Fungal diseases of potato and their management

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Introduction

The importance of potato as a food crop was duly recognized soon after its introduction in Europe in the 16^{th} century. This is going to be the future food crop for the millions especially in the third world countries. Potato production and consumption is accelerating in most of the developing countries including India primarily because of increasing industrialization. In fact, potato production in developing countries surpassed that of developed countries. Potatoes in India are grown under varied climatic conditions ranging from tropics, subtropics to temperate highlands. Consequently, the spectrum of insect-pests and diseases is very large. All of them put together have the potential to limit potato production upto 85% depending upon the weather/region. Scope of this chapter is limited to the important fungal diseases of potato, which causes considerable losses to the growers. For the convenience these diseases are grouped into foliar diseases and soil & tuber borne diseases.

FOLIAR DISEASES

Late blight (*Phytophthora infestans* (Mont.) de Bary)

It is one of the most devastating diseases of potato and losses upto 85% have been reported if crop (susceptible cultivar) remains unprotected. Disease appears every year in epiphytotic forms in hills as well as in plains.

Symptoms

Late blight affects all plant parts viz. leave, stem and tubers. It appears on the leaves as pale green, irregular spots which enlarge into large water soaked lesions. In moist weather the spots enlarge rapidly with central tissue turning necrotic and dark brown or black. Often, the spots have a purplish tinge. On the lower side, white mildew (cottony growth) ring forms around the dead areas. In dry weather the water soaked areas dry up and turn brown.

On stems and petioles light brown elongate lesions develop often encircling the stem/petiole. Under favourable conditions, the whole vine may be killed and blackened and the disease spread rapidly killing the entire crop in a few days.

Tubers are readily infected while in soil by rain borne spores from blighted foliage. Initially the tubers show a shallow, reddish brown dry rot that spreads irregularly from the surface through the flesh. At low storage temperatures, the lesions usually remain firm and frequently show a metallic tinge especially at the border of healthy tissues.

Epidemiology

Tubers carrying the pathogen are the real carriers and serve as the source of the disease in the subsequent season. In the plains, the pathogen over summers through infected seed tubers in cold stores. Infected seed tubers grow into healthy plants but under conditions favourable for the disease (temperature 10-20^{o}C and RH>80%) the resting pathogen develops within the infected seed and affects the stem base/lower leaves. Such infected stems and leaves serve as the primary source of inoculum. The pathogen sporulates on the primary lesions and the sporangia so formed are carried over by wind currents/rain splashes to other plants/fields thereby setting a chain reaction. Fungal sporangia are also washed down to soil with rain water or dew and infect the new tubers.

Appearance and buildup of late blight depend solely on weather conditions. There are specific requirements of temperature and humidity for initiation and further buildup of disease. Temperature requirements are different for fungus growth (16-20^{o}C), spore production (18-22^{o}C), spore germination (10-20^{o}C) and for infection and disease development (10-22^{o}C with 18+1^{o}C). Spore germination and infection requires 100 per cent humidity and spores get killed under low humidity (<75%). Fungal spores are produced during the night and are sensitive to light. Cloudiness favours disease development.

Disease Management

Following integrated management schedule is recommended for the management of late blight in the country.

i) Reduction of the primary sources of inoculum is the first step in management of late blight. Control of contaminated sources such as waste heaps, infected tubers, volunteer plants, disease in neighboring fields and re growth after haulms destruction can help in management of the disease.
ii) Follow sound crop rotation for reducing the risk of soil-borne infections of *P. infestans*.
iii) Grow late blight resistant varieties recommended for the region.
iv) Use disease free seed.
v) Follow high ridging and earthing up.
vi) Stop irrigation under overcast conditions.
vii) Give prophylactic spray (just before the canopy closure) of mancozeb (0.2%) followed by cymoxanil+mancozeb (0.3%)/ dimethomorph/ fenamidone followed by one more spray of mancozeb.
viii) Kill the haulms and bury them in pits at 75% disease severity.
ix) Harvest the crop 12-15 days after haulms cutting, sort out the late blight infected tubers and store the seed after treating it with boric acid (3%).

