination of techniquessuch as biological control, habitat manipulation, and modification of cultural practices and use ofresistantvarieties.

Managementofpathogeninvolvesthepracticesdirectedtoexclude,reduceoreradicateinoculums.

Management of the host involves the practices directed to improve plant vigor andinduceresistancethroughnutrition,introductionofgeneticresistancethroughbreedingandprovidin g need based protection by chemical means. Management of environment involves thepractices that modify the environment which is not favorable to pathogen or disease developmentanddoes not predisposehost to attack.



Lecture05

Regulatory methods – Plant Quarantine and Inspection – Quarantine Rules andRegulations

PlantQuarantine

The term 'Quarantine' means simply forty i.e., 40 days period. This was more commonlyreferred to the period of detention for ships arriving from countries subject to epidemic diseasessuch as the Bubonic plague, cholera and yellow fever. The crew and the passengers used to becompelled to remain isolated on board for sufficient period to permit the diseases to develop andbe detected. The purpose of the health authorities was to establish adequate detention period.Lateron,theterm'Quarantine'cametobeonlyusedforthedetentionandthepracticesconnected with it. The term got associated from the human disease field to the animal diseasefield and later on adopted to cover protective methods for the exclusion of pests and diseases ofagriculturaland horticultural crops.

In strict sense 'Plant Quarantine' refers to the holding of plants in isolation until they arebelieved to be healthy. Now, broader meaning of the plant quarantine covers all aspects of theregulation of the movement of living plants, living plant parts/plant products between politicallydefined territories or ecologically distinct parts of them. Intermediate quarantine and post entryquarantine are used respectively to denote the detention of plants in isolation for inspectionduringorafter arrival at their final destination.

Importance

Theentryofasingleexoticinsectordiseaseanditsestablishmentinthenewenvironment continues to cause great, national loss (table) till such time it is brought undereffective control. In certain cases a country has to spend a few million rupees before success incontrollingtheintroduced insect pest or diseaseisachieved.

Lossescausedbyintroducedplantdiseases

Disease	Host	Country	Introduced from	Lossescaused
Canker	Citrus	U.S.A	Japan	$13million;19.5million treesdestroyed
Dutchelm	Elm	U.S.A.	Holland	$25 million-$ 50,000 diseasemillion

Blight	Chestnut	U.S.A.	EasternAsia	$100-1000 million
Powdery mildew	Grapevine	France	U.S.A	80%in wine production
Downymildew	Grapevine	France	U.S.A	$ 50,000 million
Bunchytop	Banana	India	SriLanka	Rs.4crores
Wart	Potato	India	Netherlands	2500acresinfected
SouthAmerican leafblight	Rubber	Dutch–Brazil	Guiana	40,000trees destroyed
do	-do-	NorthColumbia	Brazil	78%treesdestroyed
Blue mould	Tobacco	Europe	U.K	.$ 50 million
–do	--do-	Sweden	U.K.	1.2millionKroner

History

The first plant quarantine law was promulgated in Rollen, France in 1860 to suppress andprevent the spread of common barberry, the alternate host for wheat stem rust. Among othercountries,thefirstfewtoestablishplantquarantineserviceswereGermany,France,Australiaand the U.S.A. In India, legislative measures against crop pests and diseases was initiated undertheDestructiveInsectsandpestsActof1914(DIPact)anditwaspassedbyGovernorGeneralof India on 3 rd February, 1914. Under this Act, rules governing the import and movement ofplantsand plant materials, insects and fungiareframed. TheAct provides

- It authorizes the Central Government to prohibit or regulate the import into India or anypart thereof anyspecificplacetherein, of anyarticle ofclass ofarticles.
- Itauthorizes theofficers oftheCustomsat everyportto operate, as iftherulesunderthe D.I.P.Actismadeunder theSeaCustomsAct.

1. It authorizes the Central Government to prohibit or regulate the export from aState of thetransport from one State to another State in India of any plants and plant materials, diseases orinsectslikelytocauseorinfestation.Italsoauthorizesthecontroloftransportandcarriageand

gives power to prescribe the nature of documents to accompany such plants and plant materialsandarticles.

2. It authorizes the State Governments to make rules for the detention, inspection, disinfection ordestruction of any insect or class of insects or of any article or class of articles, in respect ofwhich the Central Government have issued notifications. It also authorizes the State governmentsforregulating thepowers and duties of theofficerswhom it mayappoint onthis behalf.

3. It provides penalty for persons who knowingly contravene the rules and regulations issuedundertheAct.

4. Italsoprotectsthepersonsfromany suitorprosecutionorotherlegalproceedingsforanything done in good faith or intended to be done under the Act. Consequent to Bengal famine1943, a Central Plant Protection organization was established in 1946 under the then Ministry ofFoodandAgriculture.Oftenanewpest,diseaseorweedhasaccidentallyenteredacountrywhereitdidn otexistbeforeandhasmultiplied,spreadandcausedenormousdamagetothecropsofthat country.

For instance powdery mildew of grapevine (*Plasmopara viticola*), introduced into Francefrom America, was responsible for the destruction of the vine industry of that country untilhybridization with resistant American stock offered a solution. The blight disease of chestnut(*Endothiaparasitica*)whichwasintroducedintoU.S.A.fromAsiain1904,completelywipedou t chestnut trees. Coffee rust (*Hemileia vastarix*) which came into India in 1879 from Sri Lankais now widespread in all coffee growing areas. Fire blight (*Erwinia amylovora*) of pear and otherpomes which was introduced from England in 1940 is well established in Uttar Pradesh. Lateblight (*Phytophthora infestans* of potato introduced into India in 1889 from Europe is nowpresent in many parts of the country. Flag smut (*Urocystis tritici*) of wheat introduced fromAustralia is now well spread in Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh. Rubberpowdery mildew (*Oidium heavea*), which was introduced from Malaysia in 1938, is also causinggreat concern in Kerala. Black rot of crucifers (*Xanthomonas campestris* pv.*campestris)* believedtohavebeenintroducedtoIndiawithseedsimportedfromHolland,andotherEuropeancountries after World War II, prevailed for some years on the hills and then spread to the plainsand became established in Indian seed stocks, especially in West Bengal. Among the moreimportant plant disease introductions, mention may be made of bunchy top virus of bananaintroducedfrom SriLankain1940 whichhas sincespread widelyinKerala, Orissa,West Bengal

andAssam.Thewartdisease(*Synchytriumendobioticum*)ofpotatowasfirstnoticedinDarjeeling district of West Bengal having been introduced with seed potatoes from Holland. By1962, the disease spreadover nearly 1000ha and has recently beenreported from Nepal also.The mosaic disease ofbanana isanother introduced disease whichis only confined to Gujaratand Maharashtra states. Recently the apple scab (*Venturia inaequalis* which was only confined tosmallarea inJammu andKashmir hasnow appearedinsevere forminmany locationsinHimachal Pradesh, and is posing a problem to apple industry. The establishment of a plantquarantineregulation should rest onthe following fundamental pre-requisites.

i. The pest/disease under consideration must be one that will offer actual or expected threats tosubstantialinterests (Agricultural and / orcommercial)

ii. The quarantine regulation or degree must represent a measure for which no substitute actioninvolvingless interferencewith normal activitiesis available.

DiseasesbelievedtohavebeenintroducedintoIndiafromforeigncountries

Disease	**Host**	**Date of firstrecord**	**Introduction from**
Leaf rust(*Hemileia vastarix*)	Coffee	1879	SriLanka
Lateblight(*Phytophthorainfestans*)	Potato	Tomato1883	Europe
Rust(*Pucciniacarthami*)	Chrysanthemum	1904	JapanorEurope
Flagsmut(*Urocystistritici*)	Wheat	1906	Australia
Downymildew(*Plasmoparaviticola)*	Grapevine	1910	Europe
Downy	Cucurbits	1910	SriLanka

mildew(*Pseudoperonospora cubensis)*			
Downymildew(*Sclerospora philippinensis*)	Maize	1912	Java
Foot rot (*Fusarium moniliforme*var.*majus*)	Rice	1930	SouthEast Asia
Leaf spot(*Phyllachora sorghi*)	Sorghum	1934	SouthAfrica
Powdery mildew(*Oidium heveae*)	Rubber	1938	Malaya
Blackshank(*Phytophthorap arasitica*var. *nicotianae*)	Tobacco	1938	DutchEast Insides
Fire blight Pear and other(*Erwiniaamylovora*	pomes	1940	England
Crown-gallandhairyroot (*Agrobacteriumtumefacien sA.rhizogenes)*	Apple,Pear	1940	England

1. Bunchytop Banana1940SriLanka
2. CankerApple1943Australia(*Sphaeropsismalorum*)
3. WartPotato1953Netherlands(*Synchytriumendobioticum)*

Despiteeveryprecautionofinspection,certificationandtreatment,itisnotalwayspossibletoguaranteethataconsignmentiscompletelyfreefrompathogens.Indoubtfulcasesitis advisable to subject plants to a period of growth in isolation under strict supervision in theimporting country (post-entry quarantine). The plants are grown at a quarantine station. Whendirect importation of plants to a country's own quarantine station is considered very dangerous,quarantineduring transitfrom the countryof origin (intermediatequarantine) maybe required.

Therequirementsofanintermediatestationaresimilartothoseforapost-entrystation.Intermediatequarantineinspectionmustalwaysbefollowedbypost-entryquarantineafterarrival of the consignment at its final destination. During post-entry or intermediate quarantineplants must be kept under close supervision, so that any pest or disease which appears may beimmediately detected and grown under optimum conditions, so that symptoms are not marked byphysiologicaldisturbances.

International plant protection convention the first effort towards international agreementonPlantProtectionwasmadein1914undertheauspicesoftheInternationalInstituteofAgriculture in Rome. This was followed by an International Convention of Plant Protection byover50membercountriesoftheInstitutein1919andcertainAgreementsregardingtheissueand acceptance of phytosanitary certificates were finalized. The projectreceived a set back dueto Second World War and was later on revived by the FAO. In post-war period Internationalaction in Plant Protection and particularly in plant quarantine was encouraged by FAO with theestablishment in 1951 of the International Plant Protection Convention. This agreement wasconstituted with the purpose of securing common and effective action to prevent the introductionand spread of pests anddiseases of plants and plant products as to encourage Governments totakeall steps necessaryto implement its prevention (Ling, 1953).

ThefollowingregionalPlantProtection Organizationsarenowinoperation.

1. TheEuropeanandMediterraneanPlantProtectionOrganization(EPPO)
2. TheInter-AfricanPhytosanitaryCouncil(IAPSC)
3. OrganismoInternationalRegionaldeSanidadAgropecnario(OIRSA)
4. ThePlantProtection Committeefor,the SouthEastAsiaandPacificregion.
5. Comit'eInteramericanodeProtectionAgricola.(CIPA)
6. TheCaribbeanPlantProtectionCommission(CPPC)
7. TheNorthAmericanPlantProtectionOrganization(NAPPO).

Under article 3 of that International Plant Protection Convention, the Plant ProtectionAgreement for South East Asia and Pacific Region was sponsored by F.A.O in 1956, and Indiabecame inparty tothisAgreement inthe sameyear thealongwithAustralia, SriLanka, theU.K.,Laos,Netherlands,Indonesia,PortugalandVietnam.OurGovernmentagreedtoadopt

legislativemeasuresspecifiedintheConventionforthepurposeofsecuringcommonandeffective action to prevent the introduction and spread of pests and diseases of plants and plantproducts and to promote measures for their control and also agreed to assume all responsibilitiesfor the fulfillment within its territories of all requirements under the Convention. It was agreedthatthe Government shall makeprovision for:

a. Anofficialplant protectionorganization, withthefollowing mainfunctions:

1. The inspection of growing plants, of areas under cultivation and of plants and plant products instorage and in transportation with the object of reporting the existence, outbreak and spread ofplantdiseases andpests and ofcontrollingthose pests and diseases.

2. The inspection of consignments of plants and plant products moving in international traffic,the inspection of consignments of other articles or commodities moving in international trafficunder conditions where they may act incidentally as carriers of pests and diseases of plants andplant products and the inspection and supervision of storage and transportation facilities of allkinds involved in international traffic whether of plants and plant products or other commodities,with the object of preventing the dissemination across national boundaries of pests and diseasesofplantsand plant products.

3. The disinfestation or disinfection of consignments of plants and plant products moving ininternational traffic, and their containers, storage places, or transportation facilities of all kindsemployed.

4. The issue of certificates relating to phytosanitary condition and origin ofconsignments ofplantsand plant products(Phytosanitarycertificates).

b. The distribution of information within the country regarding the pests and diseases of plantsandplant products and themeans of their prevention and control

c. Research and investigation in the field of plant protection. A revised text of convention wasapproved in 1979. As of December 1980, the number of states party to the convention is 81.Besides this world-wide convention, other regional agreements and organizations have beencreatedtosafeguardtheinterestsofgroupsofneighbouringcountrieswithsimilarplantprotectionproblems.

Regional action is needed to prevent a pathogen or pest absent from a whole area frombeingintroducedintoanypartofthearea,asitsentryintooneterritorywillendangerneighbouringcountries.

Plantquarantinemethods

There are number of plant quarantine methodswhich are used separately or collectivelytopreventorretardtheintroductionandestablishmentof exoticpestsandpathogens.Thecomponentsof plant quarantineactivities are:

1. Completeembargoes

It involves absolute prohibition or exclusion of specified plants and plant products from acountry infected or infested with highly destructive pests or diseases that could be transmitted bythe plant or plant products under consideration and against which no effective plant quarantinetreatmentcan beappliedorisnot available forapplication.

2. Partialembargoes

Partialembargoes,applyingwhenapestordiseaseofquarantineimportancetoanimporting country is known to occur only in well defined area of the exporting country and aneffectively operating internal plant quarantine service exists that is able to contain the pest ordiseasewithin this area.

3. Inspectionandtreatmentatpointoforigin

It involves the inspection and treatment of a given commodity when it originates from acountrywherepest/diseaseofquarantineimportanceto importingcountryis known tooccur.

4. Inspectionandcertification atpointoforigin

Itinvolvespre-shipmentinspectionbytheimportingcountryincooperationwithexporting country and certification in accordance with quarantine requirements of importingcountry.

5. Inspectionatthepointofentry

It involves inspection of plant material immediately upon arrival at the prescribed port ofentryand if necessarysubject to treatment before the same related.

6. Utilizationof postentryplantquarantinefacilities

It involves growing of introduced plant propagating material under isolated or confinedconditions.

PlantquarantineorganizationsinIndia

The first recorded plant quarantine measure in India dates back to 1906 when perceivingthe danger of introducing the Mexican boll weevil, the Government of India directed that allcottonimportedfromtheNewWorldshouldonlybeadmittedtoIndiaafterfumigationwith

carbon disulphide at the port of entry. In India two categories of regulatory measures are inoperation for controlling pests, diseases and weeds. In the first category regulatory measures areaimed to prevent the introduction of exotic pests and diseases into the country or their spreadfromone State orUnionTerritoryto another(Plant Quarantine).

The second pertains to suppression or prevention of spread of pests and diseases inlocalized areas within a State or Union Territory. The former derives its authority from theDestructive Insects and Pests (DIP) Act 1914 of the Central Government and the latter fromAgricultural Pests and Diseases Acts of the various States. The legislative measures against croppests and diseases were initiated under the DIP Act of 1914 which was passed by the thenGovernor General of India in Council on 3 February 1914. Prior to the establishment of theDirectorate of Plant Protection, Quarantine and Storage in 1946, under the Ministry of Food andAgriculture, the various rules and regulations of the DIP Act were enforced by the customsdepartment. The quarantine regulations are operative through The Destructive Insects and PestsAct,1914 (which hasbeen revised 8times from 1930to 1956 andamended in 1967and 1992.

TheprovisionsoftheDIP Actare

1. It authorizes the Central Government to prohibit or regulate the import into India or any partthereoforanyspecific placetherein ofanyarticle orclass ofarticles.
2. It authorizes the officers of the Customs at every port to operate, as if the rules under DIP Actaremadeunder theSeaCustoms Act.
3. It authorizes the Central Government to prohibit or regulate the export from a State or thetransport from one State to another State in India of any plants and plant material, diseases orinsects, likely to cause infection or infestation. It also authorizes the control of transport andcarriage and gives power to prescribe the nature of documents to accompany such plants andplantmaterials and articles.
4. It authorizes the State Governments to make rules for the detention, inspection, disinfection ordestruction of any insect or class of insects or any article or class of articles, in respect of whichthe Central Government has issued notification. It also authorizes the State Governments forregulatingthepowers and duties of theofficers whom it mayappoint onits behalf.
5. It provides penalty for persons who knowingly contravene the rules and regulations issuedundertheAct.

6. It also protects the personnel from any suit or prosecution or other legal proceedings foranythingdonein good faith as intended to bedoneunder this Act.

The quarantine regulations are operative through "The Destructive Insects and Pests Act,1914 (which has been revised and time from 1930 to 1956 and amended in 1967 and 1992. TheAct also empowers the State Governments to frame suitable rules and issue notifications forinter-state movement ofplant and plant material. Those rules are known as plant quarantinerules. Under the Act, Central Government frames rules prescribing the seaports, airports and landfrontiers through which plants and specified plant material can enter India, and the manner inwhich these can be imported. The DIP Act operates under the National Sea Customs Act and thepoints of entry are located within the jurisdiction of State on the advice of Central Government,the State frames rules for detention, inspection, disinfection and destruction (as against entry) ofmaterial,ifrequired,anddelegatespowers inthisregard toconcernedauthorities withtheenforcementofrules.

Theplantquarantineserviceiscentrallyorganizedandadministeredthroughthe DirectorateofPlantProtection,QuarantineandStorageestablishedundertheMinistryofAgriculture(DepartmentofAgricultureandCo-operation)whichisheadedbythePlantProtectionAdvisertotheGovernmentofIndiaandhavingitsheadquartersatN.H.IV,Faridabad, Haryana State. Import regulations When plants are imported the following principlesshould be followed. Some plant pathogens and pests are generally distributed in most parts of theworldbut others aremoreor less restricted intheir occurrence.

In some cases this limitation is due to such factors as unsuitable environmental conditionsor lack of the required host plant, but in many other cases the absence of a pathogen. Mostcountries are aware of the desirability of delaying for as long as possible the arrival of exoticpathogens andtake action to prevent their spread by introducinglegislation and setting uporganizations to prevent their entry. Plant quarantine legislation varies from country to countrybut in most cases it restricts or prohibits the importation of the pests or pathogens themselves,plants on which they might be living, soil which might be infested, foodstuffs which might carrythem, and packing materials, particularly those of plant origin. Good legislation is as brief andclear as possible, at the same time being easy to interpret, gives adequate protection withoutinterferingmorethanisessentialwithtrade,andcontainsonlyrestrictionswhichare

scientifically justifiable. When plants are imported there are certain principles which, if followedensurethat asfewrisks as possiblearetaken.

1. Import from a country where, for the crop in question, pathogens which are particularly to beguardedagainst are absent.

2. Import from a country with anefficientplant quarantine service,so that inspectionandtreatment of planting material before despatch will be thorough, thus reducing the likelihood ofcontaminatedplants being received.

3. Obtainplantingmaterialfromthesafestknown sourcewithintheselectedcountry.

4. Obtain an official certificate of freedom from pests and diseases from theexporting country.Treatment of the material in the country of origin may be done; this should be noted on thecertificate.

5. The smaller the amount the less the chance of its carrying infection, and inspection as well aspost-entryquarantine.

6. Inspectmaterialcarefullyonarrivalandtreat(dust,spray,fumigate,heattreat)asnecessary.

7. Importthesafesttypeofplantingmaterial,e.g.seedsareusuallysaferthanvegetativematerial,unrootedcuttingsthanrooted.Theuseofaxenicculturesofmeristemtiptissues(micropropagation)fortheinternationalexchangeofgermplasmmaterialhasoutstandingadvantages,assuchtissuescanbeexpectedtobefreefromlatentinfectionsbyviruses,phytoplasmas etc., as well as other pathogens which aremorereadilydetectable byvisual means.

8. If other precautions are not thought to be adequate, the consignment for import should besubjecttointermediateorpost-entryquarantine.Suchquarantinemustbecarriedoutataproperlyequipped stationwith suitablytrained staff.

Seed was not originally included in the DIP Act, but because of the changing situation and tomeetthecurrentrequirements,theGovernmentofIndiapassedthePlants,Fruits,Seeds(RegulationofImportintoIndia)Order1984whichcameintoeffectinJune1985.Theconditions for the import of 17 crops are stipulated in this order. The main features of the orderare:

1. Seedhasbeenbroughtunderthepurviewofthe DIPAct.

2. No consignment can be imported into the country without valid import permit issued by thePlantProtection Adviser to theGovernment ofIndia.

3. No consignment can be imported without an official phytosanitary certificate issued by theplantquarantineagencyofthe exporting country.

4. Post-entrygrowth ofthespecifiedcropsatapproved locations.

A.Conditionsforimport

In India, there are general and specific conditions for the import of plants (includingbulbs, tubers, rhizomes, corms, cuttings, buddings, grafts, layers, suckers, roots and flowers) andplantmaterials(includingplant productssuchasginnedcotton,unmanufactured tobaccoetc.).

Generalconditions

1. Importpermitsareessentialfor:

a. Seedsand fruits forconsumption,

b. Seedsand plants forsowing orplanting,

c. Soil,earthclayformicrobiological,soilmechanicsormineralogicalinvestigations

d. Peatforhorticulturalpurposes

e. Liveinsectsand f. Livingfungiinpureculture,including*Rhizobiumcultures.*

2. Allplants shouldbe accompanied byPhytosanitarycertificatefromthecountryof origin.

3. All plants on arrival at port, shall be inspected and if necessary fumigated, disinfested ordisinfectedbyPlantProtectionAdvisertotheGovernmentofIndiaoranyotherofficerauthorized byhim on his behalf.

4. Plants and seeds which require post-entry quarantine inspection shall be grown in post-entryquarantinefacilities approvedbythePlant ProtectionAdviser totheGovernmentofIndia.

5. Importof hayor straw or anymaterialof plantorigin usedforpacking is prohibited.

6. Importofsoil,earth,compost,sand,plantdebrisalongwithplants,fruitsandseedsisprohibited.

Note:Cutflowers,garlands,bouquets,fruitsandvegetablesweighinglessthan2kgforpersonaluse may be imported without a permit or phytosanitary certificate, but are subject to inspection.SpecialconditionsInadditiontothegeneralconditions,therearespecialconditionsforcertain notifiedplants as follows.

1.Prohibitionfromcertainareas

Nameof theplant	**Countriesfromwhere prohibited**
Cocoaandallspeciesof Sterculiaceae	Africa, Sri Lanka, West Indies and Bombaceae
Coffeebeans	Africa,SouthAmerica,SriLanka
Rubber	SouthAmerica,West Indies
Sugarcane	Australia,Fiji,PapuaNewGuinea
Sunflower	Argentina,Peru

1. Prohibited for general public: Coconut plants and seeds, coffee plants and seeds, cotton seedsand unginned cotton, forest tree seed (*Castanea*, *Pinus*, *Ulmus*), groundnut seeds and cuttings,potato,sugarcane, tobacco seeds and wheat seeds.

2. Plants/seeds which require post entry quarantine: Cocoa, citrus, coconut, groundnut, potato,sugarcane,sunflower, tobaccoand wheat.

3. Additionaldeclarationsrequiredfornotifiedplants(seeTablebelow)

Plant/seedAdditionaldeclarationsforfreedomof pests

Allspeciesof*Allium*(onion,garlic,leek, chive,shallot,etc.).	Smut(*Urocystiscepulae*)
Cocoa and all of the family speciesSterculiaceae andBombaceae	Podrot(*Moniliarorei*),Mealypod(*Trachysphaeri a*and*fructigena*),Witches'broom(*Crinipelliaper niciosus*)Swollenshoot Virus
Allspeciesof*Citrus*(lemon,lime,orange etc.,)	MalSecco(*Deuterophomatracheiphila*)
Coconutseedsand allspecies of*Cocos*	Lethalyellowing,Cadang,Bronzeleafwilt, Guam,Coconutdisease, Leafscorch
Coffee–plants,seeds	Americanleafspot(*Omphaliflavida*),virus diseases

Cottonseeds	Bacterialblight(*Xanthomonasaxonopodis* pv. *malvacearum*and*Glomerellagossypii*)
Foresttreeseeds(allspecies*Cronartiumribicola,Endothea* of*Pinus, Ulmus, Castanea*)	*parasitica,Ceratocystisulmi,Dothiostromapini*.
Groundnut seeds (all speciesof*Arachis*)	i. production of seeds in areas free of *Pucciniaarachidis*and *Sphaceloma arachidis*. ii. Inspection of parent crops in active growingseasonsandcertificationforfreedomfrompeanutmottle,peanutstunt,marginalchlorosis andpeanut stripeviruses
Lucerne(all speciesof*Medicago*)	Bacterialwilt(*Corynebacterium incidiosum*)
Potato(allspeciesof *Solanum*)	Wart(*Synchytriumendobioticum*)andfreedom ofparentcropfromvirusdiseases
Rubber(allspeciesof *Hevea*)	SouthAmericanleafblight(*Microcyclusulei*, *Sphaerostilberepens*)
Sugarcane(allspeciesof*Saccharum*)	Leafscald(*Xanthomonasalbineans*),Gummosis (*Xanthomonas vasculorum*), Sereh,downymildew,chloroticstreakandFiji disease.

Agenciesinvolvedin plantquarantine

The authority to implement the quarantine rules and regulations framed under DIP Actrests basically with the Directorate of plant Protection, Quarantine & Storage, under the Ministryof Agriculture. This organization handles bulk importand export of seed and planting materialfor commerical purpose. Under this organization 9 seaports, 10 airports and 7 land frontiers arefunctioning. These are the recognized ports for entries for import of plant and plant material. Thenamesand places of the ports and stations areasfollows.

A. Seaports-PlaceState/Union territory

1. Bhavnagar-Gujarat
2. Calcutta-West Bengal
3. Chennai-TamilNadu
4. Cochin-Kerala
5. Mumbai-Maharashtra
6. Nagapattinam-TamilNadu
7. Rameswaram-TamilNadu
8. Tuticorin-TamilNadu
9. Visakhapatnam- AndhraPradesh

B. Airports

1. Amritsar-Punjab
2. Calcutta-West Bengal
3. Chennai-TamilNadu
4. Hyderabad-AndhraPradesh
5. Mumbai-Maharashtra
6. NewDelhi- NewDelhi
7. Patna-Bihar
8. Tiruchirappalli-TamilNadu
9. Trivandrum-Kerala
10. Varanasi -UttarPradesh

C. Landfrontiers

1. AmritsarRailwayStation-Punjab
2. AttariRailwayStation-Punjab
3. Attari-WagahBorder-Punjab
4. BangaonBenapolBorder-West Bengal
5. GedeRoad RailwayStation-West Bengal
6. Kalimpong-WestBengal
7. SukhiaPokhri -WestBengal

TheGovernmentofIndiahasalsoapprovedthreeothernationalinstitutionstoactasofficialquarantineagencies, especiallyfor research material.

