

Disease management in seed potato production

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Potato is affected by many diseases which affect at both pre-and post-harvest stage of the crop. Major fungal and bacterial diseases which affect the crop are late blight, early blight, black scurf and stem canker, dry rot, silver scurf, common scab, bacterial wilt, soft rot and black leg. These diseases are prevalent in most potato growing areas and can cause a significant reduction in potato production. A brief description of these diseases and their management is given in this article.

Keywords: Biotic stresses, Disease symptoms, Management approaches

THE potato has the potential to be a particularly useful crop for helping marginal farmers to achieve food security and alleviate poverty as it has one of the most diverse distribution patterns of any global crop. Potato production has increased at a consistent rate across Asia for nearly half a century, with China and India leading the way. Potato cultivation in developed and developing nations is consistently threatened by biotic stressors that critically hamper crop production and productivity. The diseases which were earlier considered minor and less damaging are now emerging as major concerns in the potato cultivation system. Among the fungal (including oomycete) and bacterial diseases, we have highlighted the critical concerns

and possible management of late blight, early blight, black scurf and stem canker, dry rot, silver scurf, common scab, bacterial wilt, soft rot and black leg which are raising alarms in the potato industry.

Late blight

Late blight, caused by the oomycete *Phytophthora infestans*, has remained a serious threat to potato production worldwide and is still considered a threat to global food security because of its regular emergence of novel strains with increased virulence and appearance in new locations with surprising intensity. It causes losses to the tune of € 12 billion per annum of which the losses in developing countries have been estimated around € 10 billion per annum. In India, average

annual crop losses to the tune of 15% have been estimated which amounts to 8.0 million tonnes of potatoes. Late blight affects all plant parts including leaves, stems and tubers. It appears on leaves as water-soaked irregular pale green lesions mostly near tip and margins which rapidly grow into large brown to purplish black necrotic spots. A white mildew, which consists of sporangiophores and sporangia of the pathogen, can be seen on lower surface of the infected leaves especially around the edges of the necrotic lesions. In dry weather, the water-soaked areas dry up and turn brown. On stems and petioles, light to dark brown lesions encircle the stems as a result the affected stems and petioles become weak at such points and may collapse. Entire crop



Fig. 1. Symptoms of late blight

gives blighted appearance especially under disease favourable conditions and may be destroyed within a week. Tubers in soil become infected by rain/dew borne sporangia trickling from the diseased foliage and show irregular reddish brown to purplish areas which extend into internal tissues of the tubers (Fig. 1). The infected tubers usually are hard, dry and firm but may get attacked by soft rot causing bacteria and rot in fields and stores. Sepals, flowers and berries may also get infected and show white mildew under humid and cloudy weather.

Understanding the diversity of *Phytophthora infestans* populations is crucial for developing effective management strategies. Changes in the pathogen's populations directly impact the deployment of resistant cultivars, the performance of disease warning systems, and the efficacy of plant protection products. Appearance of late blight and its subsequent build-up and spread depends on several factors. These include sources of inoculum, host resistance, plant protection support provided through fungicide sprays and weather conditions. Weather conditions such as temperature, relative humidity, rainfall, dew, sunshine hours etc. have a direct effect on *P. infestans*. Moderate temperature (15-20° C) and high humidity (>80%) are conducive for the spread and build-up of late blight in the field.

Early blight and Leaf spot

Alternaria symptoms on potato are due to a disease complex caused by different species. Earlier, *A. alternata* was considered to be the causal agent of potato brown spot, while *A. solani* causes potato early blight. However, different species are commonly found together on an infected leaf, symptoms of which are hard to discriminate and for these reasons; Alternaria on potato is referred to as a disease complex.

The typical symptoms on leaves appear as small, round, oval or angular, dark brown to black, dry and papery necrotic spots which have angular margins. These spots are generally limited by leaf veins.