Late Blight Forecasting

Development of late blight mainly depends on moisture, temperature and cloudiness. In India, the rains are heavy and the weather is cool and cloudy/foggy during summer in the hills but in plains the weather is generally clear with scanty rains (during autumn or spring) and therefore, the disease epidemic is not a regular feature. The monsoon moves from East to West in the Himalayas. Therefore, the blight occurs early in the eastern Himalayas. Taking weather parameters in account, Bhattacharya *et al*. (1983) developed forecasting models for Shimla, Shillong and Ootacamund i.e. i) if the 7-day moving precipitation (30 mm for Shimla, 28.9 mm for Ootacamund and 38.5 mm for Shillong observed to be critical rainfall lines) associated with mean temperature of 23.9^oC or less continues for 7 consecutive days, late blight would appear within 3 weeks and ii) if hourly temperature ranges from 10-20^oC associated with high RH (80% or more) for continuous 18 hr for two consecutive days, the blight would appear within a week. Based on these criteria a late blight warning service was started since 1978 for Shimla hills and successful warnings are issued through All India Radio, Shimla every year.

Late blight forecasting in the sub-tropical plains is different to that of temperate highlands. In the hills, environmental conditions (temperature, RH, rainfall) favourable for late blight appearance are assured. There are plenty of rains during the crop season which led to high RH (>80%) for most of the crop season. Temperature remains moderate and congenial throughout. It is therefore, possible to rely on weather parameters like, rainfall, RH and temperature for making disease forecasts. Such situations, however, do not exist in the sub-tropical plains, where there are scanty rains during the crop season. In such a situation, role of micro-climate, fog dew and sunshine becomes critical for the appearance of the disease. Besides, weather data for substantial period is required to develop reliable empirical models.

A late blight forecasting system has been developed for western Uttar Pradesh using temperature, RH and rainfall data. It consists of two models, one each for rainy and non-rainy years.

Model for rainy years

i) Measurable rains (0.1-0.5 mm) for a minimum of two consecutive days
ii) 5-day moving >85% RH period 50 hrs or more
iii) 5-day moving congenial temperature (7.2-26.6^oC) for 100 hrs or more

If above conditions prevail for five consecutive days, blight would appear within 10 days time.

Model for non-rainy years

i) 7-day moving ≥85% RH period ≥50 hrs
ii) 7-day moving congenial temperature (7.2-26.6^oC) ≥ 115 hrs

If above conditions prevail for 7- consecutive days, blight would appear within 10 days time.

Model for Punjab

i) 7-day moving ≥85% RH period ≥90 hrs
ii) 7-day moving congenial temperature (7.2-26.6^{o}C) ≥ 105 hrs

If above conditions prevail for 7- consecutive days, blight would appear within 10 days time.

Model for Tarai region of Uttarakhand

i) 7-day moving ≥85% RH period ≥85 hrs
ii) 7-day moving congenial temperature (7.2-26.6^{o}C) ≥ 135 hrs

If above conditions prevail for 7- consecutive days, blight would appear within 10 days time.

Software for this forecasting system has been developed as JHULSACAST and has been successfully validated.

Early blight (*Alternaria solani* (Ell. & Mart.) Jones & Grout)

Early blight occurs in all the potato growing areas but is common in central India and plateau of Bihar/Jharkhand and Maharashtra. The disease has been reported to cause significant losses (up to 20%) in *Kharif* crops in Ranchi and adjoining plateau region. In north-western and north-easten hills and plains, the disease appears regularly but in lesser significant form since late blight takes over.

Symptoms

Initially the symptoms occur on the lower and old leaves in the form of small (1-2 mm), circular to oval, brown spots. These lesions have the tendency to become large and angular at later stage. Characteristic ‘target board’ concentric rings of raised and depressed necrotic tissue can be observed, often with a chlorotic halo surrounding the lesion. The tuber symptoms comprise brown, circular to irregular and depressed lesions with underneath flesh turning dry, brown and corky. Lesions tend to enlarge during storage and affected tubers later become shriveled.

Epidemiology

The fungus can survive in soil and plant debris particularly in temperate climate. The infected tubers form the primary source of inoculum. The disease is favoured by moderate temperature (17-25^{o}C) and high humidity. Intermittent dry and wet weather is more conducive for early blight.