1. NationalBureauof PlantGeneticResources (NBPGR)

TheNBPGRinNewDelhianditsregionalstationatHyderabadintheagencyinvolvedin processing of germplasm, seed, plant material of agricultural, horticultural, and silviculturalcrops of all the institutions of Indian Council of Agricultural Research (ICAR) functioning in thecountry. It is also responsible for quarantine clearance of seed and plant material received fromInternational Agricultural Research Centers *viz*., ICRISAT, ICARDA, CIMMYT, etc. ICRISATwas established in 1972 at Patancheru (near Hyderabad) to work on improvement of sorghum,pearlmillet, chickpea, pigeonpea and groundnut. The quarantine clearance of all its exchangeswas handled by Central Plant Protection Training Institute of Directorate of Plant Protection,Quarantine & Storage, until July 1986. This authority was later passed on to NBPGR in August1986.

2. ForestResearchInstitute(FRI),DehraDun,forforestryplantsand

3. BotanicalSurveyofIndia(BSI)forotherplants.

Quarantine inspection, treatment and certification procedures Inspection: Inspection ofplant material is an important part of plant quarantine procedure, and may be done both in theexportingcountry,beforeissueofahealthcertificateandafterarrivaltodetectanypestordisease which may have become evident during transit. Publications like manuals, hand books onindividual organisms of quarantine importance are prepared with illustration by each country /regiontohelpinspectors.ThefollowingseriespublishedbyCommonwealthMycologicalInstituteill be useful forall countries.

1. CMIdescriptions of pathogenic fungi and bacteria
2. CMI/AABdescriptionsofplantvirusesand
3. CMIdistribution maps ofplant diseases.

The various steps involved in import quarantine clearance of seed and propagating plantmaterialis outlined below

i. Securitization of import application filed along with attached documents such as phytosanitarycertificate (original), permit (importer's copy), shipping bill, invoice, packing list and customsbillof entry etc., toensure the importisinorder andthatnoprohibited plantmaterialisimported.

ii. Assessmentofinspectionfeesand registrationofapplication.

iii. Inspectionandsamplingoftheconsignmentatportwarehousesorcontainerterminal.Sampling of seed usually carried out as per the provisions of ISTA Rules and Regulations.Whereas in case of bulk import of vegetative planting material such as cuttings/saplings/ budwoods/bulbs/tubers etc., at least a minimum of 0.1% of propagules are sampled variety andexamined to ensure free from exotic pests or pathogens. In case of quarantine pests suspected,100per cent inspection iscarried out forcritical assessmentof the risk.

iv. Detailed laboratorytesting

a. Visual inspection: The samples of seed/ propagating plant material is examined with the helpof illuminated magnifier to record live insect infestation, contamination by soil and weed seeds,nematode galls, sclerotia, smut/bunt balls etc. Sometimes inspections are carried out under U.V.lamptofacilitate detectionof specificseed-borneinspectionbycharacteristicfluorescence.

b. X-Ray test for detecting hidden insect infestation such as bruchids and weevils that bore intoseed.

c. Washing test to detect surface-borne oospores of downy mildew/smut spores/ bunt spores etc.and nematode cysts. Seed samples of onion, clover and lucerne are soaked for 24 to detect stemandbulb nematodeandalso rootwashings areexaminedforectoparasiticnematodes.

d. Incubation tests such as blotter test or agar plate test carried out for detecting seed-bornepathogens such as fungi. Fluorescent pseudomonas agar used for selective detection of seed-bornebacteria.

e. Grow-out test coupled with indicator inoculation tests for detecting seedborne viruses andbacteria.Besidesthis,specialdiagnostictestssuchasElectronMicroscopy(dipmethod),Enzyme Linked Immunosorbent Assay (ELISA) are used for detection of specific viruses in theimported seed / planting material pencillnase based DAC-ELISA is widely used for the detectionof virus in imported seed/plant material. The detailed testing procedures for the detection ofseed-bornepathogensare outlined inthe seed health testing chapter.

v. Fumigationandtreatmenttechniques

Fumigation is the versatile technique used for eliminating insect infestation. Methyl bromide isthe most commonly employed for controlling insect infestation and readily adopted in quarantineprogrammes as the exposure time involved is short and affect all stages of insect pests and highpenetrating power. Two types of fumigation *viz*., i. atmospheric fumigation under gas-proofsheetsorchambersand ii.vacuumfumigation invacuumchamberis widelyemployed.Theother

chemical treatments include insecticidal/fungicidal drippings or spraying or seed dressings areinvariably associatedwithgrowingunderpost-entry quarantineconditions.Thetemperaturetreatments such as hot water treatment/ hot air treatment or vapour heat treatment are carried outto control internally borne infection/infestation and the latter particularly employed to controlfruit flyinfestation.

Cold treatments such as refrigeration to control insect infestation in fresh fruits andvegetables. Of late, irradiation is used to control insect infestation and spoilage of food productsduringstorageandaswellasapplicationofhighintensityelectronicbeamsthroughanacceleratoris under experimentation.

Certification

Phytosanitary or health certificate is a certificate which should accompany a plantorplant material or seed which is to be moved from one place to another place. This certificateindicates or certifies that the material under transit is free from pests or diseases. A modelphytosanitary certificate proposed at the Government consultation on the International PlantProtectionconvention atRome in 1976 (Chock, 1977)andapproved by F.A.O.in1979 isgiven below.

MODELPHYTOSANITARYCERTIFICATE

(tobetypedor printedinblockletters)

PlantProtectionOrganizationNo._____of_____

To:Plant Protection Organization(s)of

_____

DESCRIPTIONOFCONSIGNMENT

Nameandaddressof exporter_____

_____Declarednameand addressofconsignee_____Number anddescriptionofpackages _____Distinguishingmarks _____Placeof origin _____Declared means ofconveyance_____Declaredpointofentry _____Name of produce and quantitydeclared_____Botanicalnameof plants

_____

Thisistocertifythattheplantsorplantproductsdescribedabovehavebeeninspected according to appropriate procedures and are considered to be free fromquarantinepestsandpracticallyfree frominjuriouspests; andthattheyare consideredtoconformto thecurrentphytosanitaryregulations oftheimportingcountry.

DISINFESTATIONAND/ORDISINFECTIONTREATMENT

Date_____Treatment

_____Chemical(activeingredient) _____

Durationandtemperature_____Concentration

_____Additionalinformation _____

Additionaldeclaration:

(Signature)

Note:Nofinancialliabilitywithrespectto thiscertificateshall attachto.....(nameofplantprotectionorganization)... or to anyof its officersorrepresentatives.

DomesticQuarantine

Under the DIP Act, the Directorate of Plant Protection, Quarantine and storage has theresponsibilitytotakethenecessarystepsandregulatetheinter-statemovementofplantsandplant material in order to prevent the further spread of destructive insects and diseases that havealready entered the country. The sole object of enforcing domestic quarantine is to prevent thespread of these diseases from infected to non-infected areas. Currently, domestic plant quarantineexists in four diseases, wart (*Synchytrium endobioticum*) of potato from 1959, bunchy top (virus)of banana from 1959, mosaic (virus) of banana from 1961 and apple scab (*Venturia inaequalis*)from 1979. Most of thestates inIndia have plant quarantine laws to avoid entry of plant pestsanddiseases

1. Bunchy top of banana: The export and the transport from the States of Assam, Kerala,Orissa, West Bengal, Tamil Nadu to any other State of Banana plant or any other plant of thegenus *Musa*, including sucker, stem, leaf, flower, and any other part thereof which may be usedfor propagation, or the materials of banana plant or any other plant of the genus *Musa*, which areusedforpacking and wrapping, excluding the bananafruit is prohibited.

2. Banana mosaic : The export and transport from the States of Maharashtra andGujarat of anyplantofBananaoranyotherplantofgenus*Musa*includingthesucker,stem,flowerandany

other part thereof, but excluding leaf and fruit thereof is prohibited; videGovernment of IndianotificationNo.F. 6-10-PPS dated the11thApril, 1961.

3. Potato wart: The export to potato tubers from the State of West Bengal to any other State orterritoryof India is prohibited.

4. Apple scab: The Directorate of Horticulture, Himachal Pradesh worked out a detailed schemefortheeradicationofscab,andalsoissuedanotificationNo.NIC.20/76dated28December1978, prohibiting the export ofplanting materialof apple outsidethe State.

In Tamil Nadu as per Madras pests and Diseases Act of 1919, quarantine regulations areperiodically enforced. e.g., cardamom mosaic prevalent in Anamalai area of Coimbatore DistrictandisfreefromNelliampattiarea.HencethemovementofdiseasedplantmaterialfromAnamalai to Nelliampatti areais prevented.

Limitations

There are many limitations to implementing domestic plant quarantine in India due to thevastnessof the country andthe unrestrictedmovementof plantmaterialfromone state toanother. As a result the diseases like bunchy top and mosaic of banana have spread to severalother states.However, the wartdisease,goldennematode of potato,andscabof apple arerestricted in thestates wheretheywereinitiallynoticed.

Exportregulations

In India the plant quarantine measures for exporting plants and material including seedshave been streamlined and rigid inspections are enforced before the material is allowed to belanded into the country. At present plant quarantine regulations differ with different countries formajoragriculturalcommoditiesthatarebeingexportedoutofIndia.TheCentralGovernmenthas authorized officers of the Directorate of Plant Protection, Quarantine & Storage,ICARResearch Institutes, National Institutes like Forest Research Institute, Botanical Survey of India,andthe Directorates of Agricultureof all States.

Thequarantineauthoritieshavealsoframedtermsandconditionspertainingtoinspection,fumigationordisinfectionoftheexportableplantsandplantmaterialinIndiaincluding the following schedule/or fee for inspection and issue of phytosanitary certificate,and/or fumigation or disinfection in respect of plants, plant material, seeds, and plant products toissuephytosanitarycertificate.Alltheplantsandplantmaterialaresubjectedtoinspectionby

officialsissuingcertificate.Infestedmaterialsaregivennecessarytreatmentwithchemicalsandfumigatedif necessary.

Thelistofplantquarantineandfumigationstationsin Indiaisgiven below.

Punjab

1. PlantQuarantineand FumigationStation,Hussainiwala,FerozepurDistrict.
2. PlantQuarantineandFumigationStation,Attari–WagahBorder,nearAttariBusStand,Attari,Ferozepur District.
3. PlantQuarantineand FumigationStation,CivilAerodrome,Rajasansi, Amritsar.

NewDelhi

1. PlantQuarantineandFumigationStation,PalamAirport,NewDelhi–10.
2. PlantQuarantineandFumigationStation,GardenReachRoad,Calcutta–24.
3. PlantQuarantineand FumigationStationSukhiapokri,DarjeelingDistrict.

Gujarat

1.PlantQuarantineandFumigationStation,HaryanaPlotNo.75,BehindYusufBagh.Bhavnagar.

Maharashtra

1.PlantQuarantineandFumigationStation,HajiBunderRoad,Sewri,Mumbai

AndhraPradesh

1.PlantQuarantineandFumigationStation,TheHarbour,Visakhapatnam–1.

TamilNadu

1. PlantQuarantineandFumigationStation,6,CliveBattery,Chennai–1.
2. PlantQuarantineandFumigationStation,335,BeachRoad,Tuticorin –1.
3. PlantQuarantineand FumigationStation,TiruchirappalliAirport,Tiruchirappalli.
4. PlantQuarantineand FumigationStation,110,RailwayFeederRoad,Rameswaram.

Kerala

1. PlantQuarantineand FumigationStation,WillingdonIsland,Cochin– 3

Lecture06

Cultural methods – Rouging, eradication of alternate and collateral hosts, crop rotation,manureandfertilizermanagement,mixedcropping,sanitation,hotweatherploughing, soilamendments,timeof sowing, seedrateandplant density,irrigation and drainage

Eradication

Eradication is the elimination of pathogen after it has become established in the areawhere host is growing.The following are the important methods followed to prevent the spreadofthe disease:

i. eradicationofalternatehosts,
ii. eradicationofcollateralandselfsownoverwinteringhosts
iii. eradicationoftheaffectedplantsortrees,
iv. eradicationofpathogensfrominfected plantpartsbysurgeryand
v. eradication of culled out plant materials, debris, etc., through different culturalpractices

i. Eradicationofalternatehosts

Removal of alternate hosts helps to prevent and check the spread of the disease caused byheteroecious rust pathogens in the primary hosts.Barberry bush is the alternate host for blackstem rust pathogen *Puccinia graminis tritici* on wheat where the pathogen survives in the off-season.BarberrywaseradicatedinCanada,Denmark,France,Hungary,Norwayandinthe U.S.A.by passing stringent laws in each country.The eradication of barberry had two benefitsi.e., it elimination of early spring primary inoculum and prevention of the formation of newphysiologic races of the pathogens.In the U.S.A. white pine blister rust *(Cronartium ribicola)*was controlled by eradication of alternate host, *Ribes*.In Australia, Europe and the U.S.A. theapple rust (*Gymnosporangium juniperi-virginianae*) is controlled by eradication of alternate host,cedar.

ii. Eradicationofcollateralandselfsownoverwinteringhosts

There are many weed hosts or wild species of cultivated plants act as collateral hosts orvolunteer plants of an economic crop which act as reservoirs of pathogens of annual crop.Reservoir hosts help the pathogen to continue the infection chain.The primary inoculum isproduced on and dispersed from these hoststo the cultivated crop hosts.If these wild oruneconomichostplantsofthepathogenaredestroyed,thesourcesofprimaryinoculumare

eliminated and chances of initiation of the disease in the crop hosts are reduced.Destruction ofthese hosts breaks the life cycle of the pathogen and the infection chain.Reservoir hosts orindigenous plant species which are not actually involved with the life cycle of the pathogen butprovide additional sites for its persistence and multiplication.In some cases such plant speciesact as symptomless carriers, especially for viruses and root pathogens.Regional elimination ofsuchhosts requirescareful attention toroadside areasandother non-agriculturalland also.

Crop	**Disease**	**Pathogen**	**Collateralhosts**
a.Fungi 1.Rice	**Blast**	***Pyricularia oryzae***	*Brachiaria muticaDinebraretroflexa,Leersiahexandra, Panicumrepens.*
2.Sorghum	Ergot	*Sphacelia sorghi*	*Panicum*spp.
b.Bacteria 1.Rice	Bacteriall eafblight	*Xanthomonas oryzae* pv.*oryzae*	*Cyanodon dactylon, Cyperusrotundus, Leersia hexandra,Leersia oryzoides, Panicum repens,Paspalum dictum.*
2. Apple and pear	Fireblight	*Erwinia amylovora*	*Hauthom*bushes *Crataegus* sp.
3. Cotton	Bacterial blight	X. *axonopodis* pv.*malvacearum*	*Eriodendron anfructuosum, Jatropha curcas, Thurbariathespesoides*
c.Viruses 1.Potato	Rugose mosaic	Rugose mosaicvirus	*Physalis*spp.

2.Bean	Yellow mosaic	Beanyellow mosaicvirus	Sweetclover
3.Bhendi	Yellow veinmo saic	Bhendiyellow vein mosaic virus	*Hibiscustetraphyllus*
d.Phytoplasma 1. Brinjal	Littleleaf	Phytoplasma	*Catharanthusroseus, Datura* sp.

Self sown crops / volunteer plants help the pathogen to overwinter / oversummer in theabsence of economic hosts.In Sudan it was enforced through legislation to pull out the cottonplants to prevent regrowth which facilitate the carryover of the cotton leaf curl virus.Wheatstreak mosaic virus has been effectively controlled by eliminating the volunteer wheat plants thatservedasreservoirs forthevirus.

iii. Eradicationofaffectedplantsortrees

In some threatening plant diseases, it is essential to eradicate the host and the pathogenfrom an area. Citrus, canker (*Xanthomonas axonopodis* pv. *citri)* is an example of success of aneradicationprogramme.ThisdiseasewasfirstnoticedinFloridacitrus treesin1913.Aneradication campaign was started in 1915.All the citrus nurseries and orchards were inspectedand the infected trees were cut and burnt.The eradication programme continued till 1927 and nocitrus canker was present in that area.Peach yellows and peach rosette were also controlled byremoval and destruction of diseased trees.In Tamil Nadu also there were some eradicationcampaigns launched under Destructive Pests and Diseases Act.Eradication programme was setup to control bud rot of palms and completed with success.At Sathyamangalam eradication ofsandalwood treeaffected byspikediseasewas also madeto contain this disease.

iv. Eradicationofpathogensfrominfectedplantpartsbysurgery

Eradication of affected plant parts (tree surgery) are also practiced in certain cases whichreduces the source of primary inoculum.Lesions caused by fire blight bacterium*(Erwiniaamylovora)* on pear and apple trees are removed during winter months.This not only preventsfurther spread in the affected trees but also reduces the amount of inoculum that can spread toother branches and trees.The cankered areas in the branch or trunk of almond and

pear treescausedby *Ceratocystisfimbriata*aresurgicallyremovedandthetreesaresaved.Treesurgeryis

also practiced in coconut trees affected by stem bleeding disease *(Ceratocystis paradoxa),* citrusgummosis(*Phytophthoracitrophthora*),*Dendrophthoe*spp.oncitrus,budrotofpalms(*Phytophthorapalmivora*) and kolerogaof arecanut (*P.arecae*)

v. Eradicationofculledoutplantmaterials,debrisetc.throughdifferentculturalpractices

2. Croprotation

Croprotationisessentiallyapreventivemeasureandhasitseffectmainlyonthesucceeding crop.Crop rotation is the oldest and cheapest method adopted in agriculture foreradicationofcertaintypesofpathogensfrominfestedsoil.Continuouscroppingormonoculturing provides opportunity for perpetuation of pathogenicorganisms in the soil whenthesame crop is raisedyear afteryear in thesamefield.

The soil-borne pathogens of that crop easily perennate in the soil and increase in theirpopulation.After sometime, the soil becomes so heavily infested that it becomes unfit forcultivation of the particular crop. Virus diseases of crop plants and their vectors are found toincrease after every crop if a crop is cultivated continuously in a field.On the other hand, whenimmune, resistant or non-host crops are grown for a definite duration after a susceptible crop inthe field it is expected that in the absence of nutrition, the pathogen will be starved off and thepopulation of such pathogens consequentlydecreases.

It is also possible that different crops release some biochemical substances in their rootexudateswhicheitherdirectlykillthepathogenorencouragedevelopmentofantagonisticmicroorganisms in the soil. In this way, crop rotation is one of the most effective methods ofroot disease control.Organisms which are soil inhabitant types remain in soil for a very longtime, even more than five years in the absence of the host. Long-lived spores or the organismsby themselves, subsist as saprophytes and therefore their presence in soil is long term.Onionsmut(*Urocystis cepulae*)and club root (*Plasmodiophora brassicae*)organisms are producingresistant type of spores while *Rhizoctonia, Fusarium*andsome species of *Pythium* are thosewhichcould remain in soil as saprophytes for averylong time.

Eradication of such organisms becomes fairly difficult.Soil also harbours soil invaders.These organisms are not persistent and they can live as long as the host residues serve assubstrate.Theyperishwhentheyareforcedtoexistinthesoilincompetitionwithsoilinhabitants and disappear gradually in due course.Bean anthracnose fungus *Colletotrichumlindemuthianum*,cabbageblackrotbacterium,*Xanthomonascampestris*pv.*campestris* are

some examples, which live in soil for 1 to 2 years.They can be eliminated from soil by adopting3 or 4 year rotation with non-host crops.Crop rotation is effective in the control of brown stemrot of soybean (*Cephalosporium gregatum*).The disease incidence can be reduced to a greatextentbyrotating with corn for4 to 5yearsbetween twosoybean crops.

Crop rotation with sugarcane or paddy is effective in the control of 'Panama wilt' ofbanana (*Fusarium oxysporum*f.sp. *cubense*) and crop rotation with paddy or green manuresiseffective in the control of red rot of sugarcane (*Colletotrichum falcatum*).Rotation of cerealcropslikepearlmillet,fingermilletorfox-tailmilletisrecommendedforthecontrolof*Macrophomina* root rot of pulse crops.Two year crop rotation with lucerne is recommended inthe control of *Verticillium*wilt of cotton.Many diseases such as *Fusarium* wilt of pigeonpea(*F.udum*),footrotofbetelvine(*Phytophthoracapsici*),bacterialleafblightofrice(*Xanthomonasoryzae*pv.*oryzae*),bacterialblightofcotton(*X.campestris*pv.m*alvacearum*)etc., are controlled by this method.Soybean seed infection by *Phomopsis*sp.can be reduced byrotatingsoybeanwithmaize.Pathogensarereducedoreliminatedbyfollowingthecroprotationsgiven in thetable.

Table.Effectofcroprotation inreduction/eliminationof plantpathogens

Beneficial crop	Pathogenreducedoreliminated	Precedingcrop
1.Rice	*Verticilliumdahliae*	Cotton2.Pea
	Gaeiimannomycesgraminis	Wheat3.Sudangrass
	Pseudomonassolanacearum	Tomato

3. Fallowing

Fallowing starves the pathogen and helps in reduction of the inoculum by elimination ofthehost.Diseaseslike*Macrophomina*rootrotondifferentcropplantsiscontrolledbyfollowing this method.Flood fallowing is to a depth of 0.6 to 1.5 m for 4 to 6 months markedlyreduced the Panama wilt pathogen *Fusarium oxysporum* f.sp.*cubense* inoculum in banana.Soilinoculum of *Phytophthora parasitica*var.n*icotianae*, the causal organism of black shank oftobacco was destroyed by flooding the field for 3 to 4months and by raising swamp rice in a 2year rotation with tobacco-rice crop in Java.Flooding the soil strewn with debris infected by*Xanthomonas*

*axonopodis*pv. m*alvacearum*for 4 days reduced the inoculum level and thus theincidenceofdiseasewasonly2.1%asagainst69.5%inunfloodedfields.Wetfallowingmakes

the pathogenic propagule in or on the soil to germinate, spent them, is become susceptible attackofsaprophytes.Example,*Sclerotiumrolfsii*and*Verticilliumdahliae*.Thesclerotiaormicrosclerotia of these fungi are activated in the absence of root exudates of this host.Theygerminate quickly when there is alternate wetting and drying of the soil.When the population of*Pythium myriotylum* is not high wet fallowing is successful in reducing the population. Wetfallowingreduces saprophyticsurvivalof*Alternaria solani*oncrop debris.

4. Applicationoforganicmanures

Addition of organic manures like farm yard manure or green manures or oil cakes to thesoilincreasestheantagonisticmicroorganismsinthesoil.Buildupofantagonisticmicroorganisms reduces the population of soil borne plant pathogens and the diseases caused bythem.Application of farm yard manure at the rate of 12.5 tonnes/ha reduced the incidence of*Macrophomina* root rot of cotton.Application of 5 kg of neem cake/tree three times in a yearreduces the basal stem rot (*Ganoderma lucidum)* of coconut.In the control of sesame root rot*(Macrophomina phaseolina)* application of neem cake at the rate of 150 kg/ha is recommended.Application of neem cake at the rate of 2 tonnes/ha in two split doses and covering with mudreducedfoot rot diseasein betelvine garden.

Soilamendment

It has been proved that the organic amendments rich in carbon and deficient in nitrogencontrol the take-all disease (O*phiobolus graminis*) of wheat. There is considerable liberation ofCO$_2$bysoilsaprophyteswhichsuppressesthepathogenicactivityofthisfungus.Intheprocessofsurvival also,lownitrogencontentinthesoilreducesthelongevityofthefungus.*Phytophthora*rootrotof avocadoiscontrolledby amendingthe soilswithalfalfa meal-amaterial of low C/Nratio. The other diseases are pea root rot *Aphanomyces euteichus* whencruciferousplantresidueswereincorporatedintothesoil.Alfalfamealandbarley strawapplication in the soil reduced the root rot of cotton and sorghum caused by *Macrophominaphaseolina.*Black scurf of potato (*Rhizoctonia solani*) is less in the field where wheat straw wasincorporated.

5. Summerploughing

Deep ploughing during summer periods buries the inocula of fungi of soil borne nature.Fungal propagules, sclerotia and different types of spores conidia on plant refuses die whenexposedtosunlightduetothehighertemperatureprevailingduringthesummer.Further

infected self sown plants, volunteer hosts plants, weed hosts, regrowths from the plant roots,alternate hosts and alternative hosts are also destroyed. Here, the spread of the disease isavoided.Groundnut blight (*Corticium rolfsii*) is controlled by ploughing the soil to a depth of 20cm.The inverted plough sole soil buries the sclerotia of the fungi, *Claviceps, Sclerotium* and*Sclerotinia*inassociationwithplantoralone,impedesthedischargeofascosporesfromperithecia.Bu ntandsmutsporesofwheat,smutsporesofsugarcaneandsorghumandmicrosclerotiaof*Verticillium*inco tton areburieddeepin to thesoil bydeep ploughing.

6. Cropgrowingseasons

Rice blast becomes serious when the rice crop is raised from August to September inTamil Nadu.Ragi blast becomes serious when sowing is made between June and August.Similarly yellow mosaic of blackgram/green gram and phyllody of sesame are serious duringkharif season in SouthIndia.Incidence of powdery mildews of different crops is found to behigh during rabi when compared to kharif and summer seasons.In bhendi, yellow vein mosaicincidence is very high during summer.The seasons with high incidence of diseases should beavoidedin the epidemicareas.

a. Adjustmentofsowingtime

In many diseases the incidence is more severe when the susceptible stage of the plantgrowthandfavourableconditionsfor thepathogenscoincides.While choosingthe timeofsowing it should be taken into consideration that susceptible stage of the crop growth and soilconditionsand other environments favourable for maximumactivity ofthe pathogen doesnotfall at the same time.Properly adjusting the sowing dates can give good dividends.Late plantedwheat crops contract less infection than wheat planted on normal dates.Early and late sowncropshavebeen found to be freefrom Oodhubathi diseaseof rice.