Fig. 2. Symptoms of early blight

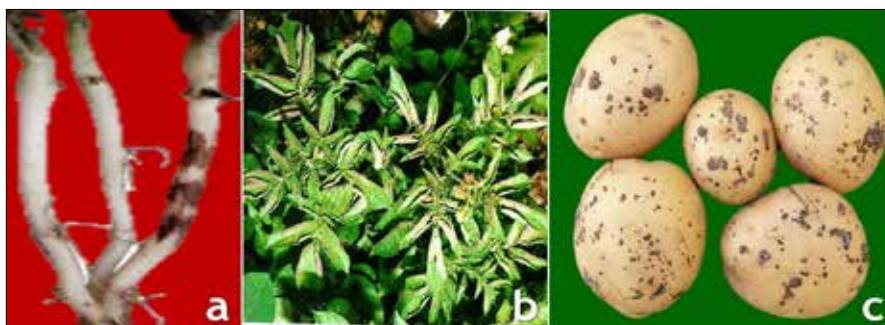


Fig. 3. Stem canker (a), rosetting of plant tops (b) and black scurf (c) caused by *Rhizoctonia solani*

The spots may or may not have concentric rings. The rings are more prominent in large blotchy spots that give them a bull's eye or target board appearance. Early blight lesions are less prone to secondary infections. Leaf tissues around the spots often become chlorotic and yellow suggesting involvement of toxins. The leaf spots may coalesce and the affected field appears severely blighted (Fig. 2). The disease may also affect the tubers. On tubers, the lesions are dark, sunken, circular to irregular in shape, shallow and separated from healthy tissue by purplish-brown dry cork layer.

Across the globe, a total of eleven *Alternaria* species have been associated with causing foliar diseases on potatoes. These species encompass *A. solani*, *A. alternata*, *A. tenuissima*, *A. dumosa*, *A. arborescens*, *A. infectoria*, *A. grandis*, *A. interrupta*, *A. longipes*, *A. arbusti*, and *A. protenta*. The prevalence of *A. alternata* and *A. solani* may differ in various regions. The disease is able to thrive from season to season on volunteer tomato and potato plants as well as other weedy Solanaceous hosts such as horsenettle and nightshade in locations where the temperatures are quite mild. Warm and humid (24-29°C) conditions are favourable

for the spread of infection. Infection can take place in environments that experience alternating periods of wet and dry circumstances.

Black scurf and Stem canker

The disease affects tuber quality by the development of sclerotia on progeny tubers, thus their market value is reduced. Yield losses up to 35% primarily due to reduced crop stand have been reported. The disease can kill eyes during storage; affect stems before emergence (stem canker) and form black scurf (black irregular lumpy encrustations of fungal sclerotia) on progeny tubers after senescence. Infected sprouts become blackened and may not emerge in severe cases. Reddish brown lesions develop on stems and often girdle them. Partial or complete girdling of the stems results in rosetting of plant tops, purple pigmentation, upward chlorosis or rolling of leaves. Formation of aerial tubers in axis of leaves due to interference with starch translocation, are also observed in the infected plants (Fig. 3).

The disease is prevalent in most potato growing regions of the world including India. In India, it has spread widely in most potato growing regions.

The disease is caused by a fungal pathogen *Rhizoctonia solani* Kuhn (perfect basidial stage: *Thanatephorus cucumeris* (Frank) Donk). *R. solani* is classified into 14 anastomosis groups (AGs) based on the hyphal anastomosis reaction. These AGs, designated as AG1 to AG13, provide a broad categorization of different subgroups within the species. Research in the past has linked specific symptoms of disease to AGs, suggesting that these AGs have host preferences. *R. solani* AG 3 is most often found in Solanaceae plants and can be further classified as AG 3-PT on potatoes, AG 3-TB on tobacco, and AG 3-TM on tomatoes. Infecting all underground components of potato plants at any stage of development, AG 3-PT has been identified as the most widespread AG worldwide connected with potato diseases.

The pathogen is both soil and seed borne but the disease spreads to new growing areas primarily through sclerotia-covered seed tubers. Soil-borne infection emerges later in the season since the fungus needs some time to grow into proximity with its potato host. Optimum temperature for germination of sclerotia is 23°C and for development of stem lesions is 18°C. Sclerotial development on tubers is initiated depending on environmental conditions. Maximum development of sclerotia takes place in the period between dehauling and harvest of the crop. Late harvested crop show more black scurf incidence. The host range of *R. solani* is very wide and the pathogen causes diseases of many economically important plants belonging to Solanaceae, Fabaceae, Asteraceae, Poaceae and Brassicaceae as well as other ornamental plants and forest trees.

Fusarium dry rot

Potato dry rot, caused by *Fusarium* spp., is a devastating pathogenic disease that has a major impact on potato tubers around the world. Potatoes suffer a drastic drop in quality due to the disease, which in turn causes massive economic losses. Fifteen different *Fusarium* species have been identified as the causal agents of potato dry rot.