Phoma leaf spots (*Phoma exigua* Desm., *P. sorghina* Doerema, Doren & Kest.)

Leaf spots caused by *Phoma* spp. also occur widely both in hills and plains. Depending upon the severity, these leaf spots may cause significant yield losses.

Symptoms

Leaf spots due to *P. exigua* are larger (1-2.5 cm) with broad alternate light and dark concentric zones. Affected tubers have grey to greenish black depressed lesions (up to 3cm) on the surface. Leaf spots due to *P. sorghina* are characterized by pin head size spots, which may be oval, circular or irregular (not exceeding 4mm). Infected tubers show grey large lesions (up to 1.7cm).

Epidemiology

These fungi can survive in soil and plant debris and on infected tubers during storage. The infected tubers form the primary source of inoculum. Infection usually appears on the lower leaves near ground level and results in the infection of young immature tubers if not covered by the soil. The disease is favoured by moderate temperature (17-25^{o}C) and high humidity.

Management

The integrated management of early blight and leaf spots is as below:

i) Use disease free tubers for raising the crop.

ii) Removal and burning of haulms of the affected potato crop help in reducing the inoculum in the field.

iii) Cultivation of solanaceous crops, being collateral hosts, nearby potato field must be avoided.

iv) Spray the crop with mancozeb (0.2%), chlorothalonil (0.2%), copper oxychloride (0.3%) and Bordeaux mixture (1.0%).

SOIL AND TUBER BORNE DISEASES

Soil and tuber borne diseases are multifaceted in nature. Most of the pathogens have a very long soil phase and also carried through potato tubers. These diseases may cause disfiguring of tubers thereby impairing the quality, tuber rots in storage & transit, and wilts and stem rots in field.

Black scurf (*Rhizoctonia solani* Kuhn)

Symptoms

Almost all plant parts are affected. The fungus attacks young sprouts through epidermis and produces dark brown lesions thereby killing the sprout before emergence, which result in gappy germination. Elongated reddish brown lesions develop on the stem at or below soil surface that may girdle the stem. When the girdling is complete the foliage curl and turn pinkish to purplish. Often aerial tubers are formed as a result of interference in starch translocation. Towards the end of the season, the fungus produces numerous hard, small, dark brown to black sclerotia on the surface of mature tubers. These sclerotia when get deposited continuously, form a black encrustations on the tuber surface. The fungus also causes foliage blight of potato.

Epidemiology

Seed tubers serve as the main source of the disease. In the hills, the fungus survives in the soil throughout the year and is a potential source of the disease. However, high summer temperatures are not conducive for the production of sclerotia and their survival. Therefore, *R. solani* has to over summer either as saprophytic mycelium or by infecting the crops grown during summer period. The soil temperature governs production of sclerotia on the tuber surface. The optimum temperature for growth of the fungus is 25-30^{o}C and for the germination of sclerotia is 23^{o}C.

Charcoal rot (*Macrophomina phaseolina* (Tassi) Goid

Symptoms

The pathogen produces three types of symptoms i.e. stem blight, charcoal tuber rot and dry tuber rot. The charcoal tuber rot phase is important under Indian conditions. The first visible symptoms are black spots (2 to 8 mm) surrounding the lenticels and eyes. As the disease advances, the tissue underneath the skin becomes uniformly black up to a depth of 2 to 5 mm. No sclerotia are formed.

Epidemiology

Both tubers and soil may serve as primary source of inoculum. However, soil is the main inoculum source. Soil temperature at or preceding harvest is the most crucial factor for disease development. Temperature below 28^{o}C almost completely checks the disease. Therefore, in sub-tropics, tuber rottage is less in crop lifted before middle of February. Disease buildup is faster in sandy-to-sandy loam soil as compared to clay soil.

Black dot (*Colletotrichum coccodes* (Wallr.) Hughes (Syn.: *C. atramentarium* {Bek. & Br.} Traub.)