Avoiding cool and cloudy days for planting will help to reduce red rot of sugarcane. Latesowing of winter wheat and barley is considered to be the most effective measures in reducingtake all disease of wheat.Rapeseed sown in mid to late August is more liable to attack by leafspot (*Alternaria brassicae*) than late-sown crops. Pea and gram planted soon after rains whensoil temperature and moisture are at a high level, show high incidence of root rot and blight.Asthe soil temperature falls and moisture becomes less (Nov-Dec) these diseases are also reduced.In areas where these diseases are serious, late sowing helps in saving the crop.Stem rust ofwheatdamagesthelatesowncropmorethantheearlysowncrop.Because,timeofonsetof

disease and ear formation coincides.Sowing from January to April or October to December isadvocated to escape from the attack of neck blast of finger millet.Peas and chickpea sown inOctober usually suffer heavily from root rot and wilt (a complex of *Fusarium*, *Rhizoctonia*and*Sclerotium*). When these crops are sown late, the diseases are not so severe or almost absent.Thegroundnut rosetteistransmitted by*Aphis craccivora.*

In Nigeria the population of this vector is low in crops sown in June than in July. Thesowing time is adjusted in cumbu and sorghum in such a way that the flowering stage does notcoincide with the rainy season to avoid the sugary diseases. Early sown crops show decreasedincidence of curly topandyellows on sugarbeet,rosette on groundnutand barley yellow dwarfoncereals.Delayed sowing ontheotherhandis beneficialto maizeroughdwarfdisease.

b. Adjustmentofharvesting time

Harvesting of groundnut should not coincide with the rainy days and it helps to avoidinfection by *Aspergillus flavus*.Freedom of onions and roses grown in rainless seasons fromdowny mildew diseases and freedom of beans, chilli and cucurbits frombacterial diseases insuch seasons are the best examples for sowing of crops at correct season to avoid diseaseoutbreaks.In the case of deciduous fruit trees and grapevines, the season of sprouting, floweringandfruitsetcanbeadvancedordelayedbypruningpracticesorbytreatmentstobreakdormancy .Advantage can sometimes be taken of this fact to avoid coincidence of all or one ofthese phases of host growth with weather periods particularly favourable to specific pathogensthatattack trees in thephases.

7. Growingof seedcrops

Coffee can be grown in the western Hemisphere usually free from coffee rust whichcauses heavy losses in Eastern Hemisphere. In the case of virus diseases this will be moreuseful.By growing seed materials in isolated places where the population of vectors is very lowand the condition is uncongenial for the vectors.Virus free potato tubers to be used as seeds aregrown in cool and windy places in many parts of the world.Under tropical and subtropicalcountries, such conditions prevail in the hills at high altitudes.Obtaining seed from disease-freelocalities has been very successfully resorted to the elimination of many seed –borne diseases.Inthe U.S.A. seed-potatoes are invariably grown in northern snow-clad sections, where viruses arepractically absent and then exported to various other sectors in the south. Similar practice hasbeeninvogueinIndia,whereseed-potatoesareannuallyimportedinsouthernstatesfromSimla

hills for control of virus diseases and bacterial ring.In the U.S.A, the seed growing areas havebeen shifted to arid pacific regions for crops like cabbage, turnip, beans and peas for obtainingdisease-free seed and indirectly controlling such diseases like black leg and black rot of cabbageand turnip and anthracnose of beans and peas.Similar practice is obtained in parts of Bombay,where the foot rot of ginger (*Pythium myriotylum*) prevalent in the southern parts, iscontrolledthrough the importation of seed-rhizomes from disease-free arid regions of the north, where thedisease is practically non-existent on account of the dry climate, lighter soils and moderaterainfall.

8. Selectionofseedsandseedmaterials

Seeds and seed materials carry many fungi, bacteria, viruses and phytoplasmas and mayintroduce these pathogens into the field, i.e., seeds and seed materials form the primary source ofinfection.Seed and seed materials like cuttings, tubers, grafts, setts etc., should be well matured,disease free, uninjured and have a high germinating capacity.The absence of an initial inoculumin seeds is definitely helpful in delaying or suppressing the incidence of the disease.It is apreventivemethod.

The diseases like foot rot, brown spot, short smut of sorghum, loose smut of wheat,bacterial blight of rice, bacterial blight of cotton, leaf crinkle of blackgram etc., are transmittedthrough seeds.Virus diseases and black ring of potatoes, foot rot of ginger, foot rot of betelvine,Panama disease of banana, red rot of sugarcane cassava mosaic, bunchy top and virus diseases offruit trees are transmitted through tubers,setts, rhizomes, corns, grafts and budwoods. 'Tuberindexing' is a special method to obtain disease free seed materials in potato.It is commonlypracticed by nurseries and seed merchants selling potato seed tubers.Use of seeds in the place ofrhizome/suckeris recommended in thecontrol of'katte' diseaseof cardamom.

9. Levelingofthefieldandprovisionofdrainagefacilities

Waterstagnationindifferentpatchesoffieldfavoursthefungilike*Pythium,Phytophthora, Rhizoctonia solani*, etc., for which proper leveling of the field before sowing orplanting is very essential.Further improving the drainage is necessary in the control of sheathblight of rice. Provision of drainage channels in orchard crops like citrus, jack, mango etc., inthe garden is necessary before planting.In the control of damping-off diseases of vegetable andother crops, raising seedling in the raised beds method is followed.Foot rot of ginger (*Pythiummyriotylum*)is also controlled byfollowing the raised bedsystem of nursery.

10. Seedrate

Use of higher seed rate in the nursery creates favourable microclimate for the pathogenscausing damping-off in vegetables, tobacco, chillies and forest nurseries.Hence, use of optimumseedrateshould beadhered in such crops.

11. Burningof stubblesandcropresidues

Burning of plant wastes, crop residues, stubbles, *etc.,* in the areas selected for raisingnurseries for vegetable crops, tobacco, chillies and forest trees etc. heats the soil and kills theinoculum of the pathogens present in the top layer of the soil.When nurseries are raised in theseareas incidence of damping off disease is highly reduced.This practice is also followed in pitsmade for planting coconut, banana, fruit trees etc., Burning of wheat plant every second or thirdyear is suggested for eradication of pathogen in the field when *Cephalosporium gramineum*infects wheat.Otherwise, debris in the field helps the perpetuation of the pathogen and thedisease. Burning of rice crop residues avoid carryover of sheath blight (*Rhizoctonia solani*); stemrot(*Sclerotium oryzae*) of rice and bacterialblight of cotton.

12. Depthof sowing

Depth of sowing greatly influences seed transmission of smuts.Shallow planting in wetsoils protects wheat plants from U*rocystis tritici* (flag smut) of wheat.Deep planting may causedelay in the emergence of seedlings, which may be vulnerable to pre-emergence damping off.Early emergence results in early lignification of tissues which become resistant to attack of soil-bornepathogens.

13. Spacing

Closerspacinginvariably altersthemicroclimateunderneaththecanopy ofthecropwhich may provide favourable environment for development of diseases.Boll rot in cotton isquite common in crowded crop.Defoliation of plants or skip cropping gives better controlagainst the boll rot disease.In certain virus diseases like groundnut rosette the incidence isobserved to be less when wider spacing is adopted.Closer spacing favours many air bornediseases because of high humidity in the crop canopy.Early and late blight of groundnut andblister blight of tea are more in dense canopy.Early spread of black rot of cabbage takes place incloser spacing. Crowded stands may reduce some systemic diseases.Cotton wilt caused by*Verticillium albo-atrum* will be less in closely planted crop if the fungal inoculum is less in thesoil.Similarlycloserspacingofricereducesricetungrovirusinfectionparticularlywhenvector

populationisless.Avoidingshadeandprovidingwiderspacingreducestheincidenceofpowdery mildew of tobacco.Late blight of potato and downy mildew of grapevine spread fast incloser spaced crops.In the case of bud necrosis of groundnut caused by tomato spotted wiltvirus, seeds are sown adopting closer spacing of 15x15cm to compensate the rogued out plantswith regard to plant population and yield.These are examples where dense sowing helps indiseasereduction.

The virus of tomato leaf curl, transmitted by *Bemisia tabaci*, is less severe in a crowdedplantingthaninspacedplanting.Sameistrueforcucumbermosaic,transmittedby*Aphisgossypi i* and groundnut rosette transmitted by *Aphis craccivora*.The fungal diseases for whichthephenomenonoflowerincidenceatcloserspacingofthecrophasbeenstudiedmostprofitably is the wilt caused by *Verticillium albo atrum*and V.*dahliae*in cotton.This isascribed to the reduction of effective inoculum per plant in proportion to the increase in thenumber of plantsper unit area in the densely sown field.The incidence of brown rot(*Cephalosporium gragatum*) of soybean is also higher in widely spaced planting than in closerrows.

14. Methodofsowing/planting

In places where water accumulation is a problem to the crop growth sowing of seeds onthe sides or ridges is found effective in reducing the incidence of *Sclerotium rolfsii* on groundnutand vegetable crops and *Sclerotinia sclerotiorum* and *Rhizoctonia solani* on vegetable crops and*Phytophthora* blight of pigeonpea. High ridging prevents infection of potato tubers, by zoosporesfrom leaf lesions in late blight diseases.Ridging is disadvantageous in water deficit areas whereitencourages pathogens like *Macrophomina phaseolina.*

15. Highbudding

High budding is a practice to avoid infection by gummosis fungus of citrus trees.In lowbudded plants the bud point is close proximity to infection centre (the soil), become readilydiseased.High budding is a simple device for lengthening this distance between the bud pointandinfectedsoil.Inthismethodthesoilbornepathogens(*Phytophthorapalmivora*and*P.citrophth ora*) have no chance of reaching the bud point, through which they enter the bark.Staking of lower most branches arising close to the soil, increases the distance between the fruitsand soil inoculum and removes the chances of brown rot (*Phytophthora sp*) infection and buck-eye rot of tomato (*P. nicotianae* var. p*arasitica*).

16. Avoidinginjury

Injury of plant parts should be avoided in order to check the entry of pathogens.Clippingof tips of tall rice seedlings favours the entry of bacterial blight pathogen and incidence of thedisease.Hence clipping should be avoided at the time of transplanting of rice. While harvestingthe pods in groundnut, fruits in tree crops and vegetable crops injuries to the fruits pave the wayforthepathogenandcausingpod/fruitrot.Italsoreducesthestoragelifeoffruitsandvegetables.Henc emuchcareshould begiven toavoid wounds duringtheharvest time.

17. Alteringthesoil pH

Incertainsoilbornediseasesadjustmentofsoilreactionhelpsinthereductionofinoculumleveloft hepathogens.ThealteredpHoftheenvironmentformsabarrieragainstthepathogen.AverylowpHlessth an5.2isunfavourabletocommonscabbacteriumonpotato(*Streptomycesscabies*).Thus,useofacidform ingfertilizers(likesulphur)andavoidinglimeandcalciumammoniumnitrateapplicationareeffectivein controllingthecommonscabdisease.

On the other hand the club root pathogen of cabbage (*Plasmodiophora brassicae*) cannotlive and infect when the soil pH is 7.0 or more.Hence liming which increases the soil pH givessatisfactorycontrolofclubrootdisease.InPunjab,rootrotoftobacco(*Macrophominaphaseolina*) has been overcome byapplication of2.5 to 5.0 tonsof lime/hato thesoil.

18. Mixedcropping

Mixed cropping materially helpsin checkingcertain diseases.Blight of pulse crop(*Phyllosticta phaseolina)* has been successfully overcome by growing pulses as a mixed cropwithcereals like sorghum and pearlmillet.

19. Intercropping

Intercropping is also a device in the control of some soil borne diseases.Intercropsshouldbeproperlychosensothattheyshouldnothaveanycommonpathogenfore.g., *Macrophomina phaseolina*hasgot wide host range and hence common host should not begrown as intercrops.Intercropping with moth bean (*Phaseolus aconitifolius*) in a cotton fieldreducedtheroot rot (*M.phaseolina*) incidence.

Duetoreductioninthenumberofhostplantsthereissufficientspacingbetweenthemandchances ofcontactbetweenfoliageofrootsofdiseasedandhealthyplantaregreatlyreduced.Therefore, root pathogens are unable to spread from diseased to healthy roots andspreadoffoliarpathogensisalsoreducedtoagreatextent.Intercroppingofsorghumin

pigeonpea field reduced the wilt (F. *udum*) incidence.The roots of non-host plants may act as abarrier obstructing the movement of pathogens in soil.They may release toxic substances fromtheirrootswhichmaysuppressthegrowthofthepathogensattackingthemaincrop.Hydrocyanic acid (HCN) in root exudates of sorghum is toxic to *F. udum*, the pigeonpea wiltfungus.Intercropping of sorghum or mothbean in a crop of clusterbean reduced the incidence ofroot rot (*R.solani*) and wilt(*F.coeruleum*) from 50 to60% insingle crop to8 to15% inthemixedcrop.

Intercropping of pigeonpea with gingelly at 1:6 ratio reduced the incidence of phyllodydisease. In Jordan, intercropping tomatoes with cucumber is found to be effective and cheaper incontrolling the whiteflies and lowering the incidence of tomato yellow leaf curl virus. (TYLCV)Cucumber is planted one month before tomato.Cucumber is known to be a preferred host forwhiteflies and immune to TYLCV.Insecticides are applied when adult whitefly populations areat high levels, usually two weeks after planting of cucumber and the second one beforetomatoplanting.Growing of an intercrop of cereals such as corn or sorghum between rows of peachtrees is an effective method in combating Texas root rot (*Phymatotrichum omnivorum*) infectionin theU.S.A.

20. Barriercropping

Taller crops can be grown to protect a crop of lesser height from virus vectors.Theinsects may land at the taller crops (barrier crops) and the dwarf crop may escape from virusdiseases by those insects.Barrier cropping with 3 rows of maize or sorghum or pearlmilletaroundthemaincropnamelyblackgramorgreengramiseffectiveinreducingthevectorpopulation and incidence of yellow mosaic.Another best example is growing of 3 rows of kaleorbarleyasbarriercropsincauliflowerseedbedsandundersownbeetstecklingagainstcauliflower mosaic and beet yellows diseases respectively.The incoming aphids are thought toland on the barley or kale and probe briefly, causing them to lose the non-persistently transmittedvirus they are carrying. Maize or sunflower are the other barrier crops considered for thesecrops.

21. Decoycropandtrapcrop

Decoy crops (hostile crops) are non-host crops sown with the purpose of making soil-bornepathogenswastetheirinfectionpotential.Thisiseffectedbyactivatingdormant

propagules offungi,seedsofparasiticplants,etc.inabsenceofthehost.Alistofpathogensthatcanbedecoyed is given in table.

Table.**Decoycropsforthereductionofpathogenpopulations**

Host	**Pathogen**	**Decoycrops**
1.Sorghum	*Strigaasiatica*	Sudangrass
2.Cabbage	*Plasmodiophorabrassicae*	Ryegrass,*Papaverrhoeas,Reseda odorata*
3.Potato	*Spongosporasubterranea*	*Daturastramonium*
4.Tomato, tobacco	*Orobanche*spp.	Sunflower, safflower, lucerne, chickpeaetc.

Trap crops are host crops of the pathogen, sown to attract pathogens but destined to beharvested or destroyed before they complete their life cycle.Fodder sorghum can be raised as atrap crop to reducedownymildewof sorghum.

22. Trenching

Trenching between rows of trees in orchards has been effectively utilized in arresting thegrowth and spread of the pathogen in the soil to the neighbouring trees. *Ganoderma lucidum*rootrotinfectedcitrustreesshouldbeisolatedbydiggingatrenchof30cmwideand60cmto90 cm deep around the tree at a distance of 2.5 to 3.0 m from the base to prevent the contact ofdiseased roots with healthy roots.Thereby the spread of the pathogen to neighbouring tree isprevented. Similar method is also followed in the control of basal stem rot (*Ganoderma lucidum*)ofcoconut inIndia.

23. Isolationdistances

The distance between seed production and commercial plots has been worked out forreducing seed borne loose smut of barley and wheat.Barley and wheat crops should be isolatedby at least 50 m from any source of loose smut infection for production of certified seeds in theU.K.

The number of viruliferous insects reaching a healthy crop from a diseased one decreaseswith distance between them so that cultivation of susceptible crops at a distance from each otherdelays or reduces the severity of virus diseases.Incidence of lettuce and cucumber mosaicvirusesisabout3%ifthenewlettucecropissown0.8kmawayfromanoldlettucefieldMuch

greater incidence of mosaic in sugarbeet fields occurs within 90 metres of a seed crop than in thefields at a greater distance.Beet mosaic and beet yellows are markedly reduced by isolating beetfieldsby19 to 24km and24 to 32km mites respectivelyfrom alargesourceof infectedbeets.

24. Yellowstickytraps

Sticky, yellow polythene sheets erected vertically on the windward side of red pepperfields have been sown to reduce the incidence of potato virus Y (PVY) and cucumber mosaicvirus (CMV) in the crop.The aphids are attracted to the yellow colour and are caught on thesticky polythene.The control obtained was so successful that the method has become a standardcontrol procedure in red pepper crops in Israel.Similar traps have also been used to protect‘seed’ potato crops, against potato leaf roll virus. Yellow sticky traps are in use to attract and killthe whitefly vectors which spread yellow mosaic of blackgram and greengram and bhendi yellowveinmosaic.

25. Mulching

Mulching or covering of top soil with organic residues often helps in reducing plantdiseases.Mulches of non-host origin should be used in the field.These mulches are known torelease inhibitory substances in the underlying soil and also promote development of parasitesand predators of nematodes.Reflective surfaces (mulches) laid on the soil around the crop plant,have been found to be highly effective in controlling aphid vectors.Aluminium strips or grey orwhite plastic sheets are used as mulch and it has successfully protected red peppers againstCMV and PVY in Israel and summer squash against watermelon mosaic virus in the Imperialvalley of California. Straw mulches have been successfully used to control the white fly–transmitted tomato yellow leaf curl virus in tomato crops in Israel.It is believed that the colourof the straw attracts the whiteflies and they are subsequently killed by the reflective heat.Thedisadvantage with straw mulches is that they eventually lose their yellow colour, but prolongedcontrolmaybeobtained if straw is replaced byyellow polythenesheets.

26. Irrigationwatermanagement

Irrigation to the crop in the field is to wet the soil to the extent that roots easily get waterand nutrients.If excess water is added to soil, it may directly affect activity of pathogens and/orit may affect disease incidence through the effect on the host.Scab attack on potato tubers isprevented by maintaining soil moisture near field capacity during tuber formation. Bacterialfloraantagonistic*to Streptomycesscabies*increasesunderhighmoistureconditions.The

charcoal rot pathogen, *Macrophomina phaseolina*attacks potatoes and cotton when the soiltemperature rises and there is water stress.By irrigating the field, soil temperature is broughtdown, stress is removed and the disease is suppressed.When excess irrigation is made thejuvenile stage of plants is lengthened making it susceptible to attack of fungi like *Pythium*.Supply of frequent but low quantity of irrigation water is, therefore, recommended for reducingchancesof damping off in nurseries.

Under conditions of excess water, respiration of roots is inhibited and many soluble saltsaccumulate in toxic amounts around the roots and base of the stem.This increases diseaseproneness of the roots.Irrigation increases guttation.Guttation drops on leaves serve as mediafor multiplication and penetration of many pathogens, such as *Helminthosporium* spp.on cerealsand *Xanthomonas campestris*on*Brassica* spp.Cereal rusts usually are more severe when thecrop is grown in wet soil than in relatively drier soils.Vascular wilts appear aggravated soonafterirrigation. Theseeffects arethrough the host.

Pathogens directly taking advantage of excess water are those that need wet soil for (i)activationoftheirrestingstructuresand(ii)formovementofthesepropagules.Thus,inpresence of excess free water bacterial cells and zoospores of Pythiaceous fungi are dispersedeasily. Therefore, at the plant stage when these pathogens can attack the crop irrigation shouldbe avoided.Generally, sprinkler irrigation increases diseases by increasing leaf wetness and bydispersingpropagulesofthepathogensbywatersplashesjustlikerainwater.Atthesametime,ithas someadvantagesalsosuch as washing offofinoculum from theleaf surface.

Irrigation especially at seed-development stage, may favour seed infection.Irrigationtime and amount of water should be controlled so that the relative humidity is not raised to suchan extent that it becomes conducive for seed infection.Control of seed-borne diseases favouredby wet climate can be achieved by raising the seed crop in dry areas.Some examples areanthracnose of bean and cucurbits (*Colletotrichum*spp.), *Ascochyta*blight of pea (*Ascochyta*spp.) and bacterial blight of legumes.Such crops can be grown in dry areas with the help ofirrigation so that these aerial parts remain dry and do not contact infection. Virus-free potatoseedtuberscanbeproducedmoresuccessfullyinareaswheretemperatureandmoistureconditions do not favourbuildup ofpopulations of the insectvectors.

Sclerotia,smutspores,chlamydospores,oosporesandmyceliumfoundinthesoilarecarriedfrom one field to another through irrigation and drainage water.Stem rot, sheath blight andbacterial blight diseases of rice, damping off of vegetables and *Macrophomina* root rots of manycrops spread mainly through irrigation and drainage water.Hence care should be taken not toirrigateahealthyfield using drainage/irrigationwaterfromadiseasedfield.

27. Fieldandplantsanitation

Field and plant sanitation is an important method of disease control through culturalpractices.The inoculum present on field plants in the field may multiply on the plant or in thesoil and in due course of time may be sufficient to nullify or reducethe effect of controlpractices.Many pathogens overwinter or oversummer on plant debris during the off-seasons andbecome active when the crop is again grown in the field. Hence plants bearing pathogens orplant debris introducing inoculum into the soil should be removed as early as possible. In mostof the soil borne diseases like wilt and root rot, it has been reported that as long as the dead rootsand other roots and other affected parts are present in the soil, the fungus continue its growth.When such diseased plant materials are removed, there is quick decline in the population ofpathogens inthesoil.

In this manner *Fusarium* wilt of cotton,pigeonpea andbanana, *Verticillium* wilt ofcotton, root rotofbeans, downy mildew of pearlmillet, sorghum, maize and peas, foot rot ofbetelvine,bacterialblightofcotton,whiterustofcrucifers,blackspotofrose,powderymildewof pea and cereals are reduced. In certain areas the linseed rust fungus (*Melampsora lini*), therice blast and brown spot fungi and the fungus causing early blight of potato also perennatethroughdormantstagesindiseasedcropdebris.Destructionofcropdebrisbyburningimmediatelyafter harvestreduces theamountof inocula which survive through debris.

Ithasbeenobservedthatleafblightdiseaseorriceparticularlyonecausedby*Helminthosporium oryzae*is carried over in the stubbles and primary infection is evident in theself-sown tillers arising from these stubbles. Infection of *Sclerotium rolfsii* on jute is carried overin the foot and root regions in the stubbles left over after harvest of the jute plants. Sugarcanestubblesleftoverinthefieldhelptocarry overredrotfungus*Glomerellatucumanensis,Xanthomonasoryzae*pv.*oryzae*causingbacterialleafblightdiseaseonriceiscapableofsurviving for some timein rice stubbles. In many cases, diseased planting materials left in thefieldafterdiscardingthem,serveassourcesofinfectionasinthecaseoflateblightofpotato

where piles or refuses of rejected tubers later become an important source of infection.Left overplant parts of maize infected with the smut *Ustilago zeae* constitute an important source ofinfectionlater.

Avoidance of the transfer of inoculumfrom one field to another by man, machine orwater is one of the ground rules of cultural control. Where soil-borne diseases are concerned,anything that carries soil is suspect, this includes wheels, boots and water flowing either fromadjacent fields, or through drainage ditches from distant fields. As regards sap-borne viruses,attention must be paid to disinfection of wheels and of the hands of labourers, as they pass fromone field to another. Where such virus can also be carried on clothing. The work should beplannedso thatthelabourers donot go fromoldertoyoungerfields onthesame day.

Many pathogens are capable of surviving on implements and materials used in sequentialseasons. Tobacco mosaic virus has been shown to survive on iron stakes used for tomato trellisesand disinfection of such stakes has been recommended. Soil adhering to plastic sheeting maycarrysclerotiaand other overseasoning bodies.

28. Roguing

Roguing consists of completely removing or uprooting the diseased plants to preventfurther spread of the disease. This method is widely adopted in the control of virus diseasesspread by insects (cassava mosaic, yellow mosaic of blackgram and greengram, citrus tristeza,katte disease of cardamom, bunchy top ofbanana) and basal stem rot of coconut, green ear

ofpearlmilletandbroomrape(*Orobanche*)intobacco.Thewhipsmutofsugarcane(*Ustilagoscitaminea*) in the canal areas of Bombay in Co.475 variety has been greatly checked by roguingcarried out over wide areas and long period. In Jamaica, a country-wide campaign of destroyinginfected plants has succeeded in the control of Panama wilt of banana. Root rot and wilt attachedplants after their death should be as and when noticed in the field uprooted and burnt to check theinoculum buildup in thesoil.

29. Managementofplantnutrients

Theplantnutrientsingeneralwhenappliedinexcessmayincreaseorreducetheresistance in plants to diseases. Increased application of nitrogenous fertilizers increases theincidence of many diseases. Crops fed with heavy doses of nitrogenous was fertilizers growrobust with foliage and succulent tissue but become highly susceptible to the attack of diseaseslikerustpowderymildew,blast,tobaccomosaicandsomebacterialdiseases.Inthecaseofblast

of rice optimum dose of nitrogenous fertilizers are recommended and it is applied in 3 split dosesviz. 50% as based at transplanting, 25% at tillering and 25% at panicle initiation stage. Lateapplicationofnitrogenousfertilizersincreaseswheatleafblotch(*Septorianodorum*)andpowdery mildew(*Erysiphe graminis tritici*).

Somediseasesarefavouredbyammoniacalformofnitrogenwhileothersarefavouredby nitrate form of nitrogen. In general wilts (*Fusarium* sp.) and root rots (*Rhizoctonia* spp.) arefavoured by ammoniacal nitrogen while *Verticillium* wilts and root rots due to *Pythium* spp. arefavoured by nitrate nitrogen. In rice, blast disease is favoured by ammoniacal nitrogen whilebrown spot (*Helminthosporium oryzae*) is favoured by nitrate nitrogen. In maize Northern cornleaf blight caused by *H. turcicum* is favoured by ammoniacal nitrogen while stalk rot (*Diplodiamaydis*)is favoured bynitrate nitrogen.

In wheat, sharp eye spot (*Rhizoctonia solani*) is favoured by ammoniacal nitrogen whilestem rust (*Puccinia graminis tritici*) is favoured by nitrate nitrogen. In potato, wilt (*Verticilliumalbo-atrum)* and scab (S*treptomyces scabies)* are favoured by nitrate nitrogen while ammoniacalnitrogenincreases blackscurf (*R. olani*) .

Effects of nitrogenous fertilizers on major soil borne diseases have been studied. Theireffect on the disease i.e., whether increased or decreased incidence by nitrogen in different formsaregiven in thefollowing table.