Fig. 4. Symptoms of *Fusarium* dry rot on tubers

Tubers that have dried out, shrunk, and withered usually show an exterior skin that is paper-thin, light- to dark-brown in colour. The diseased area has a soft, spongy touch, a bad odour. On the surface of the tuber, there is a black, dry, and powdery fungus growth. The longitudinal cut on tubers shows internal rotting, necrotic lesions, tan brown to white or pinkish mycelial mass (Fig. 4).

The life cycle of *Fusarium* species, including *Fusarium solani*, is comprised of several stages, including sexual and asexual reproduction. *Fusarium* species can produce chlamydospores, which are thick-walled, spherical structures that serve as survival structures for the fungus. Chlamydospores can persist in the environment for long periods and can give rise to new infections when conditions are favourable. Additionally, macroconidia and microconidia are a key component of the survival and dispersal strategies of *Fusarium*, and play a critical role in the spread of the fungus and the establishment of new infections. The survival of *Fusarium* spores in soil and on plant debris serves as the primary reservoir of inoculum and the main source of tuber infections in the field. Subsequent rotting of progeny

tubers occurs only after wounds develop due to intercultural operations.

Optimal temperatures for the mycelial growth of *F. sambucinum*, *F. graminearum*, *F. solani*, and *F. culmorum* range between 20 and 25°C, while temperatures between 25 and 30°C are necessary for sporulation. Temperatures below 5°C generally reduce the risk of infection; however, *F. sambucinum* and *F. graminearum* have shown mycelial growth even at temperatures below 5°C, contributing to the development of dry rot even at extremely low temperatures. Temperatures exceeding 40°C completely inhibit the growth of all fungal species involved in dry rot disease.

Silver scurf

Silver scurf disease of potatoes, caused by *Helminthosporium solani*, has emerged as a significant skin blemish disease over the past two decades. It is a global issue affecting potato crops in various regions, both in the field and during storage, leading to economic losses. The typical symptoms of silver scurf include light brown or greyish leathery spots primarily observed on the stem end of tubers. These spots can expand to cover the entire tuber surface, and their lustrous



Fig. 5. Symptoms of silver scurf on tubers

appearance is more noticeable when the tubers are moist, even when dry (Fig. 5).

The earliest studies on epidemiology indicate that the minimum conditions for infection are a temperature of 3°C and a relative humidity of 90%. The observation provided strong support for the hypothesis that if the storage conditions are optimal for the pathogen, then multiple disease cycles are finished within six months of the product being stored. As soon as the spores are produced beneath the soil surface, irrigation water and rainwater carry these spores downwards with percolation, which ultimately leads to further infection and sporulation on the stolons and roots of progeny tubers. The abundant sporulation that takes place on progeny tubers happens repeatedly within a week, and as a result, multiple infection cycles take place in the soil. The same thing happens when the infected seed tubers are stored; even though they may have shown very few or no symptoms at the time of harvest, as soon as they are transported to warehouses and cold storage facilities, they develop severe infections within a week. On the surface of infected tubers that are maintained at high relative humidity (85–95%), multiple sporulation cycles can begin.

Common scab

Common scab causes superficial lesions on surface of potato tubers. The disease seldom affects yield but economic losses may be high as the affected tubers fetch low price in market due to their poor appearance. Seed lots exceeding 5% incidence are rejected by seed certification agencies (in India) causing huge loss to seed industry. Scab begins as small reddish or brownish spot on the surface of the potato tubers and its initial infection takes place during juvenile period of tubers. Infection takes place mainly through lenticels and surrounding periderm turns brown and rough. Lesion becomes corky due to elongation and division of invaded cells. Under Indian conditions, multiple kinds