Black dot is commonly found in most potato growing regions. It is generally considered to be a surface blemishing disease of tubers, which downgrades potatoes, destined for table purposes and may affect seed tuber sales due to disease tolerance restrictions. Recent studies indicate that the fungus may be associated with the potato relatively early in the growing season, and with many plants over a wide geographic area. Therefore, yield effects may be more significant than formerly assumed.

Symptoms

Symptoms on leaves are less common than stem or tuber symptoms in the field. Infection of vascular tissue and girdling stem lesions can induce yellowing and wilt like symptoms, which generally progress from plant apices to lower portions of the plant. Wilt symptoms may be confused with those caused by *Fusarium* or *Verticillium*. Small, black, dot-like sclerotia (microsclerotia) are formed abundantly in stem lesions, particularly late in the growing season, and are visible to the naked eye. Sclerotia may form in internal tissues as well.

On roots and stolons silvery brown lesions are formed on which characteristic microsclerotia are readily formed-aiding to diagnosis. Infected remnants of stolons oftn adhere to tubers at harvest.

Tubers infected with *Colletotrichum* develop dark, grayish lesions which appear similar to silver scurf. However, black dot lesions are more irregular, with undefined margins. They also usually contain microsclerotia which are smaller than those on stolons. Extensive tuber blemishes may increase tuber respiration, resulting in shriveling and tuber shrinkage.

Epidemiology

The pathogen overwinters as microsclerotia occurring free or on colonized plant debris in the soil. The fungus can persist in the soil for at least 8 years. The fungus may also overwinter as sclerotia on infected seed tubers and, therefore, infection of plants may be due to tuber –borne and/or soil borne inoculum. Conidia probably serve as the primary inoculum for infection. Conidia do not germinate at 7^0C, the optimum temperature for germination and infection is between 22 & 28^0C. Roots are the organs most susceptible to infection; stems generally become diseased only after the fungus is well established on the underground stem of the plant. Black dot is commonly associated with high temperature, poor soil drainage and sandy soils, and low nitrogen levels. Other solanaceous plant species and several weed species also act as hosts for *C. coccodes*. In storage, infection and symptom development are favoured by warm, humid conditions.

Silver Scurf (*Helminthosporium solani* Dur. & Mont.)

It is a common storage disease and occurs wherever potatoes are grown. Now, it has become an economically important disease through reduction in cosmetic quality of washed fresh-packed potatoes. Silver scurf does not usually cause yield loss, but severe seed infection can affect vigour. The disease is also becoming important in potato processing, because crisps made from potatoes with severe silver scurf infection may result in blackened edges, making the product unmarketable. Fresh weight reduction of tubers may also occur due to excessive moisture loss from the tubers through lesions.

Symptoms

There are no above ground symptoms and on roots. However, lesions can be observed on stolons soon after tuber initiation. The most conspicuous symptoms are produced on tuber periderm. The lesions are roughly circular in size, expanding up to several centimeters. The edge of the lesion is regular. The disease gets its name because the lesions are mostly silvery in colour. In soil, established lesions expand rapidly within a few weeks of planting infected seed tubers. Lesions on progeny tubers spread slowly on the surface when in soil. The lesions are usually small at the harvest but enlarge during storage.

Epidemiology

Perpetuation of the disease takes place through soil as well as tuber borne inoculum. Therefore, transmission of silver scurf can occur through infected seed introduced into soil or through conidia present in soil. Conidia produced in storage conditions are released and carried to other tubers via circulating air. Under favourable conditions – moderate to warm temperatures (10-32^{o}C) and very high humidity or free water-conidia germinate on plant tissue by polar germ tubes and cause infection of tubers.

Fusarium wilt and dry rot (*Fusarium* spp.)

Symptoms

Variety of symptoms is produced on potato including wilt, stem rot and damping off of seedlings. On tuber they produce spots, necrosis, dry rot and seed piece decay. In wilting, lower leaves turn yellow and the affected plant dries off rapidly. Both stems and tubers at stolon end show vascular browning. In some cases wilting may be accompanied by rotting of stem base. It may cause damping off of seedlings if planted early in the season when temperature is high.

Dry rot is a storage disease and does not become evident until 2-3 months of storage. Rot may occur in any part of the tuber but wounded site and stolon end are the most vulnerable. Initially the infected tissue develops slight depression, which increases, and the skin develops wrinkles in the form of irregular concentric circles. Underlying tissue assumes mealy and brown fungal mycelium.

