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REVIEW ARTICLE

ECONOMICALLY SIGNIFICANT BACTERIAL AND VIRAL DISEASES OF POTATO AND THEIR MANAGEMENT

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ABSTRACT

In India, about 80 per cent of potato crop is cultivated under subtropical and 20 per cent under temperate to sub-temperate climate. The cultivation of this crop is often affected due to attack of various diseases caused by bacteria and viruses. Among bacterial diseases soft rot *Erwinia* spp., Bacterial wilt caused by *Pseudomonas solanacearum,* the brown rot pathogen *Ralstonia solanacearum*, the ring rot pathogen *Clavibacter michiganensis* subsp. *sepedonicus* and the scab forming *Streptomyces* spp. Commercial propagation of potato is normally done vegetatively using 'seed' tubers. Therefore, 'Degeneration' of seed stocks due to viruses is common as vegetative propagation results in the continuity of several viral pathogens. There are over 30 viruses infecting potatoes, but only five or six are actually important in India/ S. Asia. The losses in potato yield due to one or more virus(s) infecting potatoes vary from low to very high. Generally severe mosaic caused by potato virus Y (PVY) and potato leaf roll virus (PLRV) alone can reduce the yields up to 70-80% while mild viruses, like PVX, PVS, PVM also depress the yields by 10-30%. If the seed stocks are not maintained well or frequently replaced with fresh ones, the virus infiltration reaches 100% level within 3-4 successive crop seasons/years resulting in almost only half to one third yields which is rather uneconomical. In the past two decades, several systemic fungicides and insecticides with significantly better efficacy have been found promising these economically important diseases. Microorganisms that can grow in the rhizosphere are ideal for use as biocontrol agents.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important vegetable crop and is cultivated over an area of about one million hectares in India, with the total production of more than 1.5 million tons. Important potato growing states are Uttar Pradesh, West Bengal, Bihar, Assam, Himachal Pradesh, Madhya Pradesh, Punjab and Karnataka. One to three crops per year are taken under varied agroclimatic conditions. In India, about 80 per cent of potato crop is cultivated under subtropical and 20 per cent under temperate to sub-temperate climate. The cultivation of this crop is often affected due to attack of various diseases caused by fungi, bacteria, viruses and nematodes etc (Khurana, et al., 1998).

BACTERIAL WILT

Bacterial wilt of potato is a destructive disease in tropical, sub tropical and warm temperate regions of the world. It was first recorded in India from Pune, Maharashtra. Bacterial wilt causes premature wilting of standing crop and rotting of tubers both in fields and stores. Heavy yield losses may occur due to premature wilting before tuber setting. Up to 75% losses have been reported in some areas of Karnataka (Gadewar et al., 1991).

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Symptoms

Both above and underground plant parts are affected. There is a sudden wilting and death of infected plants or collapse of one or more branches is observed. Wilting appears during July in the hills about two weeks after the onset of monsoon (Fig. 1). Many wilted plants also show stem rot at soil level. Grayish brown discoloration appears through the stem of affected tubers. Cross-section of such tubers reveals a distinct brown coloration in the vascular ring. A slight pressure on the cut tuber causes oozing of typical grayish white bacterial slime out of the vascular ring (Fig. 2). Vascular browning is a characteristic symptom of the disease. Typical 'sore-eye' symptom on infected tuber (Fig. 3). In North-eastern hills, lenticels infection of potato tubers in the form of water-soaked lesions is quite common.

Causal Pathogen

Bacterial wilt is caused by *Pseudomonas solanacearum* Smith (Syn. *Ralstonia solanacearum*) which was first described as *Bacillus solanacearum* by E.F. Smith in 1896 which was later changed to *Pseudomonas solanacearum* (Smith, 1914).

Figure 1. Typical wilt symptoms caused by Pseudomonas solanacearum

Figure 2. Bacterial ooze from vascular ring of a cut infected potato tuber

Figure 3. Typical 'sore-eye' symptom on infected tuber

The name was later changed to *Burkholderia solanacearum* (Yabuuchi *et al*., 1992) and is currently known as *Ralstonia solanacearum* (Yabuuchi *et al*., 1995). It is a rod shaped Gram negative bacterium measuring 0.5-0.6 x 0.8-1.2 µm and having 1-4 polar flagella. Three races of the bacterium have been identified and potato is affected by race 1 and 3. Based on phylogenetic divergence at molecular level using a series of probes based on regions of the genome concerned with virulence, *R. solanacearum* has been split into five biovars comprising two Divisions (Cook *et al*., 1989). This bifurcation has been confirmed on the basis of sequencing of tRNA genes in the bacterium (Taghavi *et al*., 1996).