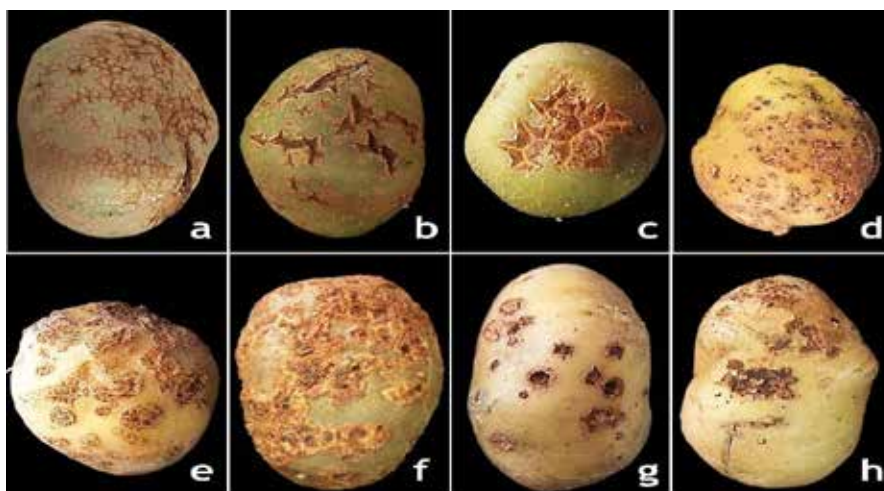


Fig. 6. Various types of scab symptoms caused by *Streptomyces* species on potato tubers

of symptoms have been recorded and they are grouped as, (1) a mere brownish roughening or abrasion of tuber skin, (2) proliferated lenticels with hard corky deposition, might lead to star shaped lesion, (3) raised rough and corky pustules, (4) 3-4 mm deep pits surrounded by hard corky tissue, (5) concentric series of wrinkled layers of are around central black core (Fig. 6).

More than 19 *Streptomyces* spp. have been reported to cause common scab on potato worldwide. The prominent are *Streptomyces scabies*, *S. acidiscabies*, *S. turgidscabis*, *S. collinus*, *S. griseus*, *S. longisporoflavus*, *S. cinereus*, *S. violanceoruber*, *S. alborgriseolus*, *S. griseoflavus*, *S. catenulae* etc. *Streptomyces* spp. may be pathogenic or non-pathogenic. The pathogenic species produce thaxtomins which are phytotoxins and cause hypertrophy and cell death. Ability to produce thaxtomin toxin is strongly correlated with the pathogen's pathogenicity.

Potato is physiologically most susceptible to *Streptomyces* spp. in the period following tuber initiation. *Streptomyces* species infects the newly formed tubers through stomata and immature lenticels. Once the periderm has differentiated, tubers are no longer susceptible to the pathogen. The pathogen is both seed and soil borne. It can survive in soil for several years in plant debris and infested soil. Soil conditions greatly influence the pathogen. Favourable conditions include pH between 5.2 to 8.0 or more, temperature in the

range of 20 to 30°C and low soil moisture. The pathogen is aerobic in nature and maintaining high soil moisture for 10 to 20 days after tuber initiation can help in reducing the common scab. The organism is a tuber-borne and is well-adapted saprophyte that persists in soil on decaying organic matter and manure for several years. Infected tubers serve as source of inoculum in the field, giving rise to infected progeny tubers.

Brown rot or Bacterial wilt

Brown rot or bacterial wilt is one of the most damaging diseases of potato. The disease causes wilting of plants in standing crop and also causes rot of infected tubers in field, storage and transit. The earliest symptom of the disease is slight wilting in leaves of top branches during hot sunny days. The leaves show drooping due to loss of turgidity followed by total unrecoverable wilt. Bacterial wilt in field can be distinguished from other fungal wilts by placing the stem cut sections in clear water. Within a few minutes, a whitish thread like streaming can be observed coming out from cut end into water. This streaming represents the bacterial ooze exuding from the cut ends of colonized vascular bundles. The same test can also be carried out to see infection in tuber. In tubers, the vascular tissues of a transversely cut tuber show water soaked brown circles where dirty white sticky drops appear in about 2-3 minutes.