Table.Effectsofdifferentformsof nitrogenonsoil-bornediseases

Pathogen	Host	Amendment
Diseasesincreased		
Fusarium oxysporum f.sp. *lycopersici*	Tomato	NO_3
F.moniliforme	Sorghum	$NaNO_3$-
F.roseum	Carnation	$NH_4NO_3NO_3$
*F.solani*f.sp.*phaseoli*	Bean	$NH_4(NH_4)$
Gaeumannomycesgraminis	Wheat	$_2SO_4NO_3$
Phytophthoranicotianae var.*nicotianae*	Tabacco	$(NH_4)_2SO_4.Ca(NO_3)_2.KNO_3$
Verticilliumalbo-atrum	Cotton	$NH_4\ NO_3$+$CaCO_3$
Streptomycesscabies	Potato	

Diseasedecreased		
*F.oxysporum*f.sp.*cubense*	Banana	Urea(nitrite)
*F.solani*f.sp.*phaseoli*	Bean	$KNO_3(NH_4)$
Gaeumannomycesgraminis	Wheat	$_2SO_4KNO_3$
Phytophthoracinnamomi	Avocado	$Ca(NO_3)_2$
Sclerotiumrolfsii	Tomato	$NH_3.(NH_4)_2SO_4.Ca(NO_3)_2$
S.rolfsii	Sugarbeet	

Repeated application of phosphatic fertilizers delays the onset and lessens the severity oftake-alldiseaseofbarley(*Gaeiimannomycesgraminis*).Potassiumapplicationreducesthedisease incidence in many crop diseases probably by increasing phenolics synthesis in plants.Application of potash induces resistance in groundnut against root rot caused by *Macrophominaphaseolina*. Calcium application suppresses the lesions due to the*R.solani* on bean roots. It isdue to formation of calcium pectate, which is less available to action by polygalacturanase (PG)enzymethan is pecticacid.

Calcium has also been shown to affect *Sclerotium rolfsii* by neutralizing the oxalic acidproducedby the fungus.Applicationof molybdenumreducesinfectionof potatotubersby*Phytophthora infestans* and also diminishes incidence of *Ascochyta* blight on beans and peas.Manganese reduces late blight of potato, ferric chloride controls rice brown spot and siliconapplicationreduced riceblast.

30. Timeofharvesting

Time of harvesting affects the cleanliness of the seeds. Delayed harvesting of grain cropsin temperate climatic conditions enables the pathogen more time to contaminate the seeds. Thebestexampleisgrainmouldofsorghumwherecontaminationbyspeciesof*Fusarium,Curvularia, Alternaria, Aspergillus, Phoma* is seen.Potato tubers harvested when the tops aregreen get easily contaminated by the late blight pathogen present on the leaves.Removal of topsandmakingthemtodrybeforediggingthetuberskillsthesporangiaandavoidscontaminationoftuber s harvested later.

31. Avoidingratoons

Ratooning is a general practice in sugarcane when the incidence of grassy shoot diseaseandred rotareveryhigh.Henceratooning should beavoided.

32. Solarheating

When the soil is covered with white polythene sheets during hot seasons, soil temperatureincreases. Increased soil temperature eliminates wilt pathogens like *Fusarium oxysporum* f.sp.*lycopersici*andV*erticilliumdahliae*fromtomatofield.Highsoiltemperaturealsofavoursantagonisticfungi.

Lecture07

Biological control and PGPR – Scope and importance – Role and mechanisms of biologicalcontroland PGPR withexamples. Plant growthpromoting rhizobacteria

Biological control is defined as the reduction of inoculum density or disease producingactivities of a pathogen or parasite in its active or dormant stage by one or more organismsaccomplished naturally or through manipulation of the environment, host or by introduction ofoneor moreantagonistsorbymass introduction ofoneor moreantagonists.

Biological control is but control of plant diseases using living microorganisms. Root rotdisease *(Macrophomina phaseolina)* is a major disease in pulses, oilseeds, cofton, etc., and themostcommonmethodofcontrolisusingfungicides.Butthechemicalmethodsareuneconomical and law effective, as seed treatment with chemical may give protection only in theearlystages of crop growth 2 weeks.

In addition, it is harmful to the beneficial microorganisms in soil and creates residualproblems.So,thebiologicalcontrolcanbeveryefficasyusedfortherootrotdiseasemanagement as the biological agent multiply in soil and offer protection throughout the cropgrowth.Thefourmainmechanismsinvolvedinthebiocontrolare(i)thebiologicalagent(antagonist) ,mayparasitetheotherorganism,(ii)antagonistmaysecretemetabolites(antibiotics)harmfultothepatho gens(Antibiosis)(iii)antagonistmaycompetewiththepathogens for nutrients or space (Competition) and (iv) may cause death of the parasite byproducingenzymes(Lysis).

Parasitismand Lysis

Thebiocontrolagainstparasitizesthepathogenbycoilingaroundthehyphae,e.g.,*Trichoderma* viride; various bacteria and fungi secrete hydrolytic about the degradation of cellwallof pathogens.

e.g. (i)*Bacillus*sp. causeshyphallysis of*Gaeumanornyces*graminis

(ii) The chitnolytic enzymes of *Serratia marcescens* caused cell wall lysis of *Scierotiumrolfsii.*(iii)*Trichoderma*sp.produceschitinasesandβ-1,3glucanaseswhichlysesthecellwallof*Rhizoctonia solani.*

Antibiosis

The antibiotic compounds secreted by the biocontrol agent suppress the growth of thepathogen. e.g. Phenazine-l-carboxylic acid produced by *P fluorescens* plays an important role insuppressingthe takeall diseaseof wheat.

Competition

Thebiocontrolbacteriaandfungicompeteforfoodandessentialelementswiththepathogenthere bydisplacing and suppressing the growth of pathogen.

e.g.

(i)thecompetitionfornutrientsbetween*Pythiumaphanidermatum,Pultimum*andbacteriasupp ress thedamping off diseasein cucumbers.

(ii)Fluorescentsiderophores(ironchelaters)suchaspseudobactinis&*pyoverdins*produced by P *fluorescons* chelates iron available in the soil, thereby depriving the pathogen ofItsFerequirements.

A. TRICHODERMAVIRIDE

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

SystematicPosition

Asexual**(conidial)Sexual(sscospore)**

Subdivision:DeuteromycotinaAscomycotinaCl

ass: HypomycetesPyremomycetes

Order : Moniliales

SphaerialesFamily:MoniliaceaeHyp

ocreaceaeGenus : Trichoderma

Hypocrea**Isolationof*Trichoderms*f**

romsoil

Trichoderma is isolated from the soil by using *Trichoderma* selective medium developedby Elad and Chet (I 983). Collect soil samples from the field, mix well and make it into fineparticles. Soil samples should be collected in root zone at 5-1 5 cm depth and from rhizospherewherever possible. Ten gram of soil sample is taken, and suspended in 100 ml of sterile distilledwater and stirred well to get I : IO dilution. Transfer one ml from this to 9 ml of sterile water in atest tube to get 1: 100 dilution. Make serial dilutions by transferring one ml of

suspension

tosubsequenttubestogetdilutionof1:10,000.Transferonemlofthedesiredsoilsuspensionto

sterile petriplates. Pour 15 ml of melted and cooled *Trichoderma* selective medium in the samepetriplates. Rotate the plate gently and allow to solidify, incubate at room temperature for 5-7days and observe for the development of fungal colonies. Trichoderma colonies will be whiteinitiallyandturntogreen.Countthenumberofcoloniesdevelopinginindividualplates.Transferthe individual colonies to potato de)droseagar slants.

TestingMethod

DualCultureTechnique

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 tosterilised petridishes. Allow it to solidify. Transfer 8 mm disc of test organism to one end of thepetriplate. In the opposite end, 8 mm disc of the pathogenic culture is transferred in the samepetriplate (if the antagonistic micro-organism is slow growing it should be plated in the previousday itself). Incubate the plate at room temperature. Observe the development of inhibition zone.Observeunder microscopewhereboth thetest organism andthe pathogencomein contact.

MassProduction

Molasses yeast medium (Molasses 30g + yeast 5g + water 1000ml) is prepared in conicalflasks and sterilized at 1.1 kg/CM 2 for 20 minutes. *T.viride* culture is inoculated by taking afungal 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 isadded to the fermenter @ 1.5 litre/50 litres of medium and incubated at room temperature for 10days. The fungal biomass and broth are mixed with talc powder at 1:2 ratio. The mixture is airdried and mixed with carboxy methyl cellulose (CMC) @ 5g / kg of the product. It is packed inPolythenecovers and used within 4 months.

QualityControlSpecifications

1. Freshproduct shouldcontain not lessthan 28 X10 6CfU/ g
2. After120 daysof storageatroom temperature, thepopulation shouldbe10 xIO 6 cfu/ g.
3. Maximumstorageperiodusingtalcascarrieris120days.
4. Sizeof thecarrier (talc)should be500 microns.
5. Productshouldbepacked inwhitePolythenebags.
6. Moisturecontent ofthefinalproduct should not bemorethan 20%.

B. Bacillussubtilis

Thisbacteriumiswidelyusedforthecontrolofsoil-bomeplantpathogenslike*Macrophominaphaseolina,Rhizoctoniasolani,Fusarium*spp.etc.Thistreatmentalsoconsiderably improves the plant growth and yield. *Bacillus subtilis* is a rod shaped, thermophilicgram positive, aerobic bacterium. Roots may be formed in chains. It is 5-6 mm in length and 2-3mmin width. Itformsendospores duringadverse conditions.

Isolation

One gram of soil sample is mixed with 9 ml sterilized nutrient broth in a test tube. Thishastobekeptonaboilingwaterbathat800Cfor10minutes.Thenitiskeptforincubationatroot temperature for 24-48 hrs. From this serial dilution is prepared upto 10-6 dilution. Dilution10-5 and 10 -6 are plated In Nutrient Agar and incubated for 24- 48 hrs. *B. subtilis* colonies willberough, opaquewith irregularmargins.

StainingforIdentification

Bacterialsmearispreparedwith24hoursoldculture,airdriedandheatfixed.Theslideis flooeded with crystal violet for 60 seconds and then washed with tap water. Then, the slide isflooded with Grams iodine mordant for 60 seconds and washed with tap water. It is then thesmeariscounterstrainedwithsafraninforseconds,washedwithtapwater,blotdriedandobservedundermicroscope. *Bacillus subtilis* appeared violet sinceit,is grampositive.

BiochemicaltestsforIdentification

Thefollowingbiochemicaltestsarecarriedoutforidentification.

1. Starchhydrolysis
2. Catalasetest
3. Nitratereductiontest
4. Acidandgasproductiontest

*Bacillussubtilis*isamylasepositivecatalasepositive,nitratepositive,acidpositiveandgasnegative.

Massmultiplication

Nutrient broth (Peptone 5g, beef extract 3g, sodium chloride 3g in 1 litre of distilledwater, 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 ofmotherculture istransferredto100litresofsterilizednutrientbrothinafermenterandthe

bacterial growth is harvested after 72 hrs. Then it is mixed with 250 kg of sterilized peat soilamended with 37 kg Calcium carbonate, dried in shade and packed in Polythene bags. Thisproductcan bestored upto 6 months.

C. Pseudomonasfluorescens

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 shapednonspore formingbacteriawhichmay bemonoorlopotrichousornonmotile.Itproducesgreenish,fluorescentandwatersolublepigment,pyoverdin.Thedirectinfluenceofpseudomonas on plant growth is mediated either by release of auxin-like substances or throughimproved uptake of nutrients in the environment. The indirect promotion of plant growth isachievedwhenfluorescent*Pseudomonas*decreasesorpreventsthedeleteriousinfluenceofphytopathogens.

lsolation

Onegramofrhizospheresoilsampleismixedin100mlofsterilewatertogive1:100dilution. From this serial dilutions upto 10 -7 level are made by repeatedly transferring 1 mlof 1:I00 dilution to 9 ml sterile water stants 10 -5 , 10 -6 and 10 -7 dilutions are plated in kings BAgar medium and incubated for 24-48 hours. P *ftuorescens* appears as smooth, slimy, circulartranslucentcolonies.

Massproduction

P. fluorescens is multiplied in sterilized Kings ‘B’ broth for 48 hours. The pH of thesubstrate (Peat soil or talc powder) isadjusted to7 by addingcalcium carbonate @150g / 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 ofcarboxy methyl cellulose and mixed well.The formulation is packed in Polythene covers and canbestored foronemonth.

QualityControl

1. Freshproduct should contain 2.5 xI0" cfu / g
2. After3 months of storageat room temperature,the populationshould be8-9 x10 7 CfU/ g.
3. Storageperiodis3-4months
4. Minimumpopulation loadfor useis 1.0xI08cfu/ g.
5. Productshouldbepacked inwhitePolythenebags.

6. Moisturecontent oftheproduct shouldnot bemorethan 20%in thefinal product.

7. Population perml of thebroth is 9 ± 2 x 1 0 8 cfu / g.

Methodsof Application

Crop:Paddy-blast, sheath blight

1. SeedTreatment

Mix paddy seeds with the formulation at the rate of 10 g per kg of seeds and soak theseeds in water for ovemight. Decant the excess water and allow to sprout the seeds for 24 hrs andthen sow.

2. Seedlingrootdipping

Apply 2.5 kg of the formulation to the water stagnated in an area of 25 sq.m. Theseedlings, after pulling out from the nursery can be left in the stagnating water containing thebacteria. A minimum period of 30 minutes is necessary for soaking the roots and prolongedsoakingwill enhancetheefficacy.

3. Soilapplication

Apply the product @ 2.5 kg / ha after 30 days of transplanting (This product should bemixedwith 50 kg of welldecomposed FYM / sand and thenapplied).

4. Foilarapplication

Spray theproductat0.2%concentration(1kg/ha)commencingfrom45daysaftertransplanting at 10 days interval for 3 times depending on disease intensity. If there is no diseaseincidence,asinglesprayissufficient.Crop:Groundnut,Gingelly,Sunflower,Redgram,Greengram,Blackgram-root rot and wilt

Seedtreatment:10g/kgofseeds

Soilapplication:Apply2.5kg/ha.mixedwith50kgofwelldecomposedFYM/sandat30daysaftersowing.

Crop:Banana -Fusariumwilt

Suckertreatment:10g/sucker

Capsuleapplication:50mg/capsule/sucker.

Apply once in 3 months from 3 months after

plantingSoilapplication: 2.5 kg /ha+50 kg FYM /

sand

Applyonceatthetime ofplanting andrepeat it onceIn 3 months.

PlantProductsandAntiviralprinciplesinplantdiseasemanagement

Plantproductsplayanimportantroleinevolvinganecologicallysoundandenvironmentally acceptable disease management system. Plant products have been found to havefungicidal,bactericidalandantiviralproperties.Itiswellestablishedthatabout346plantproducts have fungicidal properties, 92 have bactericidal and 90 have antiviral properties. Thisclearly indicates that the plant kingdom is a vast storehouse of chemicals that can check severalplant pathogens. As many of them have more than one type of activity there is a less chance fordevelopmentof resistanceand moreover,theplantproducts aresaferto non-target organisms.

NeemProducts

Among the plant products, the neem derivatives are reported to be effective in controllingseveral 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 acidandAzadironewhich haveanitifungal and insecticidal properties.

(i) NeemSeedKernelExtract(NSKE)

Itispreparedbysoaking5kgofpowderedneemseedkernel(inagunnybag)in100litres of water for 8 hours. The gunny bag is then removed afterthorough shaking. Then, 100 mlof teepol is mixed thoroughly, before spraying. The quantity of extract required for a liectare is500litres,

(ii) Neemoil solution

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

(iii) Neemcakeextract

Ten kg of powdered neem cake in a gunny bagis soaked in 100litresof water for 8hours. The gunny bagis removed after thorough shaking. Then, 100 ml of sticker is added andmixedwell. Thequantityof sprayfluid required is500 litres/ ha.

(iv) Neemcake

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

Diseasescontrolledbyneemproducts

(a) **Paddy:**Tungro(virus) (Vector: *Nophotettixvirescens)*

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 at15days interval.

(b) **Paddy:**Sheathrot*(Acrocyfindriumoryzae)*

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

(c) Paddy: Blast*(Pyriculariaoryzae)*Spraying5%neemoiliseffective

(d) **Paddy:**Sheathblight*(Rhizoctoniasolani)*

Applicationof150Kg ofneemcake/ha

(e) **Groundnut:**Rust *(Pucciniaarachidis)*

Applicationof3%neemoil@500lit/ha.Thefirstsprayshouldbegivenimmediatelyonnoticingthesymptom and second 15 days later.

(f) Groundnut: Footrot*(Sclerotium rolfsii)*Applicationof1%neemoiliseffective.

(g) **Coconut:**Wilt *(Ganodermalucidum)*

Applicationof5kgofneemcake/tree/yearduring therainyseason.

(h) **Blackgram:**Powderymildew*(Erysiphepolygoni)*

Twosprayswith3%neemoilor5%NSKE,startingfirstsprayattheinitiationofthediseaseand second 15 dayslater areeffective.

(i) Blackgram: Rootrot*(Macrophominaphaseolina)*Application ofneemcake@150kg/ha

(j) Blackgram: Yeliow mosaic(Virus)Applicationof3%neemoilis effective.

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

OtherPlantProducts

In addition to the neem products, products from several other plant species are also foundto be effective in disease management. The leaf extract of tuisi *(Ocimum sanctum)* is foundeffective against *Helminthosporium oryzae* (paddy brown spot). The leaf and pollen extracts ofvilvam *(Aegle marmolos)* effectively reduced early blight of tomato *(Altenaria solani)* and blightofonion*(A.porri).A.solani*isalsoeffectivelycheckedbyflowerextractofperiwinkle*(Catheranthusroseus)* and bulb extract ofgarlic*(Allium sativum).*

Rice discolouration caused by *Drechslera oryzae* is effectively reduced by leaf extract ofmint *(Mentha piperita).*The bulb extract of garlic is also effective in reducing leaf blight offinger millet *(H. nodulosum)* and blast of paddy *(Pyricularia oryzae).*The root exudates ofkolinji 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)* iseffectiveagainst*Pucciniaarachidis*causinggroundnutrust.Leafextractofnochi*(Vitexnegundo)*effec tivelyreduced,RiceTungrovirusesbycheckingthevector,Nephotettix*virescens.*

AntiViralPrinciple(AVP)

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

PreparationofAVPextract

Dried coconut or sorghum leaves are cut and powdered. Twenty kg of leaf powder ismixed with 50 litres of water and heated at 60 0 C for one hour. It is filtered and volume is madeupto 200 litres. This gives 10 per cent extract. Five hundred litres of extract is required to coverone hectare. The 10 per cent AVP extract is very effective in controlling groundnut ring mosaicvirus(bud necrosis).

Two sprays are to be given at ten and twenty days after sowing. Similarly of percent leafextracts of *P. juliflora* and C. *dactylon* effectively reduced the tomato spotted wilt virus intomato. The leaf extracts are known to containsome proteinaceous substances which inducevirusinhibition in the plants.

PGPR

Plant growth promoting rhizobacteria are bacteria that colonize plant roots, and in doingso, they promote plant growth and/or reduce disease or insect damage. There has been muchresearch interest in PGPR and there is now an increasing number of PGPR being commercializedfor crops. Organic growers may have been promoting these bacteria without knowing it. Theaddition of compost and compost teas promote existing PGPR and may introduce additionalhelpful bacteria to the field. The absence of pesticides and the more complex organic rotationslikelypromoteexistingpopulationsofthesebeneficialbacteria.However,itisalsopossibleto

inoculate seeds with bacteria that increase the availability of nutrients, including solubilizingphosphate,potassium,oxidizingsulphur,fixingnitrogen,chelatingironandcopper.Phosphorus
(P) frequently limits crop growth in organic production. Nitrogen fixing bacteria are miniature ofurea factories, turning N2 gas from the atmosphere into plant available amines and ammoniumvia a specific and unique enzyme they possess called nitrogenase. Although there are manybacteria in the soil that ‘cycle' nitrogen from organic material, it is only this small group ofspecialized nitrogen fixing bacteria that can ‘fix' atmospheric nitrogen in the soil. Arbuscularmycorrhizal fungi (AMF) are root symbiotic fungi improving plant stress resistance to abioticfactorssuchas phosphorus deficiencyor deshydratation.

The fourth major plant nutrient after N, P and K is sulphur (S). Although elementalsulphur, gypsum and other sulphur bearing mined minerals are approved for organic production,the sulphur must be transformed (or oxidized) by bacteria into sulphate before it is available
forplants.Specialgroupsofmicroorganismscanmakesulphurmoreavailable,anddooccurnaturallyin mostsoils.

One of the most common ways that PGPR improve nutrient uptake for plants is byaltering plant hormone levels. This changes root growth and shape by increasing root branching,root mass, root length, and/or the amount of root hairs. This leads to greater root surface area,whichin turn, helps it to absorb morenutrients.

Diseasecontrol

PGPR have attracted much attention in their role in reducing plant diseases. Although thefull potential has not been reached yet, the work to date is very promising and may offer organicgrowers some of their first effective control of serious plant diseases. Some PGPR, especially ifthey are inoculated on the seedbefore planting, are able to establish themselves on the
croproots.Theyusescarceresources,andtherebypreventorlimitthegrowthofpathogenicmicroorganisms. Even if nutrients are not limiting, the establishment of benign or beneficialorganisms on the roots limits the chance that a pathogenic organism that arrives later will findspacetobecomeestablished.Numerousrhizosphereorganismsarecapableofproducingcompounds that aretoxicto pathogens like HCN

Challenges with PGPR

One of the challenges of using PGPR is natural variation. It is difficult to predict how anorganismmayrespondwhenplacedinthefield(comparedtothecontrolledenvironmentofa

laboratory. Another challenge is that PGPR are living organisms. They must be able to bepropagatedartificiallyandproducedinamannertooptimizetheirviabilityandbiologicalactivity until field application. Like Rhizobia, PGPR bacteria will not live forever in a soil, andovertimegrowers will need tore-inoculate seedsto bring back populations.

PGPRinResearch

Over the years the PGPR (plant growth promoting rhizobacteria) have gained worldwideimportance and acceptance for agricultural benefits. These microorganisms are the potential toolsforsustainableagricultureandthetrendforthefuture.Scientificresearchersinvolvemultidisciplinary approaches to understand adaptation of PGPR to the rhizosphere, mechanismsof root colonization, effects of plant physiology and growth, biofertilization, induced systemicresistance, biocontrol of plant pathogens, production of determinants etc. Biodiversity of PGPRandmechanismsofactionforthedifferentgroups:diazotrophs,bacilli,pseudomonads,Trichoderma,AMF,rhizobia,Phosphatesolubilisingbacteriaandfungi,Lignindegrading,chitin degrading , cellulose degrading bacteria and fungi are shown. Effects of physical, chemicalandbiologicalfactorsonrootcolonizationandtheproteomicsperspectiveonbiocontrolandplant defense have also shown positive results. Visualization of interactions of pathogens andbiocontrolagentsonplantrootsusingautofluorescentproteinmakershasprovidedmoreunderstandingof biocontrol processeswithoverall positiveconsequences.

Waysthat PGPRpromoteplantgrowth

- Increasingnitrogenfixationinlegumes
- Promotingfree-livingnitrogen-fixingbacteria
- Increasingsupplyof other nutrients, such as phosphorus, sulphur,iron and copper
- Producingplanthormones
- Enhancingotherbeneficialbacteriaorfungi
- Controllingfungaldiseases
- Controllingbacterialdiseases
- Controllinginsectpests

Lecture08

PhysicalMethods–

Heattreatments,soilsolarization,hotwatertreatment,hotairtreatment,control by refrigerationand radiation

As early as 1832, Sinclair suggested that hot air treatment in an oven might control smutsof oats and barley. Gardeners in Scotland while treating the bulbs of different ornamental plantsfirstemployed hot water therapy.

The scientific principle involved in heat therapy is that the pathogen present in seedmaterial is selectively inactivated or eliminated at temperatures that are non lethal to the hosttissues.

Followingphysicalmethodsareemployedforreductionoreliminationofprimaryinoculumsthat maybepresent in seed, soil or planting material.

i. Hotwatertreatment (HWT)

The seeds are soaked in cold water at 20-300C for 5 hrs to induce the dormant myceliumto grow. Then the seeds are immersed in hotwater at 50-540C for 10 minutes to kill themycelium. It is very effectively used to eliminate loose smut of wheat. The setts of sugarcane canbe treated at 500C for 2 hrs to eliminate grassy shoot pathogen. The main drawback in the hotwater treatmentisthat the seedsmay be killed or looseitsgerminability,ifthe periodoftreatment exceeds the specified time. So this method is replaced by other physical methods likeHotairandAeratedsteam treatmentwhereinthe seeds areexposedonlytohotair/aeratedsteam.

ii. Hotairtreatment(HAT)

Sugarcanesettsaretreatedwithhot airat500Cfor 2 hrstoeliminatemosaicvirus.

iii. Aeratedsteamtherapy(AST)

Sugarcanesettsarealsoexposedtoaeratedsteamat500Cfor3hrstoeliminatemosaic virus.

iv. Moisthotairtreatment(MHAT)

This method is effectively used in sugarcane to eliminate grassy shoot disease. Initiallythe setts are exposed to hot air at 540C for 8 hrs, then exposed to aerated steam at 500C for 1 hrandfinallyto moist hot air at 540C for2 hours.

v. Solarheattreatment (SHT)

A simplest treatment has been devised in India to eliminate the pathogen of loose smut ofwheat.Previouslythehotwatertreatmentwasfollowedtoeliminateloosesmut.Asthetermal

death point of the fungus and the embry are very close. The extensive care should be taken toavoid killing of the embryo. Luthra in 1953 devised a method to eliminate the deep seatedinfectionof*ustilagonuda.*Themethodispopularlyknownassolarheatorsolarenergytreatment.

Luthras solar energy treatment: The seeds are soaked in cold water for 4 hours in theforenoon on a bright summer day followed by spreading and drying the seeds in hot sun for fourhours in the afternoon. Then, the seeds are again treated with carboxin or carbendazin at 2g/kgandstored. This method ishighlyuseful for treatinglargequantities of theseedlots.

vi. SoilSolarization

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

vii. SteamSterilization

Steam is passed through perforated pipes at a depth of 15 cm to sterilize the upper layersofsoil.It is mostlypracticedunderglass houseand green houseconditions.

viii. HotairSterilization

Hotair is also passedthrough pipelines to sterilizethesoils in thenurseryareas.

ix. Hotwatertreatment

Itismainlydoneinpotculturestudiestokillthefungiandnematodes.Thepotscontainingsoilarei mmersedinboilingwaterat980Cfor5minutesordrenchingboilingwater@ 20litres/ Sq.m.

Refrigeration

It is an accepted fact that the low temperature at or slightly above the freezing pointchecks the growth andactivities of all such pathogens that cause a variety of post harvestdiseases of vegetables and fruits. Therefore most perishable fruits and vegetables should betransported and stored in refrigerated vehicles and stores. Cool chains refrigerated space fromfieldtoconsumertableisbecomingverypopular.Regularrefrigerationissometimespreceded

byaquickhydrocoolingoraircoolingtoremovetheexcessheatcarriedinthemfromthefieldtoprevent development of new orlatent infections.

Radiation

Electromagnetic radiations such as ultraviolet (UV) light, x rays and y rays as well asparticulate radiations have been studied in relation to management of post harvest diseases ofhorticultural crops. Y rays controlled post harvest fungal infections in peaches, straw berries andtomatoes but doses of radiation required to kill pathogens, were found injurious to host tissues.Some plant pathogenic fungi sporulate only when they receive light in the ultraviolet range.Ithas been possible to control diseases on green house vegetables caused by species of these fungiby covering or constructing the green house with a special UV absorbing vinyl film that blockstransmissionoflight wavelengths below 390 nm.