Management

It is a difficult disease to manage as the commercial cultivars are highly susceptible and chemical control is not feasible. The reduction of the initial inoculum is of prime importance to manage bacterial wilt of potato. Different methods are used to manage bacterial wilt of potato among which cultural practices and biological control measures carry much emphasis.

Soil disinfection: Application of stable bleaching powder @ 12 kg/ha has been found to reduce bacterial wilt by 80% when applied in furrows at the time of planting (Shekhawat *et al*.,1988). Seed bed used for raising seedlings can be disinfected by maintaining the soil temperature at 85 ^{0}C for 15 minutes by steam application.

Cultural practices: Use of disease free seed is important for avoiding introduction of the wilt pathogen in the new fields. The incidence of bacterial wilt was far less in the whole seed than when cut tubers were planted.In early (February) planted crop, wilt incidence and tuber rot are almost negligible in North-western hills. Crop rotation, the most generally used control measure, is employed world wide to check bacterial wilt. Two years rotation with wheat-maize or wheat-fallow reduced bacterial wilt incidence to 7% from 80% (Shekhawat., 1988). By shifting dates of sowing to avoid periods of high soil moisture due to rainfall and high temperature can also help to decrease the disease incidence.

Chemical treatment: Plantomycin alone or in combination with Blitox-50 proved effective in controlling bacterial wilt upto 95% (Ojha *et al*., 1986). Emisan 6, Thiram, Blitox-50 and chlorinated water also checked the disease to the extent of 80, 80, 75 and 60 per cent, respectively. Pretreatment of seed tubers with 500 ppm of an antibiotic C-6 followed by two foliar sprays controlled the disease and increased the yield three times.

Host resistance: The genetic resistance to *R. solanacearum* is not general to all the strains. The resistance is usually strain specific and is broken down under warm climates. The resistant clones are susceptible to latent infection (Grandada, 1988). The resistant cultivars should be grown under cultural practices identified for control of the disease and the seed should be replaced before the latent infection reaches threshold level. *Solanum phureja* has been a valuable source of resistance to bacterial wilt but this is temperature sensitive and best suited for higher elevations or cooler climates. Some of the somatic hybrid lines developed by Laferriere *et al*. (1998) can serve as bridges for the eventual introgression of novel bacterial wilt resistance into potato plants.

Biological control: Microorganisms that can grow in the rhizosphere are ideal for use as biocontrol agents. Certain bacteria like *Pseudomonas fluorescens*, *Bacillus polymyxa*, *Bacillus* spp. and actinomyctes have been found to delay the development of *R. solanacearum* and reduce the incidence of bacterial wilt (Sivamani *et al*., 1987). Bacteria which are antagonistic to *R. solanacearum* have been isolated from various sources e.g. suppressive soils and rhizosphere of host plants. Studies have shown that isolates of *Bacillus* spp. (BSN-1 and BSN-2) reduced wilt by 87% and 89% and tuber rot by 83% and 84%, respectively and an increase in yield by 129% and 124% was also recorded.

Table 1. Distribution of viruses by their association on potato

Viruses dependent on potatoes for survival and spread	Viruses not dependent on potatoes for survival and spread	Undetermined
Potato virus X (PVX)	Tobacco rattle virus (TRV)	Potato black ringspot virus (PBRV)
Potato virus Y (PVY)	Tobacco mosaic virus (TMV)	Potato spindle tuber viroid (PSTVd)
Potato virus S (PVS)	Tomato spotted wilt virus (TSWV)	Potato yellow vein virus* (PYVV)
Potato virus M (PVM)	Cucumber mosaic virus (CMV)	Potato deforming mosaic virus (PDMV)*
Potato mop top virus (PMTV)	Tomato black ring virus (TBRV)	
Potato aucuba mosaic virus (PAMV)	Tobacco ring spot virus (TRSV)	
Wild aucuba mosaic virus (WAMV)	Solanum apical leaf curling virus (SALCV)	
Potato virus T (PVT)	Potato yellow dwarf virus (PYDV)	
Potato leafroll virus (PLRV)	Beet curly top virus (BCTV)	
Andean potato latent virus (APLV)	Alfalfa mosaic virus (AMV)	
Andean potato mottle virus (APMV)	Tobacco necrosis virus (TNV)	
Potato virus V (PVV)	Tobacco streak virus (TSV)	
Potato stunt virus (PSV)		

Source : Salazar (1993)
* Their virus origin has not been yet determined.