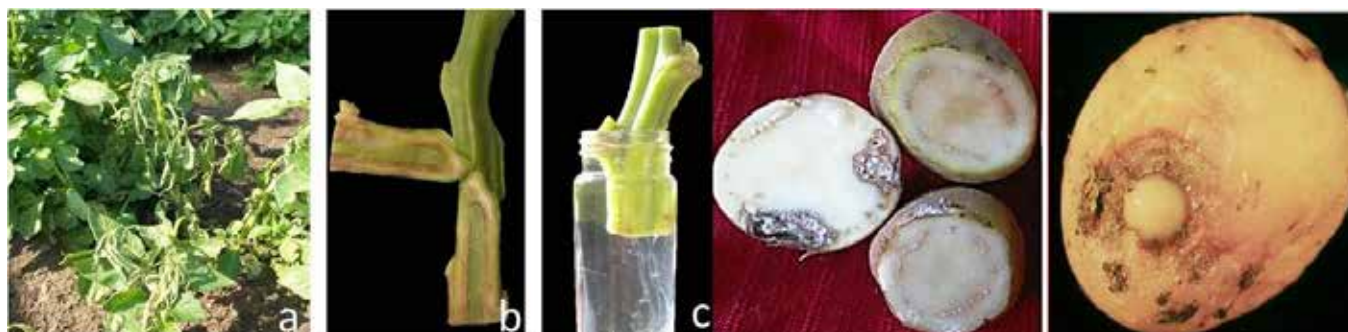


Fig. 7. Symptoms of bacterial wilt; (a) brown discoloration of stem tissues; (b) bacterial streaming in clear water from stem cut section of potato; (c) vascular browning of tubers; (d) emergence of bacterial mass through eye due to *R. solanacearum*

In advanced stages of wilt, bacterial mass may ooze out from eyes (Fig. 7).

The disease is caused by a Gram-negative bacterium *Ralstonia solanacearum*, a widespread plant pathogen that affects more than 200 different species from over 50 botanical families worldwide. This bacterium forms a species complex, which is further classified into four phylotypes and then sequevars. Based on whole genome comparisons, the complex has been reclassified into three distinct species: *R. solanacearum* (Phylotype II), *R. pseudosolanacearum* (Phylotypes I and III), and *R. syzygii* (Phylotype IV). Among these phylotypes, there are strains of *R. solanacearum* capable of causing bacterial wilt and brown rot in potatoes. The strain known as *R. solanacearum* (sequevar 1) within Phylotype IIB (PIIB1), previously referred to as race 3/biovar 2, is most commonly associated with potatoes.

The pathogen infects roots of healthy plants through wounds. Infected tubers and plant debris in infested soil are two major sources of inoculum. Mean soil temperature below 15°C and above 35°C do not favour the disease development. Soil moisture influences the disease

in at least four ways; (i) increasing survival of the bacterium in the soil, (ii) increasing infection, (iii) increasing disease development after infection, and (iv) increasing exit of the bacterium from host and spread through the soil. *Ralstonia solanacearum* is capable of causing brown rot in a wide range of soil types and levels of acidity. In majority of the cases, the disease has been reported in acidic soils (pH 4.3 to 6.8) and only in a few cases in alkaline soils. Under favourable conditions, potato plants infected with *R. solanacearum* may not show any disease symptoms. In this case, latently infected tubers used for potato seed production may play a major role in spread of the bacterium from infected potato seed production sites to healthy potato-growing sites.

Soft rot and Black leg

Bacterial soft rot can cause significant loss of potato tubers at harvest, transit and storage. Losses due to poor handling of the produce, poorly ventilated storage or transit may go up to 100%. Soft rot bacteria usually infect potato tubers which have been damaged by mechanical

injury or in the presence of other tuber borne pathogens.

Aerial stem rot (black leg symptoms) can occur when the bacteria infect stems that have been harmed by cultivation equipment or bad weather. Although bacteria can produce tuber soft rot, blackleg is the disease's main sign in potato plants. Necrosis or death of the potato stem, which starts at the point of contact with the mother tuber and spreads several centimeters above the ground, is the traditional first sign of blackleg. The plant's vascular system will become necrotic as the disease worsens, and the leaves will wilt and curl. In extreme circumstances, the stem's pith may also rot. On tubers, the disease appears as small soft water soaked spots around lenticels which enlarge under high humidity. A brown to black pigment may develop around the lesion (Fig. 8). The soft rot affected tubers become slimy and foul smelling and brown liquid oozes out from the affected tubers. The tuber skin remains intact and sometimes the rotten tubers are swollen due to gas formation. At harvest, many small rotten tubers with intact skin can be seen. The disease affects the crop at all stages



Fig. 8. Symptoms of black leg or aerial stem rot (left) and tuber soft rot (right)

of growth but it is more serious on potato tubers under poor storage conditions especially in warm and wet climate.

Pectobacterium atrosepticum (syn. *Erwinia carotovora* subsp. *atroseptica*), *Pectobacterium carotovorum* subsp. *carotovorum* (syn. *Erwinia carotovora* subsp. *carotovora*), *P. brasiliense*, *Dickeya* spp. (including *D. dianthicola*, *D. dadantii*, *D. zeae*) (syn. *Erwinia chrysanthemi*) etc. have been found to cause soft rot. The optimal and upper limits of temperature for growth vary between species. For instance, *P. atrosepticum* and *P. parmentieri* cannot survive temperatures above 33°C, while *P. carotovorum* and *P. brasiliense* are capable of growing at temperatures as high as 39°C. *Pectobacterium* is occasionally detected in or on minitubers, but it is more frequently found on potato tubers that have been cultivated in the field. The occurrence of *Pectobacterium* on potato tubers tends to increase with each generation of potato multiplication.