Lecture09

Chemical methods–studyof differentgroupsoffungicides.

Methodsofapplicationoffungicides

Fungicides–definition

The word „fungicide‟ originated from two latin words, viz., „fungus‟ and „caedo‟. Theword „caedo‟ means „to kill.‟ Thus the fungicide is any agency/chemical which has the ability tokill the fungus. According to this meaning, physical agents like ultra violet light and heat shouldalsobe considered as fungicides. However, in common usage, the meaning isrestricted tochemicalsonly. Hence, fungicideis achemical which is capable ofkilling fungi.

Fungistat

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

Antisporulant

Some other chemicals may inhibit the spore production without affecting the growth ofvegetativehyphasandarecalledas,,Antisporulant‟.Eventhough,theantisporulantandfungistatic compounds do not kill the fungi, they are included under the broad term fungicidebecause by common usgage, the fungicide has been defined as a chemical agent which has theability to reduce or prevent the damage caused to plants and their products. So, some of the plantpathologistsprefertheterm,„Fungitoxicant‟insteadoffungicide.

Charactersof an idealfungicide

1. Itshould havelow phytotoxicity
2. Itshouldhavelonfshelflife
3. Stabilityduringdilution
4. Itshouldbelesstoxic tohumanbeing,cattle,earthworms,microorganismsetc.
5. Itshouldbe abroadspectruminitsaction
6. Fungicidepreparation should bereadyforuse
7. Itshouldhavecompatibilitywith other agrochemicals
8. Itmustbecheaperone
9. Itshouldbe availableindifferentformulations
10. Itshouldbe easilytransportable

ClassificationofFungicides

Fungicidescanbebroadlygroupedbasedontheir(i)modeofaction(ii)generaluseand (iii)chemicalcomposition.

I. Based on mode of actionProtectant

As the name suggests, protectant fungicides are prophylactic in their behaviour.Fungicidewhich 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 thereby curing the plant is called chemotherapeutant. eg. Carboxin, Oxycarboxin antibiotics likeAureofungin. Usually chemo therapeutant are systemic in their action and affect the deep-seatedinfection.

Eradicant

Eradicant are those which remove pathogenic fungi from an infection court (area of thehost around a propagating unit of a fungus in which infection could possibly occur). eg. Organicmercurials, lime sulphur, dodine etc. These chemicals eradicate the dormant or active pathogenfrom thehost. Theycan remain effectiveon orin thehost forsometime.

II. Basedongeneraluses

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

1. Seedprotectants:Eg. Captan,thiram,organomercuriescarbendazim,carboxinetc.
2. Soilfungicides(preplant):Eg.Bordeauxmixture,copperoxychloride,Chloropicrin,Formaldehyde Vapam, etc.,
3. Soilfungicides:Eg.Bordeauxmixture,copperoxy(forgrowingplants)chloride,Capton,PCNB,thiram etc.
4. Foliageandblossom:Eg.Capton, ferbam,zineb,protectantsmancozeb,chlorothaloniletc.
5. Fruitprotectants: Eg.Captan,maneb, carbendazim,mancozebetc.
6. Eradicants:Eg.Organomercurials,limesulphur,etc.
7. Treewounddressers:Eg.Boreauxpaste, chaubattiapaste,etc.

8. Antibiotics:Eg.Actidione,Griseofulvin,Streptomycin,Streptocycline,etc.,

9. Generalpurposesprayand dustformulations.

III. BasedonChemical Composition

The chemical available for plant disease control runs into hundreds, however, all are notequally safe, effective and popular.Major group of fungicides used include salts of toxic metalsandorganicacids,organiccompoundsofsulphurandmercury,quininesandheterocyclicnitrogen ous compounds. Copper, mercury, zinc, tin and nickel are some of the metals used asbase for inorganic and organic fungicides. The non metal substances include, sulphur, chlorine,phosphorousetc. Thefungicides can bebroudlygrouped as follows and discussed in detail.

Groupsof Fungicides– CopperFungicides,SulphurFungicidesandMercuryFungicidesCopperFungicides

The fungicidal action of copper was mentioned as early as 1807 by Prevost against wheatbunt disease *(Tilletia caries),* but its large scale use as a fungicide started in 1885 after thediscovery of Bordeaux mixture by Millardet in France. The mixture of copper sulphate and limewaseffectiveincontrollingdownymildewofgrapevinecausedby*Plasmoparaviticola*andlater,late blight of potato*(Phytophthora infestans).*

Some other copper sulphate preparations later developed were Borduaux paste, Burgandymixture and Cheshnut compound which are all very effectively used in the control of severalplant diseases. In addition some preparations of copper oxy chloride preparations arev alsomused. These are all insoluble copper compounds very successfully used in managing severalleaf diseases and seeding diseases in nursery. Some of the important diseases controlled bycopperfungicides arelisted below.

I. Copper sulphate preparationsBoreauxMixture

In 1882, Millardet in France (Bordeaux University) accidently observed the efficacy ofthe copper sulphate against the downy mildew of grapes caused by *Plasmopara viticola.* Whencopper sulphate was mixed with lime suspension, it effectively checked the disease incidence.Themixtureofcoppersulphateandlimewasnamedas“BouillieBordelaise”(BordeauxMixtu re). The original formula developed by Millardet contains 5 lbs of CuSO4 + 5lbs of lime +50gallonsofwater.ThechemistryofBordeauxmixtureiscomplexandthesuggestedreactionis:

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

The ultimate mixture contains a gelatinous precipitate of copper hydroxide and calciumsulphate, which is usually sky blue in colour. Cupric hrdroxide is the active principle and is toxicto fungal spores. In metric system, to prepare one percent Bordeaux mixture the followingprocedureis adopted:

One kg of copper sulphate is powdered and dissolved in 50 litres of water. Similarly, 1 kgof lime is powdered and dissolved in another 50 litres of water. Then copper sulphate solution isslowly added to lime solution with constant stirring or alternatively, both the solutions may bepouredsimultaneouslytoathird contained and mixed well.

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

(i) FieldTest:Dipawellpolishedknifeorasickleinthemixtureforfewminutes.Ifreddishdepositappears on theknife/sickle, it indicates the acidicnatureof themixture.

(ii) Litmuspapertest:Thecolourofbluelitmuspapermustnotchangewhendippedinthemixture.

(iii) pHpapertest:Ifthepaperisdippedinthe mixture, itshouldshowneutralpH.

(iv) Chemicaltest:Acidafewdropsofthemixtureintoatesttubecontaining5mlof10%potassiumferrocyanide. Ifredprecipitate appears,itindicatestheacidicnatureofthemixture.

If the prepared mixture is in the acidic range, it can be brought to neutral or near alkalinecondition by adding some more lime solution into the mixture. Bordeaux mixture preparation iscumbersomeandthefollowingprecautions areneededduring preparationand application.

(i) The solution should be prepared in earthen or wooden or plastic vessels. Avoid using metalcontainersfor thepreparation, as it is corrosivetometallicvessels.

(ii) Always copper sulphate solution should be added to the lime solution, reverse the additionleadsto precipitation of copper andresulted suspension is least toxic.

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

(iv) Bordeaux mixture is sometimes phytotoxic to apples, peaches, rice varieties like IR8 andmaizevarieties likeGangaHybrid 3.

Bordeauxpaste

Bordeaux Paste consists of same constituents as that of Bordeaux mixture, but it is in theform of a paste as the quantity of water used is too little. It is nothing but 10 percent Bordeauxmixture 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 andused to protect the wounded portions, cut ends of trees etc., against the infection by fungalpathogens.

Burgundymixture

It is prepared in the same way as Bordeaux mixture, except the lime is substituted bysodiumcarbonate.Soitiscalledas„SodaBordeaux".It wasdevelopedBurgundy (France) in 1887 by Mason. The usual formula contains 1 kg of copper sulphate and 1 kg ofsodium carbonate in 100 litres of water. It is a good substitute for Bordeaux mixture and used incopper-sensitivecrops.

Cheshuntcompound

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

II. Coppercarbonatepreparation

ChaubattiaPaste

Chaubattia paste is another wound dressing fungicide developed by Singh in 1942 atGovernment Fruit Research Station, Chaubattia in the Almora district of Uttar Pradesh. It isusually prepared in glass containers or chinaware pot, by mixing 800g of copper carbonate and800gofredleadinlitre of rawlinseedoilorlanolin.Thispasteisusuallyappliedtoprunedparts

ofapple,pearandpeachestocontrolseveraldiseases.Thepastehastheaddedadvantagethatitis not easilywashed awaybyrain water.

III. Coppercarbonatepreparation

III.Cuprousoxide Preparation	Fungimar, Perenox,Copper Sandoz, Copper4% dust, Perecot,Cuproxd,Kirticop per.	Cuprous oxide is aprotective fungicide, usedmainly for seed treatmentand for foilage applicationagainst blight, downymildewand rusts.
IV.Copperoxychloride Preparation.	Blitox,Cupramar50% WP,Fytolan,Bilmix4%, MicopD-06,Micopw-50, Bluecopper 50,Cupravit, Cobox,Cuprax,Mycop.	It is a protective fungicide,controls *Phytophthorainfestans* on potatoesandseveralleaf spotandleafblight pathogensinfield.

Sulphurfungicides

Use of sulphur in plant disease control is probably the oldest one and can be classified asinorganic sulphur and organic sulphur. Inorganic sulphur is used in the form of elemental sulphuror as lime sulphur. Elemental sulphur can be either used as dust or wettable sulphur, later beingmore widely used in plant disease control. Sulphur is best known for its effectiveness againstpowdery mildew of many plants, but also effective against certain rusts, leaf blights and fruitdiseases.

Sulphur fungicides emit sufficient vapour to prevent the growth of the fungal spores at adistancefromtheareaofdeposition.Thisisanaddedadvantageinsulphurfungicidesascomparedto other fungitoxicants.

Organiccompoundsofsulphurarenowwidelyusedinthesedays.Allthesecompounds,calledas „carbamate fungicides", are derivatives of Dithiocarbamic acid, Dithiocarbamates are broadlygroupedinto two, basedon the mechanism of action.

Dithiocarbamates

MonoalkylDithiocarbamates Eg.Zineb,Maneb,Eg.Thiram,Ziram,Mancozeb,Nabam,VapamFerbam	DialkylDithiocarbamates

Listof sulphurfungicides andthe importantdiseases controlled bythem aretabulated below:

TradeName	**DiseasesControlled**	
InorganicSulphur 1.Elemental Sulphur (i)Sulphur dust	Sulphurdust Cosan,Wetsulf, Microsul	Sulphur is a contact andprotectivefingicide,normallyappliedassprayosrasdust.Itisgenerally used to controlpowderymildews offruits, vegetables, flowersandtobacco.Thisisalsoeffectiveagainstapplescab(Venturiainaequalis)andrusts offield crops.
2.LimeSulphur(Calciumpolysulphide)	Itcan be prepared by boiling9 Kg or rock lime and 6.75Kgofsulphurin225litresofwater.	LimeSulphuriseffective against powderymildewsasaprotectivefungicide.
OrganicSulphur	Hexathane75%WP,	It is used to protect

(Dithiocarbamates) a.Monoalkyl	DithaneZ-78,Funjeb,Lonocol,ParzateC,	foliageandfruitsofawiderangeof crops
dithiocarbamate 1. Zineb (Zinc ethylenebisdithiocarbamate)	DuPantFungicideA,Polyram.	against diseases such asearlyandlateblightofpotatoandtomato,downymildewsandrusts of cereals, blast ofrice,fruitrotof chillyetc.
2.Maneb(Manganese ethylene bisdithiocarbamate)	DithaneM22, Manzate WP, MEB	Thesetwoareprotective fungicideusedtocontrol manyfungaldiseasesof fieldcrops,fruits,nuts, ornamentals and vegetables, especially blightsofpotatoesand tomatoes, downy mildews of vines, anthracnose of vegetablesandrustsof pulses.
3.Mancozeb(Maneb+ Zincion)	DithaneM45,Indofil M45,Manzeb.	
4.Nabam(DSE) (DiSodiumethylene bisdithiocarbamate)	Chembam,DithaneA-40, DithaneD-14,Parzate Liquid	Nabamisprimarilyused for foilar application against leaf spot pathogensoffruitsand vegetables. Soil

		applications were alsoreported to have asystemic action on*Pythium,Flusarium*and*Phytophthora.*Itisalsoused tocontrolalgaein paddyfields.
5.Vapam(SMDC) (Sodium methyldithiocarbamate)	Vapam,VPM,Chemvape, 4-SKarbation,VitaFume.	Itisasoilfungicideand nematicide with fumigant action. It is also reported to have insecticidal and herbicidalproperties.It is effective against dampingoffdiseaseof papaya and vegetables andwiltofcotton.Itis also effective against nematodeinfestationin citrus,potatoandroot knot nematodes in vegetables.
b. Dialkyl Dithiocarbamate 1.Ziram(Zincdimethyl dithiocarbamate)	CumanL.Ziram,Ziride 80WDP, Hexaazir 80% WP,Corozate,Fukiazsin, Karbamwhite,Milbam, Vancide51Z,Zerlate, Ziram,Ziberk, Zitox80% WDP.	Ziram is a protective fungicideforuseonfruit and vegetables crops againstfungalpathogens includingapplescab.It isnonphytotoxicexcept tozincsencitiveplants. It is highly effective

		against anthracnose of

		beans,pulses,tobacco& tomato,and alsoagainstrustsof beans etc.
2.Ferbam(Ferricd imethyldithiocar bamate)	Coromat, Febam, Ferberk,Femate, Fermate D,Fermicide, Hexaferb 75%WP, Karbam Black,Ferradow.	Ferbamismainlyusedfort heprotectionoffoliageaga instfungalpathogensoffru itsandvegetablesincludin g*Taphrinadeformans*ofp eaches,anthracnoseofcitr us,downymildewof tobaccoandapplescab.
3.Thiram(Tetramethyl thiramdisulphide)	Thiride75 WDP, Thiride 750,Thiram 75%WDP, Hexathir, Normerson, Panoram75,Thiram, TMTD,Arasan,Tersan 75,Thylate,Pomarsol, Thiuram.	Itisusedforseed treatmentboth as dry powderorasaslurry.It isaprotectivefungicide also suitable for applicationtofoilageto control*Botrytisspp.*on lettuces,ornamental,soft fruits and vegetables, rustonornamentalsand *Venturiapirina*onpears. It is also effective against soilborne pathogenslike*Pythium, Rhizoctonia*and *Fusarium.*

MercuryFungicides

Mercury fungicides can be grouped as inorganic and organic mercury compounds. Boththe groups are highly fungitoxic and were extensively used as seed treatment chemicals againstseedbornediseases.Ignorancecompoundsshowbactericidalpropertyalso.However,duetotheir residual toxicity in soil and plants and their extreme toxicity nature to animal and humanbeings, the use of mercury fungicides is beings discouraged. In most of the countries, the use ofmercury fungicides is banned and in countrieslike India, the use of mercury fungicides isrestricted only in seed treatment for certain crops. The list of diseases against which mercuryfungicidesused arelistedbelow

CommonName	**TradeName**	**DiseasesControlled**
I. InorganicMercury		Itisusedfortreatingpotatotubers
1. Mercuricchloride	Merfusan,Mersil	and propagative materialsofotherroot crops
2. Mercurouschloride	Cyclosan,M-CTurffungicide.	Mercurous chlorideis limited to soil application in cropprotectionusebecause ofitsphytotoxicity.
II. Organomercurials Methoxy ethyl mercuryChloride	Agallol,Aretan,Emisan, Ceresanwet(India)	These are used mainly fortreatmentofseedsandplantingmaterials.Thesefungicides areusedforseedtreatmentbydry,wet or slurry method. For seedtreatment1% metallic
Phenylmercurychloride	CeresanDry(India), Ceresol, Leytosan.	mercury is applied at 0.25% concentration

EthylMercuryChloride Tolylmercuryacetate	Ceresan(USA) AgrosanGN.	

Heterocyclic Nitrogen Compounds, Quinones and Miscellaneous FungicidesHeterocyclicNitrogenCompounds

Heterocyclic nitrogen compounds are mostly used as foliage and fruits protectants. Somecompoundsareveryeffectivelyusedasseeddressers.Someofthecommonlyusedfungicidesarelisted below.

CommonName	**TradeName**	**DiseasesControlled**
1.Captan(Kittleson‟s Killer)(N-trichloromethyl thio-4-cyclohexence-1,2-dicarboximide)	Captan50W, Captan75 W, Esso Fungicide406, Orthocide406,Vancide 89,Deltan,Merpan, Hexacap.	Itisa seeddressingfungicideused tocontrol diseasesofmanyfruits, ornamentalandvegetable cropsagainstrotsanddamping off.
2.Captafol(Cis-N-1,1,2,2-tetrachlorohexane 1,2-dicarboximide)	Foltaf,Difolaton,Difosan, Captaspor,Foleid, Sanspor.	Itisaprotective fungicide, widlyused to controlfoliageand fruit diseasesoftomatoes, coffeepotato.
3.Glyodin	Glyoxaliadine,Glyoxide,	Ithas anarrowspecrum of

	Glyodin,GlyoxideDry, Glyodex30%liquidand70%WP.	activity.Asaspray,itcontrolsapple scabandcherryleaf spot.
4.Folpet(Folpet) [N-(trichloromethyl-thi)] phthalimide	Phartan,Acryptan, Phaltan,Folpan, Orthophaltan.	Itisalsoaprotective fungicide used mainlyfor foliageapplicationagainst leafspots,downyandpowdery mildewsof manycrops.

Benzenecompounds

Manyaromaticcompoundshaveimportantanti-microbialpropertiesandhavebeendevelopedasfungicides.Some importantbenzenecompounds commonlyused in plantdiseasecontrol arelisted below.

CommonName	**TradeName**	**DiseasesControlled**
1.Quintozene(PCNB)	Brassicol, Terraclor, Tritisan10%,20%,40%D and75%WP,PCNB75%WP.	It is used for seed and soiltreatment.Itiseffectiveag ainst *Botrytis, Sclerotium,Rhizoctonia*and*S clerotinia spp.*
2.Dichloran	Botran50%WPand75%W P, Allisan.	Itisaprotectivefungicideand very effective against*Botrytis, Rhizopusand Sclerotinia*spp.

3. Fenaminsosuplh (Sodiumpdimethylaminobenzenediazosulphonate	Dexon5%Gand70%WP	Itisveryspecificinprotecting germinatingseedsandgrowingplantsfromseedsaswellassoil-borne infection of

		Phythium, Aphanomyces and*Phytophthora* spp.
4.Dinocap(2,4-dinitro-6-octylphenylcrotonate)	Karathane,Arathane, DNOPC, Mildex, Crotothane, Crotothane 25%WP, Crotothane48% Liq.	It is a non-systemic acaricide and control fungiciderecommendedto control powderymildews on various fruits and ornamentals.Itisalsoused forseedtreatment.

QuinoneFungicides

Quinone areresent naturally in plants and animals and they exhibit anti-microbial activityand some compounds are successfully developed and used in the plant disease control. Quinonesareveryeffectivelyusedforseed treatment andtwocommonlyusedfungicides arelisted below:

CommonName	**TradeName**	**DiseasesControlled**
1. Chloranil (2,3,5,6-tetrachlora-1,4-benzoquinone)	Spergon	Chloronil is mainly usedasaseedprotectantagainstsmutsofbarelyandsorghum and buntof wheat.
2. Dichlone (2,3-dichloro-1,4-napthoquinone)	Phygon,PhygonXLWP.	Dichlone has been usedwidelyasseedprotectant .This is also used as afoliage fungicide,particularly against applescabandpeach leaf curl.

Organo– Phosphorous		Ithas aspecificaction

fungicide Ediphenphos (Edifenphos)(O-ethyl-SS-diphenyldithiophosphate)	Hinosan50%ECand2%D.	against *Pyricularia oryzae*(Rice blast). It is alsoeffectiveagainst*Cortici umsesakii* and *Cochliobolusmiyabeanus*in rice.

OrganoTincompounds

Several other organic compounds containing tin, lead, etc. have been developed andsuccessfully used in plant disease control. Among them, organo tin compounds are more popularandeffectiveagainstmanyfungaldiseases.Thesecompoundsalsoshowantibactericidalproperties.Someof theorgano tin compounds commonlyused arelisted below.

CommonName	**TradeName**	**DiseasesControlled**
1. hydroxide Fentin(TPTHTiphenyltinhydroxide)	Du-TerWP20%or50%WP. Du-Ter Extra-WP,Farmatin 50 WP, Du-TerforteWP, Tubotin.	It is a non-systemic fungiciderecommendedforthecontrolofearlyandlateblightofpotato, leaf spot of sugar beet,blast of rice and tikka leaf spotofground nut.
2. acetate Fentin(tin TPTATriphenylacetate)	BrestanWP40%and60%WP.	It is a non systemic fungiciderecommended tocontrol*Ramularia*spp.oncelery andsugarbeetanthracnoseand downymildew It is effective againstCercosporaleafspotof

3. Fentin Chloride(TPTC-Triphenyltinchloride)	Brestanol 45% WP,Tinmate.	sugarbeetand paddyblast

Systemic Fungicides and AntibioticsSystemicFungicides

Since the late 1960s there has been substantial development in systemic fungicides. Anycompound capable of being freely translocated after penetrating the plant is called systemic. Asystemic fungicide is defined as fungitoxic compound that controls a fungal pathogen remotefrom the point of application, and that can be detected and identified. Thus, a systemic fungicidecoulderadicate established infection and protectthenew parts oftheplant.

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 thebasisofchemicalstructure,systemicfungicidescanbeclassifiedasBenzimidazoles,Thiophanates, Oxathilins and related compounds, pyrimidines, morpholines, organo-phosphoruscompoundsand miscellaneous group.

I. Oxathilinandrelatedcompounds

Oxathalins were the earliest developed compounds. This group of systemic fungicide isalso called as carboxamides, carboxyluc acid anillides, carboxaanillides or simply as anillideswhich are effective only against the fungi belong to *Basidiomycotina* and *Rhizoctonia solani*.Someofthechemicalsdevelopedare(i)Carboxin(DMOC:5,6-dithydra-2-methyl-1,4-oxathin-3-carboxanillide)and(ii)Oxycarboxin(DCMOD-2,3-dihydro-5-carboxanillido-6-methyl-1,4oxathilin-4,4,dioxide). Thediseasescontrolledbythesechemicalsarelistedbelow.

CommonName	**TradeName**	**DiseasesControlled**
1.Carboxin(5,6-dinydro-2-methyl-1-4-oxanthin-3-carboxanlido)	Vitavax10%D,Vitavax 75%WP, Vitavax34%liq. Vitaflow.	Itissystemicfungicide usedforseedtreatmentof cerealsagainstbuntsand smuts, especiallyloosesmut ofwheat

2. Oxycarboxin (5,6-dihydro-2-methyl- 1,4-oxathin-3-carboxianilid-4,4-dioxide) 3.Pyracarbolid (2-methyl-5,6-dihydro- 4H-Pyran-3-carboxylicacidanilide).	Plantvax5G,Plantvax5%liq.Plantvax1.5EC, 10%dust, 75 WP. Sicarol.	Itisasystemicfungicideusedforthetreatmentofrust diseases of cereals,pulses, ornamentals,vegetablesandcoffee Itcontrolsrusts,smutsofmany crops and *Rhizoctoniasolani*,butisslightly more effective thancarboxin

II. Benzimidazoles

The chemicals of this group show a very broad spectrum activity against a variety offungi.However,theyarenoteffectiveagainstbacteriaaswellasfungibelongsto*Mastigomycotina*. Two types of fungicidal derivates of benzimidazoles are known. The firsttype of derivates includes fungicides such as thiabendazole and fuberidazole. The fungicidalmoiety of the second type is methyl-2-benzimidazole carbamate (MBC). The fungicides of thisgroup may be simple MBC such as carbendazim or a complex from such as benomyl, whichtransformsintoMBCinplantsystem.Someoftheimportantdiseasescontrolledby thesecompounds areshown below:

CommonName	**TradeName**	**DiseasesControlled**
1.Benomyl(Methyl -10 (butlycarbomyl)-2 benzimidazolecarbamate)	Benlate50WP,Benomyl. Bavistin50 WP, MBC, Dersol,B.Sten50,Zoom, Tagstin,Agrozim,	It is a protective and eradicative fungicide with systemic activity, effective againstawiderangeoffungi

2. Carbendazim (MBC)(Methyl -2-benzimidazolecarbamate)	Jkenstin.	affectingfieldcrops,fruitsandornamentals.It is very effectiveagainstriceblast,applescab,powderymildewofcereals, rose, curcurbits and apple andDiseases caused by*VerticilliumandRhizoctonia.*Itisalsousedaspre-andpostharvestspraysofdipsforthecontrolofstoragerotsoffruits and vegetables.Carbendazim is a systemicfungicidecontrollingawiderangeoffungalpathogensoffieldcrops,fruits,ornamentalsandvegetables.Itisusedasspray, seedling dip, seedtreatment,soildrenchandaspost harvest treatment offruits. It is very effectiveagainst wilt diseasesespecially, banana wilt. Itcontrols effectively thesigatokaleafspotofbanana,turmericleafspotandrustdiseases in many crops.

3.Thiabendazole(TBZ)(2,4-thiazoylbenzimidazole)	Thiabendazole,Mertect, Tecto,Storite.	It is a broad spectrum systemicfungicideeffectivelaga instmanymajorfungal diseases. Pathogenicfungalcontrol

		includesspeciesof *Botrytis*, *Ceratocystis,Cercospora*, *Colletotrichum,Fusarium*, *Rhizoctonia,Sclerotinia*, *Septoria andVerticillium*.Itis alsoeffectiveforthepost harvest treatment of fruitsand vegetables to controlstoragediseases.
4.Fuberidazole (2, (2-buryl)-benzimidazole).	Voronit.	It is used for the treatmentofseedsagainstdiseases causedby*Fusarium*,Particularly*F.nivale*onryeand*F.culmorum* ofpeas

III. Thiophanates

These compounds represent a new group of systemic fungicides based on thiourea. Theyare the derivatives of thioallophanic acid. These fungicides contain aromatic nucleus which isconverted into benzimidazole ring for their activity. Hence, thiophanates are often classifiedunder benzimidazole group and the biological activity of thiophanates resembles of benomyl.Twocompounds aredeveloped under this group arediscussed.

CommonName	**TradeName**	**DiseasesControlled**
1.Thiophanate(1,2-bis (ethyl carbonyl-2-thioureido)benzene)	Topsin 50 WP, Cercobin50 WP, Enovit.	Itisasystemicfungicide with a broad range ofaction,effectiveagainst

2.Thiophanate-methyl (1,2bis(3methoxycarbonyl-2-thioureido) benzene.)	Topsin-M70 WP,Cercobin-M 70 WP,Envovit-methyl,Mildothane.	*Venturia* spp., on appleand pear crops, powderymildews,*Botryti* sand *Sclerotinia*spp.Onvariouscrops. It is effective against a widerange of fungal pathogens,including *Venturia spp.*onapplesandpears,*Mycosphaerellamusicola*onbananas,powderymildewsonapples,cucurbits,pearsand vines, *Pyricularia oryzae* onrice, *Botrytis andCerospora* on variouscrops.