Epidemiology

Infected tubers and soil are the primary source of inoculum. Dry rot development is affected by tuber age, tuber size, storage conditions, tuber damage and degree of curing. Dry rot infection gets aggravated 5-6 months after harvest. Store temperature ranging 20-28^{o}C is congenial for dry rot development. Wilt is mainly affected by soil temperature and relative humidity. High wilt incidence in early planted crop is mainly associated with high soil temperature.

Powdery scab (*Spongospora subterranean* (Wallr.) Lagerh.

Symptoms

The fungus attacks all underground parts of the plant without showing any adverse effect on plant growth. The damage to the tubers is however, more serious. The disease does not affect the potato yields but disfigures tubers, reducing its commercial value and renders them unsuitable for seed purpose. Pimple like spots appears on the surface of young tubers. These spots are circular, smooth and light brown which gradually increase in size and ultimately rupture, exposing a cavity containing a brown powdery mass of spore balls. Deep pustules of powdery scab resemble deep pitted common scab lesions. However, powdery scab pustules are filled with mass of fungal spore ball whereas common scab lesions are empty.

Epidemiology

The fungus over winters through spores in soil and on infected seed tubers. The spores germinate during crop season and produce zoospores in soil, which infect the tubers through lenticels or directly through epidermis. Soil temperature and moisture are the main factors affecting the disease. Low soil temperature (0-15^{o}C) coupled with high soil moisture is ideal for disease development. This disease is a high altitude disease and is seldom noticed below 2500 m amsl and its incidence increases with the increase in altitude.

Wart (*Synchytrium endobioticum* (Schilb) Perc.)

Symptoms

It is a disease of potato tubers and is usually not recognized in the field until the tubers are dug out. The disease is characterized by prominent warty protuberances resembling cauliflower or bunches of ‘cocks comb’ like proliferated outgrowth on tuber. Sometimes small greenish warty growths on the stalks may be observed near the ground level.

Epidemiology

Wart disease is both soil and tuber borne. Once the soil is contaminated with the resting sporangia, it becomes an important source for the spread of the disease, as winter sporangia are known to remain viable for many years. The chief means by which the disease spreads is through the transportation of material containing resting spores. The disease is worst in wet season. Both winter and summer sporangia can germinate over a wide range of temperature (12-18^{o}C) if the moisture is favourable.

Wilts

Verticillium wilt (*Verticillium alboatrum* Reinke & Berth.)

Symptoms

The infection starts from the roots and the fungus grows into the stem and colonizes the xylem vessels thereby disrupting the water and mineral supply to the aerial parts as a result plants remain stunted, lack vigour, lower leaves tend to droop and there is loss of turgidity. Vascular bundles of stem and tuber become brown. In tuber initial infection is seen as yellowish discolouration at the stolon end. In tuber, initial infection is seen as yellowish discolouration at the stolon end.

Sclerotium wilt (*Sclerotium rolfsii* Sacc.)

Symptoms

Infection starts at the stem base in the form of 1-2 cm dark brown lesions, which gradually enlarge and encircle the stem base resulting in the collapse of plant. The pathogen produces white fungal mat and mustard sized sclerotia on the underground parts within the hyphal mat.

Sclerotinia wilt (*Sclerotinia sclerotiorum* (Lib.) de Bary)

Symptoms

The disease occurs on the stem either at the soil line or at the junction with leaf petioles. Early symptoms on stems are the appearance of water soaked areas on which white fluffy mycelial growth subsequently develops, which gradually enlarge and encircle the stem base resulting in the collapse of plant. Rotting of the stem may extend up to 5 cm above the ground. In the later stages of symptom development, large, dark, compact resting sclerotia are formed in stem pith.

Epidemiology

All the wilt causing fungi survive in the soil and plant debris although infected seed tubers my also act as the primary source of inoculum. *Sclerotium* survives in the soil in mycelial as well as in sclerotial form. The fungus may also survive on collateral hosts. The fungus gets aggravated at high soil temperature (25-30^{o}C) and requires alternate periods of wet and dry soil. Flooding of soil kills *S. rolfsii* thereby reduces the wilt.