Soft rot bacteria may be carried latently in lenticels, wounds and on surface of tubers without any visible symptoms and spread to healthy tubers in stores, during seed cutting, handling and planting. Water film on surface of tuber which cause proliferation of lenticels and creates anaerobic conditions and injury on surface of tuber predispose potatoes to soft rot. Decaying tubers in soil could serve as source of contamination for healthy tubers. Tubers harvested in wet soil, poor ventilation in transit and storage promotes the rot. In warm climates, where one potato crop follows another or where only short rotation cycles are applied, the bacteria can pass easily from one crop to the next, especially in poorly drained soil. The bacteria can survive at places where rotten potatoes and vegetables are dumped.

Management approaches

Off-season management of field: Most pathogens perpetuate in plant

remnants and in the root system of many weeds and crops. Clean the field from weeds and root/ foliage remnants and burn or deep bury them. The pathogen in remnants can be exposed to high temperature above 40°C in summer in plains and plateau and low temperature below 5°C in hills by giving deep ploughing twice at 20-30 days interval during peak summer or winter. This may cause extinction of many pathogens from the field.

Healthy seed: Use of healthy planting material can take care of tuber borne diseases. Procurement of certified seed tubers from a reliable source can check the spread of a disease to new areas. Do not cut seed tubers as cutting knife spreads pathogens from diseased to healthy tubers. Also cut tubers contact disease from soil easily.

Host resistance: Host resistance is the best plant disease management method since it is cost-effective, environmentally benign, sustainable, stable, and flexible. Use resistant varieties wherever possible. Lot of late blight resistant varieties are available for different ecologies.

Ecosystem management: There has been a renewed interest in employing eco-evolutionary strategies for managing plant diseases in agricultural ecosystems. One such approach is the utilization of biodiversity, which involves the use of mixtures of genotypes from the same species. Increasing biodiversity can have multiple benefits for plant disease management: i) diversifying selection exerted by the presence of diverse genotypes can limit the evolution of pathogen infectivity; ii) the physical barriers created by increased biodiversity impede pathogen dispersal, resulting in reduced inoculum levels; iii) the increased biodiversity may indirectly promote the development of host immunity while being suboptimal for pathogen survival, reproduction, and transmission.

Increasing genetic diversity through the implementation of varietal mixtures can have multiple positive effects. It can enhance potato yield and reduce the incidence of late blight. Besides, it can also increase the diversity of microorganisms in the rhizosphere which further improves the nutrient availability and thereby plant health and productivity. Studies have indicated that increased genetic diversity among potato varieties led to the minimal chances for the development of fungicide resistance in *Phytophthora infestans*.

Crop rotation practices

Studies have revealed that shorter rotations with few years between succeeding potato crops in the same field increased the incidence of one or more potato diseases as compared to longer rotations. This is most likely due to the fact that short rotations provide pathogens more opportunities to survive on potato host plants and less time for inoculum to diminish between potato crops. *Phytophthora infestans* oospores can survive up to three years in the host debris in soil. Fields that are not used for crop rotations tend to experience early infections. However, the incidence of early infection decreases significantly in fields that have undergone crop rotations for three or more years between potato crops. Therefore, the practice of crop rotation is essential for reducing the risk of soil-borne infections caused by *P. infestans*. Longer rotations lower the incidence of stem canker and *Rhizoctonia* black scurf. When implementing rotations with canola and rapeseed, the severity of *Rhizoctonia* canker, black scurf, and common scab in potatoes consistently decreased. These findings highlight the effectiveness of incorporating canola and rapeseed rotations, as well as a winter rye cover crop, in reducing the severity of *Rhizoctonia* canker, black scurf, and common scab in potato crops. The emerging and consistent problem of common scab in potato cultivation requires the old but effective crop management

technique of crop rotation. It has been demonstrated that the *Streptomyces scabiei* population in soil can be effectively reduced in one of two ways: either by leaving the field fallow after potato cultivation or by including mung bean or sun hemp as green manure in a single-year cropping sequence over the course of a period of four years. Crop rotations that included mung bean and sun hemp were particularly effective at boosting the rhizosphere's microflora, particularly fluorescent *pseudomonads* and various species of *Trichoderma*. The effectiveness of crop rotation in managing potato dry rot, specifically caused by *Fusarium*, has been found to be limited. One of the primary reasons for the limited effectiveness of crop rotation in managing potato dry rot is the ability of *Fusarium* to infect a wide range of hosts and can persist in the soil for extended periods. This characteristic poses a significant challenge in controlling the pathogen solely through crop rotation.