IV.Morpholines

CommonName	**TradeName**	**DiseasesControlled**
Tridemorph(2-6-dimethyl-4-cyclo - tridecyl morpholine)	Calixin75EC,Bardew, Beacon	Itisaneradicantfungicide withsystemicaction,being absorbed through foilage and roots to give some protectiveaction.Itcontrols powderymildewdiseasesof

		cereals, vegetables andornamentals.Itis highlyeffective against*Mycosphaerella,Exobasidium*

V. Pyrimidines,Pyridines,PiperidinesandImidazole

CommonName	**TradeName**	**DiseasesControlled**
1.Triadimefon (1-(4-chlorophenoxy)-3, 3-dimethyl-1-(1-2-triazol-1yl)butan-2-one)	Bayleton,Amiral	Itisvery effectiveagainstpowdery mildews and rustsofseveral crops.
2.Triadimenol (1-(4-Chlorophenoxyl-3, 3-dimethyl-1(1,2,4-triazol-1-yl)butan-2-ol)	Baytan	It is also veryeffective againstpowdery mildewsandrustsof severalcrops.
3.Bitertanal (B-(1-1-biphenyl-4-yloxy-a-(1-1-dimethyl-ethyl-1-H-1,2-4-triazole-1-ethanol)	Baycor Terrazole30%WP, Terrazole95%WP,	It is highly effective againstrustsandpowderymildewof a variety of crops. It isalsousedagainst*Venturia*and *Monilinia* on fruits and*Cereospora*leafspotsof groundnutandbanana.

4. Etridiazole (5-ethaoxy-3-trichloromethyl,1,2-4-thiadiazole)	Terrazole25%EC, Koban, PansolEG,Pansol4%DP, TurbanWP,Terracoat Aaterra.	Itisveryeffective against *Phytophthora*and *Pythium*spp.and seedingdiseasesof cotton,groundnut, vegetables,fruits andornamentals

VI. HydroxyPyrinidines

CommonName	**TradeName**	**DiseasesControlled**
1. Ethirimol (5-butyl 2-ethylamino-4-hydrop-6-methylpyrimidine)	Milliatem 80 WDP,Milcurb Super,Milgo	Itiseffectiveagainstpowdery mildew of cerealsand other field crops. It isalsoeffectiveagainstpowderymildewsofcucumberandornamentals.
2.Dimethirimol(5-butyl2-dimethylamino-4-hydroxy-6-methypyrimidine)	Milcurb	Itisveryeffectiveagainstpowdery mildews ofchrysanthemum andcucurbits.
VII.Furanderivatives 1.Furcarbanil (2-5-dimethyl-3-furanilide)		Itisusedasseedorsoilapplication,Itsystemicallycontrolled beanrustandis being used as a seed

2. Cyclafuramid(N-cyclohexyl-2,5-dimethylfiramide) **VIII.Benzanilide derivative** 1.Mebenil (2-methylbenzanilide)		dressingfungicideagainstloosesmutofwheatandbarley. Itiseffectiveagainst bunts,smutsandrustsofcereals,coffeerust,blisterblight of tea, smut and redrot of sugarcane, *Fusariumwilt* of tomato, *Rhizoctonia*ontomato,potato,groundnut,riceaswellas*Armillaria* sp. On rubber. Itiseffectiveagainst yellowrustonwheatandbarley*(P.striiformis)*andbrown rust on barley *(P.hordei).*Itisalsohavingdirect fungitoxic activityagainst *Sclerotium rolfsli*and*Rhizoctonia.*

IX.Organophosphorouscompounds

CommonName	**TradeName**	**DiseasesControlled**
1.Pyrazophos(2-0-0-	Afugan,Curamil,WP,	It is used to control

Diethylthionophosphoryl) -5- methyl-6-carbethoxypyrazolo-(1-5a)pyrimidine)	MissileEC.	powderymildewsofcereals,vegetables,fruitsandornamentals.
2.Iprobenphos(IBP)(S-benyzl-0-0-bisisopropylphosphorothiate)	Kitazin 48% EC, Kitazin17G,Kitazin 2% D.	It is used to control*Pyriculariaoryzae*andsheathblightofric e.
X. Piperazine1.Triforine(N, N-bis-(1-foramido-2,2,2-trichloroethyl-piperazine)	Saprol-EG,Fungitex.	Itiseffectiveagainstpowdery mildew, scab andother diseases of fruits andrustonornamentalsandcereals.
XI.Phenol derivative 1.Choloroneb(1-4-dichloro-2,5-dimethoxy benzene)	Demonsan65WP,TersanSP,Turf Fungicide	It is also active againststorage diseases of fruits.It is highly fungistatic to*Rhizoctonia* spp.,moderately so to *Pythium*spp. and poorly to*Fusarium* spp. It is usedas a supplemental seedtreatment for beans andsoyabeans to controlseedlingdisease

XIII.Othersystemicfungicides

CommonName	**TradeName**	**DiseasesControlled**
1. Metalaxyl(methyl-DLN-(2,6-dimethylphenyl-N-)2-methoxyacetyl	Apron 35 SD,Ridomil Ridomil MZ 72 WP(8%Metalaxyl+64 %Mancozeb) Beam,	Itisasystemicfungicideandhighlyeffectiveforspecific use as seed dressingagainst fungal pathogens oftheorderPeronosporales.
2. Metalaxyl +Mancozeb	BimAlliette80 WP	Itisafungicidewithsystemic and contactactionandeffectiveagainstdamping-off, root rots, stemrots, and downy mildew ofgrapesandmillets.
3. Tricyclazole (5-methyl-1,2,4 triazole(3,4b)-benzothiazole)		It is a specific fungicideused against paddy blastfungus,*P. oryzae*
4. FosetylAI. (Aluminium-Trisaluminium		It is a very specificFungicide for Oomycetousfungi, especially against*Pythium*and*Phytophthora*

Antibiotics

Antibioticisdefinedasachemicalsubstanceproducedbyonemicro-organismwhichislowconcentrationcaninhibitorevenkillothermicro-

organism.Becauseoftheirspecificityof

actionagainstplantpathogens,relatively lowphytotoxicity,absorptionthroughfoliageandsystemic translocation and activity in low concentration, the use of antibiotic is becoming verypopular and very effectively used in managing several plant diseases. They can be grouped asantibacterialantibioticsandantifungalantibiotics.Mostantibioticsareproductsofseveralactinomyc etesandafewarefrom fungi and bacteria.

I. Antibacterialantibiotics

1. Streptomycinsulphate

Streptomycinisanantibacterial,antibioticproducedbystreptomycesgriseus.Streptomycinare streptomycinsulphateissoldasAgrimycin,-100,Streptomycinsulphate,Plantomycin, Streptocycline, Paushamycin, Phytostrip, Agristrep and Embamycin, Agrimycin -100 contains 15 per cent streptomycin sulphate + 1.5 percent terramycin (Oxy tetracycline).Agristerpcontains37percentstreptomycinsulphate.

Phytomycincontains20percentstrepto mycin. Streptocycline and paushamycin contains 9 parts f streptomycin and 1 part oftetracyclinehydrochloride.

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 diseasescontrolledareblightofappleandpear*(Erwiniaamylovora)*,Citruscanker*(Xanthomonascampe stris p.v. citri)*, Cotton black arm *(X.c.* p.v. *malvacearum)*, bacterial leaf spot of tomato*(Pseudomonassolanacearum)*,wildfireoftobacco*(Pseudomonastabaci)*andsoftrotofvegetab les*(Erwinia carotovora)*.

In addition, it is used as a dip for potato seed pieces against various bacterial rots and asandisinfectantinbacterialpathogensofbeans,cotton,crucifers,cerealsandvegetables.Although it is an antibacterial antibiotic, it is also effective against some diseases caused byOomycetousfungi,especiallyfoot-rotandleafrotofbetelvinecausedby*Phytophthoraparasiticavar. piperina.*

2. Tetracyclines

Antibiotics belonging to this group are produced by many species of Streptomyces. ThisgroupincludesTerramycinorOxymicin(Oxytetracycline).Alltheseantibioticsarebacteriostatic, bactericidal and mycoplasmastatic. These are very effective against seed-bornebacteria. This group of antibiotic is very effective in managing MLO diseases of a wide range ofcrops.Thesearemostlyusedascombinationproductswith Streptomycinsulphateincontrolling

awiderangeofbacterialdiseases.Oxytetracyclinesareeffectivelyusedassoildrenchorasrootdipcontrol lingcrowngall diseasesinrosaceousplantscausedbyAgrobacteriumtumefaciens.

IIAntifungalantibiotics

1. Aureofungin

Itisahepataeneantibioticproducedinsub-mergedcultureofStreptoverticilliumcinnamomeum var. terricola. It is absorbed and translocated to other parts of the plants whenapplied 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 gummosiscaused by several species of Phytophthora, powdery mildew of apple caused by *Podosphaeraleucotricha* 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 iteffectively checked are *Diplodia* rot of mango, *Alternaria* rot of tomato, *Pythium* rot of cucurbitsand *Penicillium* rot of apples and citrus. As a truck application/root feeding, 2 g of aureofungin-sol+1gofcoppersulphate in100 ml ofwater effectivelyreduce. Thanjavurwilt of coconut.

2. Griseofulvin

Thisantifungalantibioticwasfirstdiscoveredtobeproducedby*Penicilliumgriseofulvum* 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 ishighlytoxictopowderymildewofbeansandroses,downymildewofcucumber.Itisalsousedto control *Alternaria solani* in tomato *Sclerotinia fructigena* in apple and *Botrytis cinerea* inlettuce.

3. Cycloheximide

It is obtained as a by-product in streptomycin manufacture. It is produced by differentspecies of *Streptomyces,* including *S.griseus* and S. *nouresi.* It is commercially available asActidione, Actidione PM, Actidione RZ and Actispray. It is active against a wide range of fungiand yeast. Its use is limited because it is extremely phytotoxic. It is effective against powderymildewofbeans*(Erysiphepolygoni),*Buntofwheat*(Tilletiaspp.)*brownnotofpeach*(Sclerotin iafructicola)* and postharvest rots of fruitscausedby*Rhizopus* and*Botrytis* spp.

4. Blasticdin

It is a product of *Streptomyces griseochromogenes* and specifically used against blastdiseaseof ricecausedby*Pyricularia oryzae.*It is commerciallysold as Bla-s.

5. Antimycin

Itisproducedbyseveralspeciesof*Streptomyces,*especially*S.griseus*and*S.Kitasawensis.*It is effectively used against early blight of tomato, rice blast and seedling blightofoats.Itis commerciallysold as Antimycin.

6. Kasugamycin

It is obtained from*Streptomyces kasugaensis.*Itis also very specific antibiotic againstriceblast disease.It is commerciallyavailableasKasumin.

7. Thiolution

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

8. Endomycin

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

9. Bulbiformin

It is produced by a bacterium, *Bacillus subtills* and is very effectively used against wiltdiseases,particularalyredgram wilt.

10. Nystatin

It is also produced by *Streptomyces noursei.* It is successfully used against anthracnosedisease of banana and beans. It also checks downy mildew of cucuribits. As a post harvest dip, iteffectivelyreducesbrownrotofpeachandanthracnoseofbananainstroagerooms.Itiscommerciallym arketed as Mycostainand Fungicidin.

11. Eurocidin

Itisapentaeneantibioticproducedby*Streptomycesanandii*andcalledaspentaeneG-8.
Itis effectivelyused againstdiseases causedbyseveralspecies of
*Colletotrichum*and*Helminthosporium.*

Methodsofallocationoffungicides–Precautionsandsafetymeasureswhilehandlingfungicides

Proper selection of a fungicide and its application at the correct dose and the proper timearehighlyessentialforthemanagementofplantdiseases.Thebasicrequirementofanapplicationme thodisthatitdeliversthefungicidetothesitewheretheactivecompoundwill

prevent the fungus damaging the plant. This is mostly achieved by spray, fog, smoke, aerosol,mist,dust, or granules applied tothegrowing plant or byseed or soil treatment.

In addition, some trees and shrubs can be protected by injection of fungicide liquid intothe 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, thefungicide is straightly mixed with an inert carrier, impregnated into it coated on the particles,whichare applied mechanically.

The object of spraying or dusting is to cover the entire susceptible surface of hostwith athin covering of a suitable concentration of the fungicide before the pathogen has come intocontact with the host.However, these practices may not effectively eradicate the inoculumpresent on the surface of the seeds or deep-seated in the seed. So, the application of chemicals asseeddressing is highlyessential.

In addition, soil harbours several pathogens which cause root diseases in several cropplants. So treatment of soil with chemicals is also highly useful in reducing the inoculum loadpresent in the soil. The fungicidal application varies according to the nature of the host partdiseased and nature of survival and spread of the pathogen. The method which are commonlyadoptedin the application of thefungicides arediscussed.

1. Seedtreatment

The seed treatment with fungicides is highly essential because a large number of fungalpathogensarecarriedonorintheseed.Inaddition,whentheseedissown,itisalsovulnerableto attack by many common soil-borne pathogens, leading to either seed rot, seeding mortality orproduce diseases at a later stage. Seed treatment is probably the effective and economic methodof disease control and is being advocated as a regular practice in crop protection against soil andseed-borne pathogens. Seed treatment is therapeutic when it kills pathogens that infect embroys,cotyledonsorendospermsundertheseedcoat,eradicativewhenitkillspathogensthatcontamin ate seed surfacesand protective whenitpreventspenetration of soilborne pathogensinto the seedling. There are various types of seed treatment and broadly they may be divided intothreecategories(a) Mechanical, (b)Chemical and(c) Physical.

A. Mechanicalmethod

Somepathogenwhenattacktheseeds,theremaybealterationinsize,shapeandweightof seeds by which it is possible to detect the infected seeds and separate them from the healthyones. In the case of ergot diseases of cumbu, rye and sorghum, the fungal sclerotia are usuallylarger in size and lighter than healthy grains. So by sieving or flotation, the infected grains maybe easily separated. Such mechanical separation eleminates the infected grains may be easilyseparated. Such mechanical separation eliminates the infected materials to a larger extent. Thismethod is also highly useful to separate infected grains in the case of „tundu" disease of wheat.Eg.Removal of ergot incumbu seeds.

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

B. Chemicalmethods

Usingfungicidesonseedisoneofthemostefficientandeconomicalmethodsofchemical disease control. On the basis of their tenacity and action, the seed dressing chemicalsmay be grouped as (i) Seed disinfectant, which disinfect the seed but may not remain active for along period after the seed has been sown and (ii) Seed protectants, which disinfect the seedsurface and stick to the seed surface for sometime after the seed has been sown, thus givingtemporaryprotectiontotheyoungseedlingsagainstsoilbornefungi.Now,thesystemicfungicides are impregnated into the seeds to eliminate the deep seated infection in the seeds. Theseeddressingchemicalsmaybeappliedby(i)Drytreatment (ii)Wettreatment and(iii) Slurry.

(i) DrySeedTreatment

In this method, the fungicide adheres in a fine from on the surface of the seeds. Acalculatedquantity offungicideisappliedandmixedwithseedusingmachinery speciallydesigned for the purpose. The fungicides may be treated with the seeds of small lots using simpleRotary seed Dresser (Seed treating drum) or of large seed lots at seed processing plants usingGrain treating machines. Normally in field level, dry seed treatment is carried out in dry rotaryseed treating drums which ensure proper coating of the chemical on the surface of seeds. Inaddition,thedrydressingmethodisalsousedinpulses,cottonandoilseedswiththe

antagonistic fungus like *Trichoderma vitide* by mixing the formulation at the rate of 4g/kg of theseed.

Eg.Dryseedtreatment inpaddy.

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

(ii) Wetseedtreatment

This method involves preparing fungicide suspension in water, often at field rates andthen dipping the seeds or seedlings or propagative materials for a specified time. The seedscannotbestoredandthetreatmenthastobedonebeforesowing.Thistreatmentisusuallyappliedfortreatingvegetativelypropagativematerialslikecuttings,tubers,corms,settsrhizomes, bulbs etc., which arenotamenable to dryorslurrytreatment.

a. Seeddip /Seedsoaking

For certain crops, seed soaking is essential. Seeds treated by these methods have to beproperly dried after treatment. The fungicide adheres as a thin film over the seed surface whichgives protection against invasion bysoil-bornepathogens.

Eg.Seeddiptreatmentinpaddy.

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

Eg.SeeddiptreatmentinWheat.

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

b. Seedlingdip /rootdip

The seedlings of vegetables and fruits are normally dipped in 0.25% copper oxychlorideor0.1%carbendazinsolution for 5minutes to protectagainst seedling blightand rots.

c. Rhizomedip

Therhizomesofcardamom,gingerandturmericaretreatedwith0.1%emisansolutionfor20 minutes to eliminaterot causing pathogen present inthe soil.

d. Settdip /Suckerdip

The sets of sugarcane and tapioca are dipped in 0.1% emisan solution for 30 minutes. Thesuckersofpineapple mayalsobe treated bythis method toprotect from soilbornediseases.

(iii) Slurrytreatment(Seedpelleting)

Inthismethod,chemicalisappliedintheformofathinpaste(activematerialisdissolved in small quantity of water). The required quantity of the fungicide slurry is mixed withthe specified quantity of the seed so that during the process of treatment slurry gets deposited onthesurfaceof seeds in the form of athin pastewhich laterdries up.

Almost all the seed processing units have slurry treaters. In these, slurry treaters, therequisite quantity of fungicides slurry is mixed with specified quantity of seed before the seed lotisbagged. Theslurrytreatment is moreefficient than the rotaryseed dressers.

Eg.Seedpelletinginragi.

Mix2.5g of carbendazimin40 ml of water and add 0.5g of gum to the fungicidalsolution.Add2kgofseedstothissolutionandmixthoroughlytoensureauniformcoatingofthe fungicide over the seed. Dry the seedsunder the shade. Treatthe seeds24 hrsprior tosowing.

(iv) Specialmethodofseedtreatment

Eg.Acid -delintingin cotton

This is follows in cotton to kill the seed-borne fungi and bacteria. The seeds are treatedwithconcentrated sulphuric acid@ 100 ml/kgof seedfor2-3 minutes.The seedsare thenwashed 2 or 3 times thoroughly with cold water and shade dried. After drying, they are againtreatedwith captan orthiram @ 4g/kg beforesowing.

II. Soiltreatment

It is well known that soil harbours a large number of plant pathogens and the primarysources of many plant pathogens happens to be in soil where dead organic matter supports activeor dormant stages of pathogens. In addition, seed treatment does not afford sufficient

protectionagainstseedlingdiseasesandatreatmentofsoilaroundtheseedisnecessarytoprotectthem.

Soil treatment is largely curativ in nature as it mainly aims at killing the pathogens in soil andmakingthesoil„safe"forthegrowthoftheplant.

Chemicaltreatmentsofthesoiliscomparatively simple,especially whenthesoilisfallowasthechemicalisvolatileanddisappearsquicklyeitherbyvolatilizationordecomposition.Soiltreatingchemicalsshouldbenon-injurioustotheplantsinthesoiladjacentto the area where treatment has been carried out because there may be standing crop in adjacentfields.The soil treatmentmethods involvingthe useof chemicals are

(i)Soildrenching,(ii)broadcasting,(iii)furrow application,(iv)fumigation and (v)chemigation.

(i) Soildrenching

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

Eg.Emisan,PCNB,Carbendazim,Copperfungicides,etc.

(ii) Broadcasting

Itisfollowedingranular fungicideswhereinthepellets arebroadcastednearttheplant.

(iii) Furrowapplication

It is done specifically in the control of some diseases where the direct application of thefungicides on the plant surface results in phytotoxic. It is specifically practiced in the control ofpowderymildewof tobacco wherethe sulphur dust is applied in thefurrows.

(iv)Fumigation

Volatile toxicants (fumigants) such as methyl bromide, chloropicrin, formaldehyde andvapam are the best chemical sterilants for soil to kill fungi and nematodes as they penetrate thesoilefficiently.Fumigationsarenormallydoneinnurseryareasandinglasshouses.Thefumigant 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 andused 1 or 2 weeks later. Vapam is normally sprinkled on the soil surface and covered. Volatileliquidfumigants arealsoinjected toadepth of 15-20 cm,using sub-soil injectors.

(v) Chemigation

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

III. Foliarapplication

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. Themost common diluent or carrier is water. The dispersion of the spray is usually achieved by itspassageunder pressurethrough nozzle ofthe sprayer.

The amount of spray solution required for a hectare will depend on the nature of crops tobe treated. For trees and shrubs more amount of spray solution is required than in the case ofground crops. Depending on the volume of fluid used for coverage, the sprays are categorisedintohigh volume, medium volume, lowvolume, veryhigh volume andultralow volume.

The different equipments used for spray application are: Foot-operated sprayer, rockingsprayer, knapsack sprayer, motorised knapsack sprayer (Power sprayer), tractor mounted sprayer,mistblower and aircraftorhelicopter(aerialspray).

B. Dusting

Dusts are applied to all aerial parts of a plant as an alternative to spraying. Dry powdersare used for covering host surface. Generally, dusting is practicable in calm weather and a betterprotective action is obtained if the dust is applied when the plant surface is wet with dew or raindrops. The equipments employed for the dusting operation are: Bellow duster, rotary duster,motorisedknapsack duster and aircraft (aerial application).

IV. Post–harvestapplication

Fruits and vegetables are largely damaged after harvest by fungi and bacteria. Manychemicalshave beenusedasspray or diporfumigation.Postharvestfungicidesare mostfrequently applied as aqueous suspensions or solutions. Dip application has the advantage oftotally submerging the commodity so that maximum opportunity for penetration to the infectionsites.

Systemicfungicides,particularlythiabendazole,benomyl,carbendazim,metalaxyl,fosety-AIhavebeenfoundtobeveryeffectiveagainststoragediseases.Inaddition,dithiocarbamates and antibiotics are also applied to control the post-harvest diseases. Wrappingtheharvestedproducts withfungicideimpregnatedwaxpaper isthe latestmethod available.

VI.Specialmethodofapplications

1. TrunkApplication/TrunkInjection

Itisnormallyadoptedincoconutgardenstocontrol Thanjavurwiltcausedby*Ganoderma lucidum*. In the infected plant, a downward hole is made to a depth of 3-4" at anangle of 450C at the height of 3‟ from the ground level with the help of an auger. The solutioncontaining 2g of Aureofungin soil and 1 g of copper sulphate in 100 ml of water is taken in asaline bottle and the bottle is tied with the tree. The hose is inserted into the hole and the stopperisadjusted toallow thesolution in drops.Afterthetreatment, thehole is coveredwith clay.

2. RootFeeding

Root feeding is also adopted for the control of Thanjavur wilt of coconut instead of trunkapplication. The root region is exposed; actively growing young root is selected and given aslanting cut at the tip. The root is inserted into a polythene bag containing 100 ml of thefungicidalsolution. Themouth of thebag is tied tightlywith theroot.

3. PseudostemInjection

This method is very effective in controlling the aphid vector*(Pentalonia nigronervosa)*of bunchy top of bannana. The banana injector is used for injectingthe insecticide.Bananainjector is nothing but an Aspee baby sprayer of 500 ml capacity.Inwhich, the nozzle isreplaced by leurlock system and aspirator needle No. 16. The tip of the needle is closed and twosmallholes aremadein opposite direction.

Itisforfreeflowoffluidandthelocksystempreventstheneedlefromdroppingfromthesprayer.Onemlofmonocrotophosmixedwithwaterat1:4ratioisinjectedintothepseudostem of 3 months old crop and repeated twice at monthly intervals. The same injector canalso be used to kill the bunchy top infected plants by injecting 2 ml of 2, 4-D (Femoxone) mixedinwaterat 1:8 ratio.

4. CornInjection

It is an effective method used to control Panama will of banana caused by *Fusariumoxysporum* f. sp.*cubense*. Capsule applicator isused for this purpose.Itis nothing but an ironrod of 7 mm thickness to which a handle is attached at one end. The length of the rod is 45 cmandan iron plateis fixedat a distanceof 7 cm from thetip.

Thecormisexposedbyremovingthesoilandaholeismadeat45)angletoadepthof5cm.One or two gelatin capsules containing 50-60mg of carbendazim is pushed in slowly andcovered with soil. Instead of capsule, 3 ml of 2% carbendazim solution can also be injected intothe hole.

5. ParingandPralinage

It is used to control *Fusarium* wilt and burrowing nematode (*Radopholus similis)* ofbanana.Therootsaswellasasmallportionofcormisremovedorchoppedoffwithasharpknifeand 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 @ 40g/corm.

Lecture10

Host plant resistance – Importance – disease resistance, tolerance, susceptibility anddiseaseescape.Horizontalandverticalresistance –Methodof managementofresistance. Immunization–Systemicacquiredresistance

Hostplantresistance

A physiological deviation from the normal functioning of the organism (i.e., the cropplant) caused by pathogenic organisms is a disease and may be caused by fungi, bacteria orviruses. The inherent ability of an organism (i.e., the crop plant) to resist or withstandthepathogeniscalledresistance.Diseaseresistancecommonly metwithintheplantkingdomrelative in nature, total immunity being too rare. Its hereditary transmission from parent to off-springis essentially“Mendalian”, but oftenpolygenic.

Theearliestdemonstrationofthebehaviourof“disease-resistance”asacharactertransmissible from parent to off-spring in the “Mendelian” fashion was given by Biffen (1905) inhis work on yellow rust of wheat. Since then, intensive work has been done on this aspect whichhas proved the value of applying genetical principles in developing disease-resistant varieties ofplantsforeffectivecontrol of diseases.

Resistant varieties can be the simplest, practical, effective andeconomical method ofplant disease control. The use of resistant varieties cannot only ensure protection against diseasesbut also save the time, energy and money spent on other measures of control. In addition to theseadvantages, resistant varieties, if evolved, can be the only practical method of control of suchdiseasesasviruses,phytoplasmaswilts,andrustsetc.inwhichchemicalcontrolisveryexpensivean d impractical.

In crops of low cash value, chemical and other methods of control are often too expensiveto be applied. In such crops development of varieties resistant to important diseases can be anacceptable recommendation for the farmer. Pathogenicity is the ability of a pathogen to attack ahost. Pathogenicity includes virulence and aggressiveness. Virulent strains of pathogen causemuch severe symptoms of the disease and they carry the virulence gene that enables it to attack aparticularhost genotype.