Table 2. Symptoms guide for field inspection of important viruses on potatoes in India

Viruses	Main Diagnostic Symptoms
PVX	-***Interveinal or faint mosaic***: Causing mild or barely perceptible mosaic with light and dark green patches, mottling with stunting, crinkling with virulent strains.
PVS*	-***Latent***: It is barely perceptible as mottle or faint vein bending. Some cultures show severe bronzing, necrotic spotting and even leafdrop.
PVM	-***Leafrolling mosaic***: Often causes mild to severe mosaic with slight leaf deformations, necrosis of petioles and veins under certain conditions.
PVA*	-***Supermild Mosaic***: Causes faint mottling with leaf distortion sometimes, top necrosis in some vars. Sometimes severe, invokes rugosity and crinkling of leaves that turn shiny.
PVY	-***Severe/Rugose mosaic***: Symptoms vary with strain and cultivar. Mild-to-severe mosaic and venial necrosis and leaf drop streaking. Plants stunted. Severe mosaic, rugosity, bunching or twisting of leaves, down-turning of leaflet margins and stunting, necrosis in some cultivars. Only some veins develop necrosis, older leaves collapse and drop, mild mosaic in less sensitive cultivars or some remain even symptomless. Rarely some tubers also show 'ringspots' at harvest or in stores.
PVA+PVX	-(***Crinkle***): Heavy blotching, distorted leaves with wavy margins, severe stunting, mottling, deformity, puckering, necrotic spotting and streaking of leaves.
PVX+PVY	-(***Rugose***): Severe mosaic and rugosity. Plants stunted. Leaves curl downward, necrotic veins in lower leaves and severe mosaic in upper ones. Stunting leaf blotching, leaf banding, necrosis, leaf drop, rugosity and leaf crinkling.
PLRV	-***Leafroll***: Invokes rolling of lower leaves in primary infections and of the upper leaves in the secondary infection with the leaves turning leathery, brittle, pink or brown pigmented. Infected plants remain stunted, chlorotic and make rattling noise when shaken.
TSWV	-***Stem necrosis***: Characterised by scattered, necrotic lesions or 'ringspots' on shiny leaves followed by necrosis of petioles and stems. The plants have chlorotic and blighted appearance.

*Individually this virus can not be a problem but enhances effect of mild viruses upon combination and is responsible for breaking late blight resistance.

VIRAL DISEASES

Commercial propagation of potato is normally done vegetatively using 'seed' tubers.Therefore, 'Degeneration' of seed stocks due to viruses is common as vegetative propagation results in the continuity of several viral pathogens. There are over 30 viruses infecting potatoes (Table 1), but only five or six are actually important in India/ S. Asia (Khurana, 1992, Singh and Khurana, 1993). The recent advances in healthy seed potato production have overcome this major problem and greatly enhanced both the area and yields of potato. The losses in potato yield due to one or more virus(s) infecting potatoes vary from low to very high. Generally severe mosaic caused by potato virus Y (PVY) and potato leaf roll virus (PLRV) alone can reduce the yields up to 70-80% while mild viruses, like PVX, PVS, PVM also depress the yields by 10-30%. If the seed stocks are not maintained well or frequently replaced with fresh ones, the virus infiltration reaches 100% level within 3-4 successive crop seasons/years resulting in almost only half to one third yields which is rather uneconomical (Table 2). The annual losses in potatoes due to viral diseases in India may reach between Rs.5000-6000 million (Khurana, 1992).

Management of Viral Diseases

Viral diseases of potato apart from reducing crop yields are also the main causes for degeneration of seed stocks because of vegetative propagation. Since different viruses spread and perpetuate in different manners, different control measures have to be adopted for them. However, it is normally recommended to use them as an integrated control package.