Nutrient management in pathogen mitigation

The growth and development of plants, microorganisms, and the prevention and treatment of disease all depend critically on nutrition. The intensity of diseases can be affected by all important nutrients. There is a well-established report that enrichment of the foliage with nitrogen enhanced host resistance to *Alternaria* but increased late blight severity. Adequate application of potassium is found to reduce the incidence of several diseases, such as late blight, dry rot, powdery scab and early blight. Zinc (Zn) plays a crucial role in enhancing potato tolerance to early blight disease. Therefore, it should be included as a preventive measure in the disease management plan. Application of zinc and sub-toxic concentration of boron has been shown to decrease both the incidence and severity of early blight and late blight diseases in potato plants. The application of potassium phosphate or phosphorous acid alone or

in combination with fungicides suppresses late blight disease in potatoes.

It is important to consider the pH requirements and management strategies specific to each disease when aiming to mitigate their occurrence and impact in potato cultivation. Maintaining soil pH levels close to neutral has been linked to an increased incidence of diseases such as potato scab. The prevalence of potato scab, which is caused by *Streptomyces scabies*, might therefore be reduced by either reducing the pH of the soil or using Mn. The sulphur fertilization has been reported to reduce the incidence and severity of black scurf and common scab diseases in potato crop.

Disease forecasting

Disease forecasting allows the prediction of probable outbreaks of the disease in advance and thus greatly help potato farmers to take prophylactic sprays and prevent or delay appearance of the disease thereby reducing the losses. Weather conditions such as temperature, relative humidity, rainfall, dew, sunshine hour etc. have a direct effect on *P. infestans*. These parameters have been exploited to develop different models to forecast the disease both in India and elsewhere. Forecasting models for predicting first appearance of late blight have been developed for western hills, eastern hills and southern hills. Based on local weather parameters, a computerized forecast for late blight named as 'JHULSACAST' has been developed for western Uttar Pradesh, Punjab, Tarai region of Uttarakhand and Plains of West Bengal. The INDO-BLIGHTCAST, a pan India model, is being used to predict appearance of late blight across agro-ecologies since 2016. By using forecasting models, need based and judicious use of fungicides can be followed thereby reducing the cost of fungicides and saving of water, labour and environment. Similarly, models are available for the prediction of early blight.

Biological control

Heavy dependence on fungicides could pose a threat to environment and human population. Biocontrol agents and bio-pesticides could be a safe option to the use of synthetic fungicides. Bio-control agents such as *Trichoderma viride*, *T. harzianum*, *Pseudomonas fluorescens*, *P. aeruginosa*, *Bacillus subtilis*, have been observed effective against a number of potato pathogens in laboratory and field experiments. Tuber treatment with *Trichoderma viride* formulation @ 8g/kg tubers at planting is effective in reducing the black scurf and common scab severity. Tuber treatment with *Bacillus subtilis* has been reported effective against common scab.

Chemical management

Spraying with an effective fungicide has been a standard practice for control of foliar diseases of potato. Fungicides such as azoxystrobin, chlorothalonil, mancozeb, propineb, copper oxychloride, cyazofamid, dimethomorph, mandipropamid, metiram, oxathiapiprolin etc. alone or in combination such as ametoctradin + dimethomorph, cymoxanil + mancozeb, famoxadone + cymoxanil, fenamidone + mancozeb etc. are effective for the management of late blight and other leaf spotting diseases. Similarly, seed tuber treatment with 3% boric acid (dip for 30 minutes/ spray) followed by drying under shade before cold storage significantly reduce the tuber surface borne inoculum of a number of fungal and bacterial diseases of potato. Seed tuber treatment with pencycuron, penflufen and thifluzamide have been found very effective for control of the black scurf disease. Application of stable bleaching powder @ 12 kg/ha at the time of potato planting in furrow along with fertiliser gives effective control of bacterial wilt and soft rot diseases.

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