Virulence is due to the action of one or a few genes. An aggressive strain of a pathogencauses severe disease on all the host genotypes which they are able to attack and aggressivenessispolygenicallyinherited.Host–PathogenrelationshipAdiseaseistheresultofaninteraction

of genesgoverningresistance inthe hostwiththose governing pathogenicity inthe pathogen.Theresistanceofacroptoaphysiologicalraceofthepathogendependsnotonly onthegenotype of the host for resistance, but also upon the genotype of the pathogen for virulence oraggressiveness. Flor (1942) proposed the gene-for-gene hypothesis,according to which, forevery gene for resistance in the host, there is a corresponding gene for pathogenicity in thepathogen.

It means that there are atleast two alleles at a locus controlling resistance/susceptibility inthehost(R-r)andtwoallelesatacorrespondinglocusinthepathogen(V-v)controllingvirulence / aggressiveness. Out of the four possible interactions between these alleles, only onecombinationleadstotheexpressionofresistance.Thedemonstrationofgene-for-generelationshiprequires geneticstudies of both thehost and the pathogen.

Pathogen

VI v1 + Pathogen can infect; the host is R1 -+ susceptible r1 + + -

Pathogencannot infect; the host is resistant

Thedemonstrationofgene-for-generelationshiprequiresgeneticstudiesofboththehostandthepathogen

Verticalresistance(VR)andhorizontalresistance(HR)

Van der Plank (1960) has discussed the whole issue of disease resistance in a differentperspective. He calls the unstable and often complete type of resistance as vertical resistance andthe more stable but somewhat incomplete resistance as horizontal resistance.If resistance tosome races of a pathogen is more than to other races, it is called Vertical resistance. It is alsocalled Perpendicular resistance, Physiological resistance, seedling resistance, hypersensitivity,race specific resistance or qualitative resistance. As it is conditioned by one or a few genes, it iscalledmajorgeneor monogenic ofoligogenic resistance.

Resistance to more than one race of the pathogen or to many or all races of the pathogeniscalledHorizontalResistance.Itisnon-specificresistancegovernedbypolygenes.Itisseverallytermedasnon-specific,general,polygenic,minorgene,matureplant,adult,quantitative resistance, partial or field resistance or tolerance. HR causes reduction in the numberand rate of sporulation of the pathogen on the host and slows down the infection rate. HRincludestoleranceslowdevelopmentofdisease,escapeandexclusionmechanismsbesides

hypersensitivereaction.Thedifferencebetweenverticalresistanceandhorizontalresistancearegiven intable.

Differencesbetweenverticalandhorizontaldiseaeresistance*Detectablebyanalysisofvarianceo fa suitableexperiment

Feature	**Verticalresistance**	**Horizonalresistance**
Pathotype-specificity	Racespecific	Racenonspecific
Natureofgene action	Oligogenic	Polygenic;rarelyoligogenic
Responsetopathogen	Usually,hypersensitive	Resistantresponse
Phenotypicexpression	Qualititative	Quantitative
Stageofexpression	Seedlingto maturity	Expressionincreasesasplant matures(Adultplant)
Selectionand evaluation	Relativelyeasy	Relativelydifficult
Riskof„boomand burst‟	Present(rarelydurable)	Absent(durable)
Suitablefor:a.Hostb. Pathogen	Annuals but notperennialsImmo bilepathogen, e.g., Soilpathogens, but formobileair-borne, Pathogens	BothannualsandperennialsAllpa thogens
Need for specificdeploymentofr esistant varieties	Critical for successwithmobilepat hogens	None
Needforothercontrol measures	Likely	Muchless likely
Host-pathogen interaction*	Present	Absent
Efficiency	Highlyefficient against specificraces	Variable,butoperatesagainstall races

Verticalresistance tospecificracesisgenerally governedby a single(monogenic) dominantgene or by a few dominant genes. Some of these genes may be multiple alleles as in leaf rustgene,Lr2thataccordsresistanceto*Pucciniareconditetritici.*Inthatlocus,fourgenesdesignated as Lr2a, Lr2b, Lr2c and Lr2d are present and are tightly linked. Each of these genesaccord resistance to a different spectrum of races and hence can be differentiaited from oneanother. Such multiple alleles exist on Sr9 locus of wheat for *P.graminis tritici* and gene Pi-k inrice for resistance to *Pyriculariva grisea.* The tight linkage between the multiple alleles permitsanefficient transfer of all thesegenes in oneattempt.

„Horizontal resistance‟ (HR) reduces the rate of disease spread and is evenly spreadagainst all races of the pathogen. The low terminal disease severity in HR is assumed to resultfrom polygenic resistance. Morphological features such as size of stomata, stomatal density perunit area, hairiness, waxiness and several others influence the degree of resistance expressed.Partial resistance, dilatory resistance, lasting resistance are some other terms coined for denotinghorizontalresistnce.

The phenomenon of slow rusting manifested as lesser number of pustules per unit leafarea, smaller size of uredosori and increased latent period in some wheat cultivars is a typicalexampleofthistypeofresistance.Althoughitispreferabletousevarietiesthathavebothvertical and horizontal resistance, most of the resistant varieties carry only one or few (2 or 3)major genes of vertical resistance. If varieties are resisitant only to some of the races of pathogenand if the pathogen is airborne, then new races evolve easily, as happens with cereal rusts, thepowdery mildlew and *Phytophthora infestans.* Appearance of new races lead to breakdown ofresistanceofthepopular,rulinggenotype.Asaresult,varieteswithverticalresistanceneedtobereplaced atfrequent intervals.

Boomandburstcycle

In varietial improvement programmes, it is easy to incorporate the monogenic verticalresistance genes. But the success of exploiting the monogenic host resistance invariably does notlast long. Whenever a single gene-based resistant variety is widely adopted, the impact would bethearrival ofnew matchingpathotypes.

These pathotypes soon build up in population to create epidemics and eventually the variety iswithdrawn. This phenomenon is generally called " boom and burst". The avoid the implicationsof boom and burst phenomenon, use of durable host resistance is advocated in several crops.Durable resistance remains effective even though it may be widely grown ovoer a long period oftime, in an environment that favours the disease. For example, oat variety, Red Rust Proof is stillresistant against crown rust even after a hundred years. Wheat varieties, Thatcher and Lee havewithstood stem rust for 55 and 30 years, respectively. Cappelle Desprez expresses at adult stage,amoderate resistancetoyellow rustandthis hasbeen maintainedforthelast20years.

Two of the genes like Lr34 for resistance of leaf rust and Sr2 for resistance to stem rusthavebeenrecognizedfordurability.WheatcultivarssuchasHD2189,HP1102,DL153-2,DL803-3 and DL802-2, which possess Lr34 with other gene combinations have a good degree ofresistance and hae become popular with growers. So far, there is not precise way available toidentifythegeneticcomponentsthatareassociatedwithdurableresistance.Nordoesdissociation of genes for virulence totally explain the basis of varietal durability, though it islikely to be the most plausible reason Boom and burst cycle-a characteristic of vertical resistanceResistancetovirusandvirusvectorsResistanetoplantpathogenicvirusesisgenerallyoligoge nicin nature.

For example, the host pathogen reaction to the barley yellow dwarf virus (BYDV) iscontrolled by detectable single gene. The discovery of Yd2 gene in Ethiopial barley furtherconfirms that against some of the viral diseases, vertical resistance is very much functional.Antiobiotics is the most common phemomenon where the host plant metabolites interfere withthenormal lifeand growth oftheinsects followingfeeding activity.

Invariably, the adult body weight, fecundity and various facets of multiplication of theinsects are adversely affected. The number of life cycles completed in a given period of time isalso less. Therefore, in plants that exhibit antibiosis towards crop maturity, there is markedreduction in the level of pest infestation (virus vector population) and host damage. Mechanismof disease resistance or Nature of disease resistance Disease resistance is governed by several in-built mechanisms of the host, plants against infection by the pathogen. They are disease escape,diseaseenduranceortoleranceand true resistance.

a. Diseaseescape

It is a prevention mechanism that causes the host to escape pathogenic infection. Early orlate maturity of the crop may prevent physical contact of the pathogen with the host. Mechanicalandanatomicalbarrierssuchasthickcuticle,waxybloomonleavesandstem,stomatalregulationpreventpenetrationofspores.Ergot,afungaldiseaseofinflorescenceincerealscaused by *Claviceps purpurea* does not affect varieties of wheat and barley in which the flowersremain closed until pollination occurs. Erect leaves of barley avoid deposition of spores of*Erysiphe graminis tritici* in contrast to prostrate leaves. Early maturing varieties of groundnutescape early leaf spot infection (*Cercospora arachidicola*) and early varieties of wheat escaperustand loosesmut infection.

Achangeinplantingseasonhasalsobeensuccessfullyemployedasameasureofsecuring escape, e.g., the leaf rust of sugarcane (*Puccinia sacchari*) in the canal areas of Bombayseverely affects cane when planted in June, but is of minor importance or absent in crops sown inOctober.Diseaseescapeconfers pseudo-resistance.

b. Diseaseendurance

The host after being infected by the pathogen tolerates the infection and suffers lessdamage. It does not result in any substantial decrease in yield. This is brought about by influenceof external factors. It is a well-known phenomenon that plants fertilized with phosphatic andpotash manures are more tolerant to disease; this is the case in wheat against rust infection. Ricecrops fertilized by silicates are “resistant” to blast (P*yricularia oryzae*) in Japan. Wheat cropsfertilizedbypotash and phosphaticmanures arehighlytolerant to mildewand rust infection. The fertilizers act indirectly to arrest vegetative growth and promote early maturity,betterstrawandstrengtheningtissuestoprotecttheplantwhichformabulwarkagainstpathogenicinvasion.

c. Trueresistance

It is the ability of the host plant to resist or withstand the attack of a pathogen. Trueresistanceisinheritableandmuchlesssubjecttoenvironmentalinfluence. Itisspecificincharacter. The basis of resistance may be morphological, functional, structural or protoplasmic.Functional nature of resistance is determined by opening of the stomata, time of opening offlowersand time ofmaturity, rate ofcorkformation and cambial activity.

Structural characters include the proportion of strengthening tissues, fibre content, nature ofmiddle lamella, corky layers, number and structure of stomata and lenticels and their sizes.Protoplasmic factors controlling resistance are related to cell contents and include acids, tannins,anthocyanins, chemical constituents and their proportion, antibiotic activity and hypersensitivitypresent in the plant cells and in addition biological antagonism of the protoplasm of the host andthe pathogen. True resistance, however, is of a specific character and is determined by thedefence equipment and activities of the plant itself against the parasitic invasion and is thereforenotsubject to anyappreciablemodifications byexternal factors.

Methodsof breedingfordiseaseresistance

The methods of breeding varieties resistant to diseases do not differ greatly from thoseadoptedforothercharacters. Thefollowing methods areused:

1. Introduction,
2. Selection,
3. Hybridizationfollowedbyselection,
4. Backcrossmethod,
5. Inducedmutagenesis,
6. Developmentofmultilinesand
7. Tissueculturetechniques

1. Introduction

It is a very simple and inexpensive method. Varieties resistant to a particular diseaseelsewhere may be thoroughly tested in the regions in which they are proposed to be introduced.Their yield performance and disease resistance should be confirmed by large scale cultivation. Itis possible that a variety resistant in one region need not be resistant in another region due tovariation in the physiological race of the pathogen or due to a much different agroclimaticconditionin the new location.

Introductions have served as a useful method of disease control. For example, Ridleywheat introduced from Australia has been useful as a rust resistant variety. Manila, a rice varietyintroduced in Karnataka from the Philippines, has tolerance to blast, bacterial leaf blight andsheath blight.Intan, a Javanica type rice variety introduced in Karnataka fromIndonesia ishighly resistant to blast. Munal, a rice variety introduced in West Bengal from the U.S.A. istoleranttoblast,bacterialleafblightandleaffolder(pest).SomeofIRRIricevarietiessuchas

IR 20, IR.24, IR.28, IR.34, IR.36 and IR .50 possess resistance to one or more diseases. Earlyvarietiesofgroundnutintroducedfrom U.S.A.havebeenresistanttolafspot(*Cercosoraarachidicola).*

Kalyan Sona and Sonalika wheat varieties originated from the segregating materialsintroduced from CIMMYT, Mexico and were rust resistant. Introduftions also serve as sources ofresistanceinbreedingprogrammes.Forexample,Africanpearlmillet(*P.americanum)*introductions have been used for developing downy mildew resistant male sterile lines (Tift 23Acytoplams) for use in hybrid pearlmillet production. This is an important development in thehybrid pearlmillet programmes since the original male sterile lines Tift 23A and 23D2A wereextremely susceptible to downy mildew.The introduction of Co.475 variety of sugarcane inMumbaihas conquered redrot but brought inleafrust and whipsmut to thefore.

2. Selection

This is better method than introduction and has more chances of success in obtainingdisease-resistant plants. The work of selection is carried out either in the naturally infected fieldsunderfieldconditionsorunderartificiallyinoculatedconditions.Theresistanceinsuchindividuals will occur in nature by mutation. To ensure the resistant character of a plant, largepopulation of crop plant may be exposed to the attack of pathogen under artificial conditions andthe non-infected plants may be chosen. Suvarnamodan rice of Kerala is a pure line of ARC.11775 andis highlytolerant to blast.

Sugandh of Bihar is a selection from Basmati rice of Orissa tolerant to bacterial leafblight. Rice varieties Sudha (Bihar), Sabita, Nalini (West Bengal), Patel 85 (Madhya Pradesh),Janaki(Bihar), Improved White Ponni (Tamil Nadu), Ambika (Maharashtra), are some of riceselections resistant to one or more diseases. MCU 1 cotton, a selection from Co 4, is resistant toKufriRed, apotato selectionfrom Darjeeling Red Round isadiseaseresistant variety.

3. Hybridization

When selection of resistant varieties is not feasible, resistant varieties may be evolved bycrossing the susceptible popular variety with resistant wild variety where in the resistant gene orgenes transferred into the genetic make up of susceptible variety. Very often the F1 from crossesmay be resistant but carry the other undesirable qualities of the resistant parent. The bad qualitiesare removed by several back crossing of F1 with the susceptible parent may ultimately

yield aresistantprogenywith good agronomic characteristics.

Undercertaincircumstancespedigreeorbulkmethodofselectionisfollowedtoobtainaresistant variety. In this method, the crosses are made till F2 population is got. Selections aremade in F2 generation for superior genetic traits including disease resistance. By continuedselfing, selections are made through F3 to F5 or F6 generations and the best variety is selected.Thismethod issuited forsmallgrains and beansbut unsuited tofruits andvegetables.

4. Backcross method

Back cross method is widely used to transfer disease resistance from wild species. Wildspecies are rice sources of disease resistance. Interspecific hybridization is made to transfer thegene or genes for resistance to the cultivated species. Resistance to grassy stunt virus from *Oryzanivara*to*O.sativa*,lateblightresistancefrom*Solanumdemissum*tocultivatedpotato,rustresistance from*durum* to*aestivum* wheat aresome of the examples involving interspecifichybridization. Depending upon the number of genes governing resistance and the nature of thegene, whether dominant or recessive, the procedure varies. The number of back crosses to thecultivatedspeciesmaybefivetosix.Oncethebackcrossprogenyresemblethecultivatedparent,then theyareselfed and segregatingprogenyscreened fordiseaseresistance.

5. Inducedmutagenesis

While following mutation breeding for disease resistance, a large number of mutationprogeny should be produced and screened under artificial epiphytotic condition to select resistantplants. MCU10 cotton, a resistant variety to bacterial blight was evolved in Tamil Nadu bysubjecting seeds of a susceptible variety CO4 to gamma rays followed by rigorous screening andselection6.DevelopmentofmultilinesTheconceptofmultilineswasfirstsuggestedbyJensen(1952) and developed by Borlaug (1959) for evolving multiline varieties to resist stem rustin wheat. A multiline variety is a composite of genetically similar lines, except that each linepossessesa different geneforresistanceto thepathogen.

Lines thatare genetically similar, except for one gene, are called isoline.It is assumedthat gene for resistance in each isoline contributes resistance to a separate physiological race orgroup of races. Genes for disease resistance are transferred by backcrossing from donor varietiestoa commondisease susceptible, butagronomically superior,recurrentparent.Isolinesaregenerateddifferingonlyinthegenefordiseaseresistance.Theisolinesarecompositedtosynthesizeamultilinevariety.Theisolinesaremaintainedforresynthesizingthemultiline

whenever needed. A multiline variety is composed of a mixture of resistant and susceptiblegenotypes and provides a buffering effect against rapid development of disease. It will provideresistance or tolerance to a broad spectrum of races of a pathogen. If new races of the pathogenare identified at a later stage, additional isolines resistant to the newly arisen races may beconstitutedand incorporated.

Care should be taken to see that there is uniformity for height, maturity and other featuresin the multiline. Though multilines provide stability of yield due to reduction of damage bypathogens, the limitations of multiline varieties are that the yield level of multiline varieties islimited to that of the recurrent parent, 4 to 5 years are required to stabilize isogenic lines and thepathogen may produce new races at a faster rate than the development of a multiline. Multilinevarieties have been developed for resistance to stem rust and stripe rust of wheat and crown rustof oats. The first multiline variety in wheat, „Miramar 60‟was developed and released inColumbia to combat the attack of yellow rust. „Miramar 63‟ and „Miramar 65‟ were resistant tostem rust and stripe rust. „Yoqui 50‟, „Crew‟ and „Tumult‟ are a few other wheat multilines.Kalyan sona and Sonalika-based multilines of wheat resistant to different races of rust have beendevelopedinIndia.

7.Tissueculturetechnique

Tissue culture techniques to produce somaclonal variation for disease are developed indifferentcrops.Somaclonalvariationsfordiseaseresistancearereportedin*Zeamays*for*Drechslera maydis* race T-toxin resistance, in *Brassica napus* for resistance/tolerance to *Phomalingam*, early and late blight resistance in potato, *Pseudomonas* and *Alternaria* resistance intobacco,besides smut and rust diseaseresistanceinsugarcane.

Lecture11

Application of biotechnology in plant disease management – Importance, production ofpathogenfreeplants through tissueculturetechniques

Inmodernterms“biotechnology“ is definedasthe manipulation, genetic modificationand multiplication of living organisms through novel technologies, such as tissue culture andgenetic engineering, resulting in the production of improved or new organisms and products thatcanbeusedinavarietyof ways.

Genetic engineering is the technology by which it is possible to isolate particular genefromoneorganism,insertthemintothegenomeofanotherorganismandmakethemtoexpressat right time. Cells of plants can be cultured in special nutrient medium and whole plants can beregenerated from cultured cells. This technique of growing plants in *vitro* is called “Tissueculture”.

Incalli derived from infected tissues not all cells uniformly carry the pathogen. Only40% of the single cells mechanically separated from TMV - infected tobacco callus contained thevirus. The twopossiblereasonsfor the escapeof somecellsofa systemically infectedcallusfromvirusinfectionare-

.a)virusreplicationisunabletokeeppacewithcellproliferation,and

b) some cells acquire resistance to virus infection through mutagenesis. Cells resistant to virus atback may even exist in the parent tissue together with susceptible ones. Several disease resistantplants have been evolved using somoclonal variation. Out of 370 tomato plants regenerated fromcalluses six showed resistant to TMV. Similarly, late blilght *(Phytophthora infestans)* - resistantpotatoplants and bacterial blightof riceresistantcallihavebeen evolved.

The pathogen produced secondary metabolites can be used to screen calluses for evolvingdisease resistant plants. Toxins will kill the calluses, but the mutant toxin resistant calluses willsurvive. The regenerated toxin resistant calluses yielded disease resistant plants. Brown spotpathogen *(Helminthosporium oryzae)* produced a host specific toxin for which resistant plantshave been successfully developed. Similariy, *Helminthosporium maydlis* - toxin resistant maizeplants, *Phytophthora infestans* - resistant tobacco plants, *H. sacchari* resistant sugarcane plantshave been evolved. Somaclonal variation refers to the tissue culture derived variation- Plantsregenerated from somatic cells, using tissue culture. are not genetically uniform but displaysignificantgeneticvariability.Thisvariability isveryhighwhencomparedtospontaneousmutation.Somacional

variationhasbeenderyionstratedinalargenumberofplantspecies

(wheat, rice, oats, maize, tobacco, potato, sugarcane, brassica, etc.) for various traits such asresistance to fungal, viral and bacterial diseases. The procedure involves growing of cell culturesfor several cycles on nutrient medium without any selective agent, followed by regeneration ofplants.

The regenerants and their progenies are screened for disease resistance. Embryo rescueand protoplast fusion techniques are important to obtain hybrids among incompatible species andintrogression of alien genes for disease resistance. In number of cases, useful genetic variabilityin the cultivated germplasm for resistance to diseases is either limited or lacking. Under suchsituations, wild germsplasm seems to be a reservoir of useful genes for disease resistance. In theincorporation of alien genes, several crossability barriers are encountered. In many cases, thehybrid embryo aborts. However, the excised hybrid embryos when cultured on nutrient mediumran be grown to plantlets. To incorporate alien genes from divergent sources, embryo rescueappears tobepromising.

Tissue culture in conduction with recombinant DNA technology is becoming increasinglyimportant to insert foreign genes and produce transgenic plants. For successful infection of virusparticles, the coat protein should be removed from viral RNA. If the host is made to synthesizecoat proteins in large amount, naked viral RNA formation will be negligible. The host coatprotein will encapsulate the RNA of the virus and prevent its multiplication. This will result inreduction and delay in symptom development. Eg. Transgenic tobacco plants expressing thetobaccomosaic viruscoat protein protectedtheplants against this virus.

The expression of the viral genome in transgenic plants also conferred resistance to virusinfection. These regions include portion of the viral replicas as well as, antisense RNA to coatprotein.TransgenictobaccoplantstransformedwithaDNAcopyofthesatelliteRNAofcucumber mosaic virus (CMV) were shown to produce large amounts of satellite RNA followinginoculationwith CMV and symptom development wasgreatlyreduced.

Proteins with the ability to inhibit the growth of fungi *in vitro* are abundantly present inplants. Constitutive expression of these genes in transgenic plants may render these plants tofungus resistant. Transgenic tobacco plants constitutively expressing bean chitinase have beenshowntodisplayenhancedresistanceto*Rhizoctoniasolani*.Recently,tobaccoplantsexpressingari bosomeinactivatingprotein(RIP)frombarelyshowedresistanceto*R.solani*.TheRiPsdo

not inactivate self ribosomes and show activity towards ribosomes of distantly related speciesincluding thosefrom fungi.

Theconstitutiveexpression ofthe groundnut stilbenesynthasegenein transgenic tobacco plants results in the synthesis of resveratrol (phytoalexin) and the transgenic plants showresistanceto *Botrytis cinerea.*

Transgenic tobaccoplantsexpressingacetyltransferase whichdetoxifiesthe tabtoxin,showresistanceto*Pseudomonassyringae*pv.*tabaci.*Morerecently,chitinasegenefrom*Manducasexta,*tobaccohornworm,hasbeenclonedinto*P.fluorescens*toincreasetheirantagonisticpotential against R.solani.

Meristemorshoot tipculture

Meristem and shoot tipculture are used to eliminate virus from infectedgermplasm.Ithaslongbeenobservedthattherapidlygrowingmeristemsofplantsareusuallyfreeofviruses,or at least have much lower concentration of viruses than nonmeristem cells. This situation hasbeen exploited forthe production of virus-free plants by meristem culture. It is commanly used incassava,potato, sweet potato and ornamental plants.

"Virus-free" the term has been loosely used in literature. Plants infected with more thanone type of virus and also may carry some unknown viruses. Thus, a plant can be claimed as freeof only those viruses for which specifictests have givenne gative result sowever, the term "virus-free"is stillretained byhorticulturists forits commercial value.

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

Fivemainpossibilitieshavebeensuggestedtoexplainthemechanismsunderlyingthe „resistance"ofmeristemstoviruses.

(i) Exclusionofthevirusesfromthemeristemsbylackofsuitablevascularorplasmodesmatalconnections.

(ii) Competitionfor keymetabolites bytherapidlydividing meristemcells.

(iii) Theproductionofsubstancesin meristemcells thatresultin breakdownof thevirus.

(iv) Deficiencyin somekeycomponents ofthemachineryof virusreplication,and

(v) Presenceofinhibitorsofvirusreplication.

Factorsaffectingviruseradication

Factors such as culture medium explant size and culture storage influence the viruseradication.Inaddition,heattreatmentbeforeor duringculture significantlyinfluencestheefficiency of this technique. The physiological stage of the explants also affects virus eliminationbymeristem tip culture.

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

(ii) The size of meristem tip is an important factor governing regeneration capacity of meristemsand to obtain virus free plants. For example, in cassava, meristems exceeding 0.2 mm sizeregenerated to plantlets, but those less than 0.2 mm size developed either Gallus or callus withroots. In general, the larger the meristem, the greater is the number of regenerated plants, but thenumberofvirus freeplantis inverselyproportionalto thesizeofmeristem 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 beincreased to 200 lux after 4 weeks. The cultures are generally stored understandard culture roomtemperatures(25 ± 2ºC).

(iv) Meristem tips should, preferably be taken from actively growing buds. Tips taken fromterminalbuds gavebetterresults than thosefrom axillarybuds.

Meristemtip cultureto eliminate CassavaMosaicVirus

Rapidly growing vegetative buds are excised, rinsed with sterile distilled water and thendisinfected by immersing them in mercuric chloride solution (0.1%) for 2-3 minutes. The budsare then rinsed with several changes of sterile distilled water. Under the microscope, 3-4 leafprimordia (0.3 to 0.6 mm in size) is removed from the bud with a sterile scalpel. The buds arethen aseptically transferred to Murashige and Skoog (MS) medium in test tubes and incubated at25 ± 2°C in light, for 45 days. The plantlets are then removed from the test tubes, washed in tabwater and kept in Hoagland solution for 3-4 days for hardening. The plantlets are transferred topots containing peat soil and vermiculite at 3:1 ratio and kept in mist chamber for 5-7 day. Theplantsarethen transferred to glass houseforfurtherstudy.

Lecture12

DiseaseManagementbyBiotechnologicalMethods

The use of genetically modified organisms and or modern techniques (geneticengineering, tissue culture etc.) with biological systems for disease control is known asbiotechnology. Genetic engineering or Genetic manipulation is the deliberate alteration ofthecompositionofagenomebyman.Agrowthofcellsinalaboratorynutrientmediumis known as tissue culture i.e. the technique of growing of plants in *vitro*. Cells of plantscan be cultured in special nutrient medium and whole plants can be regenerated fromcultured cells. Plant biotechnology is used for rapid clonal propagation of plants. It canhelp to produce industrial plant products under tissue culture conditions Biotechnologicalmethods are employed to control important plant diseases which are not amenable tocontrol byusual methods.

Geneticengineering

Genetic Engineering is the technology by which a particular gene is isolated fromone organism and inserted into the genome of another organism and made to express attheright time.

Vectorsfortransferof genes

Genetic engineering has been used to manage plant virus diseases. For transfer ofgenes to plants vectors are needed in which the gene to be transferred will multiplyseveral folds. The most effective gene vector developed is the Tumour inducing plasmidof *Agrobacterium tumefaciens* from which the Tumor inducing genes have been removed*A.tumefaciens*inducestumors(crowngalls)throughdi-plasmid(tumor-inducing)whichisacirculardoublestrandedDNAmoleculecontainingupto2,00,000basepairs organizedinto several genes.