Infected tubers and contaminated soil serve as the source of primary inoculum for *Verticillium* wilt. For the perpetuation of the disease the seed surface contamination has been reported to be more important than the internal seed borne inoculum. The pathogen requires comparatively low temperature and therefore, restricted to cooler parts of the country.

S. sclerotiorum overwinters as mycelium in dead or living plants, but primarily in the form of sclerotia. In soil it can remain viable up to 5 years. It also requires comparatively low temperature (10-27^{o}C) and therefore, restricted to cooler regions of the country.

Management of soil and tuber borne diseases

Soil and tuber borne diseases primarily perpetuate through infected seed tubers and soil. Their management therefore, requires elimination or lowering down of the inoculum load on the tubers as well as in soil. Management strategies therefore, have to be many fold for combating these diseases.

Cultural practices

Crop rotations and green manuring: When potato crop is planted year after year in the same field, the survivability of the pathogens and their buildup gradually increases over the years. Although, most of the diseases, which infect the potato crop, have wide host range, it is still possible to keep the pathogens population within manageable limits by practicing suitable crop rotations. It has been found that long-term rotation of maize or sun hemp with potato significantly reduced black scurf and charcoal rot incidence. Sesbania, sunhemp and pearl millet are also effective against black scurf. *Verticillium* wilt can be effectively managed if potato crop is grown after two years of Kulth cultivation. Intercropping of potato with maize, rotated with bean or radish was quite effective in the management of potato wart.

Amendment of oil cakes: Oil cakes have mostly been tried for the management of black scurf and *Fusarium* wilt. Buildup of the *Fusarium* population was least in groundnut cake amended soil followed by mustard cake and cotton seed cake.

Adjustment in planting and harvesting time: Some of the soil and tuber borne diseases are temperature sensitive and can be effectively managed by altering the planting and harvesting dates. By advancing the harvest from February 16 to January 30, the incidence of black scurf was brought down by more than 50 %. Similarly, harvesting of potato tubers before the soil temperature crosses 28^{o}C reduces charcoal rot incidence in endemic areas. By delaying the planting from October 1 to October 30 resulted in 36% reduction in *Fusarium* wilt.

Sanitation: Use of disease free seed, weed control and removal of diseased plants/debris from field are some of the cultural practices that reduce soil and tuber borne inoculum.

Soil solarization: Soil solarization by the use of transparent polyethylene sheet is an effective, simple and ecofriendly way of managing soil borne diseases. This method could be useful in tropical and sub-tropical plains where summer temperatures are very high and is practicised during the hottest period of the year. Solarization was superior to deep summer ploughing as it reduced black scurf incidence by 55.6% and russet scab by 58.4%.

Biological Control

Use of *Bacillus subtilis* (B-5) has been found effective against black scurf, common scab, Fusarium wilt and bacterial wilt. A combination of soil solarization and seed treatment with boric acid or *Trichoderma viride* improved black scurf. A bioformulation developed at Central Potato Research Institute from *T*. *viride* strain A-7 was found very effective when used as seed treatment before planting potatoes (Arora and Somani 2001). An integrated use of *Trichoderma viride* and boric acid significantly further improves disease control.

Host Resistance

Disease resistant or immune varieties are the best methods to check soil and tuber borne diseases, however, such varieties are available only against few diseases. Varieties immune/resistant to art disease are Kufri, Sherpa, K. Kanchn, K. Jyoti, K. Muthu, K. Bahar, K. Chmatkar, K. Khasigro, K. Kumar, K. Giriraj, K. Chipsona-2, K. Anand, K. Pukhraj, K. Jawahar and K. Sutlej. The early maturing varieties like K. Chndarmukhi nd Up-to-Date are less prone to charcoal rot and may be cultivated in spring. Most of the varieties in India are susceptible to black scurf. However, K. Dewa, K. Bahar and K. Sherpa are comparatively less susceptible.

Chemical Control

Dipping of infected tubers in boric acid (3 %) for 30 minutes or spraying on tubers has been recommended for the management of tuber borne diseases.

Suggested readings

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