Indirect measures: Indirect measures for control of viruses and viroids include selecting vector free period and location, isolation of the crop, sanitation, use of healthy stocks, roguing, use of pesticides for control of aphid vectors, inspection and certification. Dehaulming the seed crop at the right time for multiplication of quality nucleus seed is also recommended (Mandahar *et al*., 1990).

Direct measures*:* Direct control measures include cultivation of virus resistant varieties but not many are available in our country especially having combined resistance for two or more important viruses, except for Kufri Jyoti, Kufri Sindhuri, Kufri Ashoka, etc. Breeding for virus resistant varietie is the method of choice for developing countries to cut down on the cost of seed production/ certification systems. The preferred form of resistance is either hypersensitivity or extreme resistance/immunity to the viruses and vectors (Banttari *et al.*, 1993). It has been rather easy to breed varieties with combined resistance to PVX and PVY and also PVA but not PVS and leafroll virus.

Thermo-therapy and use of apical meristem culture technique is in vogue to free the important germplasm and hybrids from the viruses. It is easy to eliminate PLRV, PVY, PVX, MLOs, etc. but PVS is probably the most difficult to get rid of. A combination of chemo-and thermo-therapy coupled with meristem culture, at alternating high (36 ^{0}C/16hr) and low (29 ^{0}C/8 hr) temperature, has assured greater virus freedom in the mericlones (Conrad, 1991; Slack and Tuford, 1995; Khurana *et al*., 1996).

Non-conventional measures: Non-conventional approaches for incorporating virus resistance are now being employed either by using viral-coat protein or replicase or protease genes or even antisense RNA or anti-viral proteins of non-viral origin, for enhancing host resistance.

Use of true potato seed: Use of true (Boatanical) potato seed (TPS) also holds promise for areas where quality seed is not available. Production of potato crop fromTPS obtained from homogeneous populations has been tried in many countries including China, India , Mongolia, New Zealand, Vietnam, etc. It is also possible to either use them directly for sowing a potato crop or by transplanting the seedlings or even going in for production of tuberlets in the first stage and then using them for raising a ware crop. TPS offers various advantages, viz.., reduced cost of seed material, easy storage and transportation, low incidence of diseases but requires more labour, lacks uniformity etc.

Preventive measures: Prevention is the best policy for virus management. Consequently, reliable detection methods have a great significance in the production of high quality virus free seed potatoes. To achieve this goal, detailed information on various aspects such as (a) nature of virus; (b) mode of transmission; (c) health standards of the planting materials, which may act as internal sources of the virus spread in the crop, (d) weed hosts which may act as external sources of the viruses, and (e) factors affecting the build up of the vector and virus diseases must be available (Singh and Boiteau, 1988). Based on the information about above mentioned factors, regulating the build up of viruses and allied diseases in the field, following measures may be adopted in a combined way for minimizing their spread.

Quarantine inspection for exclusion of unknown pathogens (especially latent viruses) through plant propagation stocks into any country is an important step in disease management. Post-entry quarantine (PEQ) of tubers, true potato seed (TPS) and even *in vitro* plantlets can help avoid introduction of new virus(es) or allied pathogens which may get into importing countries. The potato viroid (PSTVd) and viruses (PVT and APLV) and also tobacco ringspot virus-calico strain (TRSV-Ca) and Aracacha virus Oca strain (AVB-Oca) from potato in South America get readily transmitted through true seeds (Jones, 1982). PVY, Solanum apical leaf curl virus etc., restricted to Andes, can be easily excluded. They need to be checked and eliminated before allowing any vegetative or true potato seed stocks into any country.

Controlling spread of viruses is possible by avoiding contact and injury of seed/plants. Cutting of seed and mechanical damage to tuber sprouts has a major role in spreading viruses like PVX, PVS and viroid (PSTVd) (Khurana and Garg, 1998). Besides, movement of men, farm machinery and plant protection operations in fields also result in spread of the contagious viruses / viroid.

Conclusion

Decision support system with efficient, effective and economically viable integrated disease management module for potato diseases should be developed which is possible only this is only possible when we are able to generate the relevant reliable information on cultural operations like sowing dates, tuber depth and soil moisture, time of application of fertilizer vs LBP. Management of Disease Focus (secondary source of infection)

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