The Ti-plasmid is transferred from the bacteriuminto the cell. A specific regionof the plasmid, the T-DNA, is transferred from the plasmid to the nucleus of theplantcell. It becomes integrated into the plant nuclear genome, and is transcribed.Cauliflowermosaic virus (CaMV) is the only plant virus with double-stranded DNAgenome. As ithas DNA genome, it is used as a possible vector in introducing foreign genes into plant. Itis possible to insert a non-viral gene into CaMV genomeand obtain expression of thegeneintheinfectedplant.TheviralpromotorregionsfromCaMVareeffectivefor

obtaining expression of other genes in plant cells. The genes to be expressed is now fusedto a promotor element from CaMV and a gene of *A.tumifaciens*. They are then introducedintothe plants using *A. tumefaciens*Ti-DNAtransformation.

DNAconstruction

Messenger RNA is extracted and exposed to an enzyme reverse transcriptasewhichsynthesizesacomplimentary singlestrandedDNA.Thecomplimentary DNA(cDNA) is exposed to another enzyme, DNA polymerase, which produces the doublestrandedcDNA. The cDNAs areinserted into theplasmidsof*A. tumefaciens*.

Coat-proteinexpressionintransgenicplants

Example: Transgenic tobacco plants expressing coat protein gene protected theplants against TMV. Transgenic tobacco plants showing resistance to alfalfa mosaic virusand tobacco rattle virus have also been developed. Transformation using a gene encodingtheviralnucleocapsidproteinoftomatospottedwiltvirus(TSWV)hasyieldedtransgenic tobacco plants that are resistant to TSWV. The expression of the viral genomeintransgenicplantsgivesresistancetovirusinfection.Transgenictobaccoplantstransformed with a DNA copy of the satellite RNA of cucumber mosaic virus (CMV) areshown to produce large amounts or satellite RNA following inoculation with CMV andsymptomdevelopment isgreatlyreduced.

SatelliteRNAexpressionin transgenicplants

Satellite RNAs are associated with several viruses. They are packaged into virusparticles along with the genomic RNAs of the helper virus. They are not part of the viralgenome and have no obvious sequence relationships with the helper virus. The presenceof the satellite RNA suppresses the disease severity in many hosts. Hence transgenicplants which express satellite RNA have been produced to manage virus diseases. e.g.,Transgenic plants of tobacco expressed the synthesis of satellite tobacco ring spot virusand reduce the virus disease incidence. Satellite RNA expressing tobacco plants againstCucumberMosaicVirus(CMV)and Tobaccoaspermyvirushavebeen synthesized.

MICRNA expressionin transgenicplants

A DNA copy is made of one or more sections of the viral genome that include theinitiation codon for proteins vital to virus replication. The DNA copy is inserted in thehost-cellgenome,Cellsthenproducean`antiseraRNA'calledmicRNA(mRNA-

interfering complementary to 5' end of the gene). The mic RNA hybridizes in vivo withtheviralmRNAblackingtranslation.ThemicRNAisinsertedintotheplantsusingtheTi plasmid of A. *tumefaciens*. Plants regenerated from the transformed cells will beresistant to the particular virus. This possibility is also being exploited for the control ofvirusdiseases.

Useof RFLP markersforcloning resistancegenes

Molecularmarkers*viz*.,isozymesandDNAmarkers(RestrictionFragmentLength Polymorphisms - RFLPs; Random Amplified Polymorphic DNA - RAPD andothers) are being used in several areas relevant to identification of disease resistancegenes. Some of the disease resistance genes using random DNA markers have beenidentified.

Diseaseresistancegenes mappedusingRFLPmarkers

Plant	**Pathogen**
Tomato	*Fusariumoxysporum*
Citrus	*Phytophthora*spp.

Detoxificationofpathotoxin

Pathogens that produce pathogenesis-related phytotoxins usually also have thecapacity to metabolize i.e. detoxify, these compounds. The search for genes encoding theenzyme(s) performing the key catabolic step(s) should thus lead to a convenient source ofresistance, which can be engineered into plants to protect them from the effects of thetoxin.A gene encoding a tabtoxin acetyltransferase from the pathogen, *Pseudomonassyringae p*v. *tabaci* which causes wild fire disease of tobacco was isolated and transferredinto tobacco under a strong constitutive promotor.The transgenic plants expressed thisgene and, when treated with either the pathogen or its toxin, did not produce the chloroticlesionstypical of wild firedisease.

Activationofplantdefensemechanism-Phytoalexins

Phytoalexins have long been known to accumulate in certain plants upon infectionbypathogens.Theproductionofphytoalexinsisalsotriggeredbymechanicalstimulation,ultraviolet(UV)irradiation,stressandavarietyofchemicalelicitors.Phytoalexinsarepartofthelocalizedhypersensitiveresponseatthesiteofdamageor

pathogen ingress, which involves cell trauma and death. The importance of phytoalexinsinthe defense responseisunderscoredby experimentsandpathogenicity in*Nectriahaematococca* was correlated to its ability to detoxify the phytoalexin, pisatin, by way ofdemethylation.BytransferringthedemethylasegenefromNectria,*Aspergillusnidulans*,ano n-pathogen on peas,was renderedinsensitiveto pisatin.

Defenserelatedgenes

a. Singlegenedefensemechanism

There are some defense proteins which do not require any intermediate step bothfor their synthesis and their expression require only few steps and those genes encodingsuch proteins are called single gene defense mechanism. Chitinases and glucanases arethoseproteins belonging to singlegenedefense mechanism.

Chitinasesandglucanases

Chitinases are abundant proteins found in wide variety of plants. Although thephysiological function of chitinases is not known, there is strong correlative evidence thatthey are defense proteins with antifungal activity. Chitin is a major structural componentof cell walls of many fungi. The low constitutive activity of chitinase found in manyplants can be dramatically induced by wounding or by infection of the tissue with fungalpathogens.Chitinaseinconcretwithß-1,3-glucanase(capableofdegradingglucanspresent in fungal cell wall), degrades fungal cell walls and inhibits fungal growth athyphaltips and hasbeenshown toassociate withhyphalwalls in plants.

The chitinase and glucanase enzymes are having direct action against severalfungal pathogens compared to other defense related proteins. Since lytic enzymes areencoded by single genes, these defense should be high amenable to manipulation by genetransfer. The first reports of successwith this approachwas the expression of beanvacuolar chitinase gene under the control of the strong constitutive gene under the controlofthestrongconstitutivepromoterofthecauliflowermosaicvirus(CaMV)35Stranscript intobaccoand*Brassicanapus*,whichresultedindecreasedsymptomdevelopmentby*Rhizoctoni a solani*, thecausativeagent of post-emergencedamping off.

An endochitinase gene (from genomic tomato DNA library) was introduced into*Brassicanapus*.var.*oleifera*.Thetransgenic*Brassica*showedenhancedresistanceagainsts

everalfungalpathogenslike*Cylindrosporiumconcentricum,Phomalingam*and

Sclerotinia sclerotiorum under field conditions when compared to non-transgenic plants.More recently, chitinase gene from *Manduca sexta*, tobacco horn worm, has been clonedinto*P. fluorescens* to increasetheir antagonisticpotential against*R.solani*.

b. Multigenicdefensemechanism

Defense responses suchas phytoalexinbiosynthesisor lignindeposition inthecellwall requirethe action ofmanygenes.

Peroxidases

Anionic peroxidases in the cell wall catalyze the production of phenolic radicalsfor the oxidative polymerization of lignin from cinnamyl alcohols. In tomato, there is amarkedinductionoftwolinkedgenesencodinghighlyanionicperoxidasesinanincompatible interaction with an avirulent form of *Verticillium albo-atrum*, with onlyweakinductioninthecompatibleinteractionwithavirulentformofthisvascularpathogen. Expression of one of these genes in transgenic tobacco under the control ofeither itsown promoter or the CaMV35spromoter resultedinmassive increase inanionic peroxidase activity and these plants apparently showed a significant increase inresistance to *Peronospora parasitica* as judged by symptom development and fungalsporulation.

Activationofdefensegenesbychemicals

Several classes of compounds have the potential to act as inducers of naturalresistance mechanisms in horticultural crops and chemicals with such indirect modes ofactionmayofferattractivealternativesorsupplementtoexistingcontact/systemicfungicides in integrated disease management. Increase was found to occur in response tosalicylic acid treatment as well as oligosaccharides and glycoproteins originating fromeither fungal cell wall or host cell walls, the so called elicitors.Recently, chitosan seedtreatment has been found to induce defense related genes like chitinase and glucanase intomato and consequently the Fusarium crown and root rot diseases were significantlyreduced.Pre-treatmentwith2,6-dichloroisonicotinicacidwashighlyeffectiveinsignificantly reducing both anthracnose (caused by *Colletotrichum lindemuthianum*) andrust(causedby*Uromyces appendiculatus*) diseases in bean plants.

Cellandtissueculture

Tissue culture approach is one of the oldest techniques in the field of molecularbiology anditisappliedinseveralwaysforthedevelopmentofdiseaseresistancecultivarsin agriculture and horticulture.

a. SomaclonalVariation

In the past two decades, several advances have been made in culturing of isolatedplant cells and tissue under controlled conditions in vitro.When plants are regeneratedfrom cultured cells, they exhibit new phenotypes, sometimes at high frequencies.If theseareheritableandaffectingdesirabletraits,such"somaclonalvariation"canbeincorporated into regular breeding programmes.

However, the finding of specific traits by these methods is largely left to chanceand hence inefficient.Rather than relying on this undirected process, selection in vitroaims to specific traits by subjecting large populations of cultured cells to the action of aselective agent in the petridish.For purpose of disease resistance, this selection can bedone by fungal pathogens, culture filtrates of pathogens or isolated phytotoxins that areknown to have a role in pathogenesis.The selection will allow only those cells to surviveand proliferate that are resistant to the challenge.Plants regenerated from resistant cellsoften display a resistant phenotype when evaluated with either the toxin or the pathogenitself.

Diseaseresistantplants fromtissueculture

Plant	CultureSystem	Selection	ResistancetoPathogen
Potato	Protoplasts	SCV	*Phytophthorainfestans* *Alternariasolani*
	Callus	CF	*Fusariumoxysporum*
Tomato	Callus	Fusaric	*Fusariumoxysporum*
	Protoplasts	Acid	
Banana	Meristem	SCV	*Fusariumoxysporum*
Strawberry	Callus	SCV	*Fusariumoxysporum*

(SCV-plantregenerationwithoutselection;CFcrudeculture filtrate)

Although this method has obviously yielded some impressive results, it also has itsdrawbacks; *viz*, i. Many pathogens do not produce pathogenesis specific toxins useful forselection ii. Culture filtrates are rather artificial and neither pathogens nor plant cellsgrown together in vitro behave quite as they would in a natural environment iii. Theselection approach can only detect mutations in plant genes that are expressed at the timethatselection is applied.

In order to be useful, new resistance traits, whether selected or not, must beheritable sexually or in the case of vegetatively propagated crops must be transmittedthrough vegetative propagules.The pathogens produced toxins can be used to screencalluses (cultured cells) which may regenerate resistant plants.The toxins will kill thecalluses, but the mutant toxin resistant calluses will survive.The toxin-resistant callusesyield disease resistance plants.Vidhyasekaran obtained brown spot resistant rice plantsusing *Helminthosporium oryzae toxin*.Similarly, *H. maydis* resistant maize plants, *H.sacchari* resistant sugarcane plants and *Phytophthora infestans* resistant tobacco plantshavebeen evolved.

b. Antherculture

In this method, the plants are produced directly from microspores (immaturepollen grains).Through anther or microsporeculture, one has immediate access tounique and rare combinations of genes representing the recombination of the geneticmaterial contributed by the parents of the cross.Through anther culture, followed bychromosome doubling, such gene combinations can be fixed in their homozygous state asinstant inbreds in a single step.Over the past two decades, anther culture has becomewidely accepted as a tool in cultivar development.This technique can be particularlyuseful for producing plants with novel combinations of resistance genes for managingfungaldiseases.

c. Protoplasmicfusion

This generates hybrid cells by merging the total cellular components of somaticcellsfromwhichthecellwallshavebeenremovedtoproduceprotoplasts.Theincompatibility preventing sexual fertilization between species is thus avoided and viablehybrids have been created, even between unrelated distance species.Disease resistancegeneshavethus been transferredbyprotoplasts fusion fromwild species into potato.

Lecture13

INTEGRATED PLANT DISEASE MANAGEMENT (IDM) – CONCEPT,ADVANTAGESAND IMPORTANCE

Integratedplantdiseasemanagementcanbedefinedasadecision-basedprocessinvolvingcoordinateduseofmultipletacticsforoptimizingthecontrolofpathogeninanecologicallyand economically. Theimplications are:

- ✓ Simultaneousmanagementofmultiplepathogens
- ✓ Regularmonitoringofpathogeneffects,andtheir naturalenemiesandantagonistsaswell
- ✓ Useofeconomicortreatmentthresholdswhenapplyingchemicals
- ✓ Integrateduseofmultiple,suppressivetactics.

PrinciplesofPlantDiseaseControl

1. **Avoidance**—preventsdiseasebyselectingatimeoftheyearorasitewherethereisnoinoculumor wheretheenvironment is not favorableforinfection.
2. **Exclusion**—preventstheintroduction ofinoculum.
3. **Eradication**—eliminates,destroy,orinactivatetheinoculum.
4. **Protection**—preventsinfectionbymeansof atoxicant orsomeother barriertoinfection.
5. **Resistance**—utilizescultivarsthatare resistantto ortolerantofinfection.
6. **Therapy**—cureplantsthatare alreadyinfected

Factorsaffectingoccurrences

FactorswhichaffectPlantdiseasesaremicro-organisms,includingfungi,bacteria,viruses, mycoplasmas, etc. or may be incited by physiological causes including high or lowtemperatures, lack or excess of soil moisture and aeration, deficiency or excess of plant nutrients,soil acidity or alkalinity, etc. Factors that limit the rate of disease development are the relativelylow amounts of inoculum in the lag stage and the paucity of healthy plants available to theinoculumin the stationarystage.

The causative agents of disease in green plants number in a tens of thousands and includealmost every form of life. But primary agents of disease may also be inanimate. Thus nonliving(abiotic) agents of disease include mineral deficiencies and excesses, air pollutants, biologicallyproduced toxicants, improperly used pesticidal chemicals, and such other environmental factorsas wind, water, temperature, and sunlight. Nonliving things certainly qualify as primary agents ofdisease;theycontinuouslyirritateplantcellsandtissues;theyareharmfultothephysiological

processes of the plant; and they evoke pathological responses that manifest as the symptomscharacteristic of the several diseases. But the abiotic agents of disease in plants. The abioticagentsofplantdiseasearetermednoninfectious,andthediseasestheycausearetermednoninfecti ousdiseases.

Micro-organisms

The micro-organisms obtain their food either by breaking down dead plant and animalremains (saprophytes) or by attacking living plants and animals (parasites). In order to obtainnutrients, the parasitic organisms excrete enzymes or toxins and kill the cells of the tissues of thehost plant, as a result of which either the whole plant or a part of it is damaged or killed, orconsiderabledisturbancetakes placeinits normalmetabolicprocesses.

Parasites

One of the factors causing plant diseases is parasites, those living organisms that cancolonize the tissues of their host-plant victims and can be transmitted from plant to plant. Thesebiotic agents are, therefore, infectious, and the diseases they cause are termed infectious diseases.Theinfectiousagentsofplantdiseasesaretreatedinthestandardtextbooksonplantpathology.

Abilitytoproduceaninoculum

Theparasiticpestmustproduceaninoculum,somestructurethatisadaptedfortransmission to a healthy plant and this can either parasitize the host directly or develop anotherstructure thatcanestablish a parasitic relationshipwiththe host. For example, inoculaforvirusesaretheviralparticles(virions);forbacteria,thebacterialcells;forfungi,variouskinds ofspores or thehyphal threadsof mold; fornematodes, eggsor second-stagelarvae.

Agents/Mediafortransportationofinoculum

The inoculum must be transported from its source to a part of a host plant that can beinfected. Thisdispersalof inoculumtosusceptible tissue is termed inoculation.Agentsofinoculation may be insects (for most viruses and mycoplasmalike organisms and for somebacteria and fungi), wind(formanyfungi), and splashing rain (formanyfungi).

Wounds,Naturalopenings

The parasite mustenterthe host plant, which itcan do (depending on the organism) inone or more of three ways; through wounds, through natural openings, or by growing directlythrough the unbroken protecting surface of the host. Viruses are literally injected into the plantasthehomopterousinsectcarrierprobesandfeedswithinitshost.Bacteriadependonwounds

or natural openings (for example, stomates, hydathodes, and lenticels) for entrance, but manyfungi can penetrate plant parts by growing directly through plant surfaces, exerting enormousmechanicalpressureandpossiblysoftening host surfaces byenzymaticaction.

Availabilityof food

For occurrence of disease one of the factor affecting is, availability of nourishment togrowwithinitshost.Thisactofcolonizationsistermedinfection.Certainlytheparasitedamagesthe cytomplasmic memberanesof thehostcells,makingthosemembranesfreelypermeable to solutes that would nourish the parasite And parasitism certainly results fromenzymatic attacks by the parasite upon carbohydrates, proteins, and lipids inside the host cell.The breakdown products of such complex molecules would diffuse across the damaged host-cell membranes and be absorbed by the parasite in the form of sugars, amino acids, and the like.Air-borneparasites of foliage, flower, and fruit.

Preventiveandcontrol measures

A. PREVENTIVE

MEASURESCulturalpractices

Cultural practices usually influence the development of disease in plants by affecting theenvironment.Suchpracticesareintendedtomaketheatmospheric,edaphic,orbiologicalsurroundin gs favorable to the crop plant, unfavorable to its parasites. Cultural practices that leadsto disease control have little effect on the climate of a region but can exert significant influenceon the microclimate of the crop plants in a field. Three stages of parasite's life cycle namely,Survival between crops, production of inoculum for the primary cycle and inoculation can becontrolbyfollowing preventivemeasures.

SurvivalbetweenCrops

Organismsthatsurviveinthesoilcanoftenbecontrolledbycroprotationswithunsusceptible species. Depending on the system, either of two effects results. Catch crops havebeenusedtocontrolcertainnematodesandothersoil-bornepathogens.Soil-borneplantpathogenscanbecontrolledbybiologicalmethods.Plantparasitesmaybecontrolledbyantag onistic organisms that can be encouraged to grow luxuriantly by such cultural practices asgreenmanuringandtheuseofappropriatesoiladditives.Thesoil-invadingparasitethusbecomes an amensal in association with its antagonist. Soil-borne plant parasites may also bekilledduringtheirover-seasoningstagesbysuchculturalpracticesasdeepploughing(asforthe

pathogen of southern leaf blight of corn), flooding (as for the cottony-rot pathogen and somenematodes), and frequent cultivation and fallow (as for the control of weeds that harbor plantviruses). Plant diseases caused by organisms that survive as parasites within perennial hosts orwithintheseedofannualplantsmaybecontrolledtherapeutically.Therapeutictreatmentsofheat andsurgery are applicable here; thoseinvolving the use of chemicals will be mentionedlater. Removal of cankered limbs (surgery) helps control fire blight of pears, and the hot-watertreatment of cabbage seed controls the bacterial disease known as black rot. Heat therapy is alsousedto rid perennial hosts of plant-parasitic nematodes.

Productionof InoculumforthePrimaryCycle

Environmentalfactors(particularlytemperature,water,andorganicandinorganicnutrients) significantly affect Inoculum production. Warm temperature usually breaks dormancyofoverseasoningstructures;rainmayleachgrowthinhibitorsfromthesoilandpermitgermination of resting spores; and special nutrients may stimulate the growth of overseasoningstructuresthat produceinoculum.

Dispersalofinoculumandinoculation

Culturalpracticesthatexemplify avoidancearesometimesusedtopreventeffectivedissemination. A second hierarchy of regulatory disease control is plant quarantine, the legallyenforced stoppage of plant pathogens at points of entry into political subdivisions. The PlantQuarantine Act of the United States governs importation of plant materials into the country andrequires the state govt. to enforce particular measures. Also, states make regulations concerningthe movement of plant materials into them or within them. E.g., Florida imposes quarantineagainst the citrus-canker bacterium, which was eliminated from the state earlier by means ofcooperative efforts led bythe FloridaDepartmentof Agriculture.

Sampleinspection

One of the preventive measures to control the diseases is the use of sample inspectionmethod. Laboratory evaluation of the representative sample drawn by the certification agency forthe determination of germination, moisture content, weed seed content, admixture, purity, seed-bornepathogens.

B. Control

MeasuresChemical

Control

The pesticidal chemicals that control plant diseases may be used in very different ways,depending on the parasite to be controlled and on the circumstances it requires for parasiticactivities. E.g., a water-soluble eradicative spray is applied once to dormant peach trees to ridthem of the overwintering spores of the fungus of peach-leaf curl, whereas relatively insolubleprotective fungicides areapplied repeatedly tothe green leaves of potato plants to safeguardthem from penetration by the fungus of late blight. Also, systemic fungicidal chemicals may beusedtherapeutically.

The oxathiin derivatives that kill the smut fungi that infect embryos are therapeutic, as isbenomyl (which has systemic action against powdery mildews and other leaf infecting fungi).Volatile fungicides are often useful as soil-fumigating chemicals that have eradicative action.Thechemicalcontrolofplantdiseasesisclassifiedinthreecategories:seedtreatments,soiltreatments,and protectivesprays anddusts.

SeedTreatments

Chemical treatments of seed may be effective in controlling plant pathogens in, on, andaround planted seed. Seed treatment is therapeutic when it kills bacteria or fungi that infectembryos, cotyledons, or endosperms under the seed coat, eradicative when it kills spores of fungithat contaminate seed surfaces, and protective when it prevents penetration of soil-borne fungiinto seedling stems. Certified seed is usually given treatment necessary for the control of certaindiseases. Seed treatment is of two types; viz., physical and chemical. Physical treatments includehot-watertreatment,solar-heattreatment(loosesmutofwheat),andthelike.Chemicaltreatments include use of fungicides and bactericides. These fungicides are applied to seed bydifferent methods. In one method, the seed in small lots is treated in simple seed-treaters. Theseed-dip method involves preparing fungicide suspension in water, often at field rates, and thendippingthe seed in it foraspecifiedtime.

Somechemicalscommonlyusedtocontrolplantdiseases

Chemicalanduse	Relative toxicity	
	Oral	Dermal
Seedtreatments(allfungicides)		
Chloraneb	Low	Low
Dichlone	Low	High
Thiram	Moderate	High
Carboxin(systemicandtherapeutic)	Low	Low
Soiltreatments		
Methylbromide[b] (generalpesticide)	Veryhigh	Veryhigh
PCNB(fungicide)	Low	Moderate
SMDC[vapam](fungicide,nematicide)	Moderate	Moderate
MIT["Vorlex"](fungicide,nematicide)	Moderate	Moderate
D-Dmixture(nematicide)	Moderate	Low
Plant-protectivetreatments		
Coppercompounds(fungicides,bactericides)	Moderate	Low
Sulfur(fungicide)	Low	Moderate
Maneb(fungicide)	Verylow	Low
Zineb(fungicide)	Verylow	Low
Captan(fungicide)	Verylow	Verylow
Dinocap(fungicideforpowderymildews)	Low	Low
Streptomycin(bactericidalantibiotic)	Verylow	Low
Cyclohexamide[b](fungicidalantibiotic)	Veryhigh	Veryhigh
Benomyl(protectiveandtherapeuticfungicide)	Verylow	Verylow

The oxathiins (carboxin, DMOC) used to kill embryo infecting smuts of cereal grainshavelittleeffectonotherorganisms,mosteradicativeandprotectivechemicalshaveawiderange of fungicidal activity; they are effective against most seed-infesting and seedling-blightfungi.Butspecificseed-treatmentchemicalsoftenworkbesttocontrolagivendiseaseofa

single crop-plant species. Moreover, the toxicity of chemicals to seeds varies, and farmers shoulduse only thecompoundsrecommendedby the Cooperative ExtensionService of their countryandstate.

Copper and mercury-containing compounds were first used as seed-treating chemicals.But copper is toxic to most seeds and seedlings, and mercury has been banned from use in seedtreatments because of the danger it poses to humans and animals. Organic compounds nowwidely used as protective and eradicative seed treatments include thiram, chloraneb, dichlone,dexon,and captan.

SoilTreatments

Soil-borneplantpathogensgreatlyincreasetheirpopulationsassoilsarecroppedcontinuously, and finally reach such levels that contaminated soils are unfit for crop production.Chemical treatments of soil that eradicate the plant pathogens therein offer the opportunity ofrapid reclamation of infested soils for agricultural uses. Preplanting chemical treatment of fieldsoils for the control of nematode-induced diseases, and fumigation of seedbed and greenhousesoils (with methyl bromide, for example) is commonly practiced to eradicate weeds, insects, andplant pathogens. Field applications of soil-treatment chemicals for fungus control are usuallyrestricted to treatments of furrows. Formaldehyde or captan applied is effective against sclerotia-producing fungi that cause seedling blights, stem rots, and root rots of many field crops. Othersoil-treatment fungicides are vapam and "Vorlex." Soil treatments made at the time of plantingaremost effectiveagainstparasitic attacks thatcome earlyin thegrowing season.

Protectivespraysanddust

Protectivefungicidespreventgermination,growth,andpenetration.Inordertouseprotective fungicides effectively, the farmer must not only select the right fungicide for the job,but also apply it in the right amount, at the right times, and in the right way. Too little fungicidefails to control disease; too much may be toxic to the plants to be protected. The farmer andapplicator, therefore, must always follow use instructions to the letter. Timing of applications isalsocritical.

Advantages

Integrated approach integrates preventive and corrective measures to keep pathogen fromcausing significant problems, with minimum risk or hazard to human and desirable componentsoftheirenvironment.

Someofthebenefitsof an integratedapproachareasfollows:

- Promotessound structures andhealthyplants
- Promotesthesustainablebiobaseddiseasemanagementalternatives.
- Reducestheenvironmentalriskassociatedwith managementbyencouragingtheadoption ofmoreecologicallybenign control tactics
- Reducesthepotentialfor air andgroundwatercontamination
- Protectsthenon-targetspeciesthroughreducedimpactofplantdiseasemanagementactivities.
- Reducesthe need forpesticidesand fungicides byusing several management methods
- Reducesoreliminatesissuesrelatedtopesticideresidue
- Reducesoreliminatesre-entryinterval restrictions
- Decreases workers,tenantsandpublicexposuretochemicals
- Alleviatesconcernofthe publicabout pest&pesticiderelatedpractices.
- Maintainsorincreasesthecost-effectivenessof diseasemanagement programs

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