LEATHER ROT OF STRAWBERRY AND ITS MANAGEMENT - A REVIEW

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ABSTRACT

Strawberry is one of the most important soft fruit crops. It is subjected to a number of diseases of which leather rot (Phytophthora cactorum) has been observed as a serious limiting factor in cultivation of strawberry, affecting both fruit quality and quantity and leads to direct economic losses. Infection occurs on mature as well as immature berries. Moisture and temperature play important role in disease development. Use of polyethylene sheet and paddy straw mulch reduces the fruit rot incidence as compared to control. Soil solarization increased strawberry yield by 7 to 64 percent. Different species of Trichoderma viz., T. hamatum, T. harzianum, T. viride and T. virens and bacterial antagonists viz., Pseudomonas fluorescens strains and Bacillus sp. were effective against leather rot of strawberry. Fosetyl aluminium and metalaxyl foliar sprays provided 82-96 percent control of leather rot.

Strawberry (Fragaria x ananassa Duch.) is one of the most important soft fruit crops grown in temperate and subtropical countries of the world. In India, it is cultivated on a very limited scale in scattered pockets, Maharashtra being the leading state in its production. Strawberry is subjected to a large and diverse number of pathogens including fungi, bacteria, viruses, mycoplasma-like organisms, nematodes etc. Amongst these, fungal diseases especially the fruit rots namely grey mould (Botrytis cinerea Pers. ex Fr.), leather rot (Phytophthora cactorum (Leb. & Cohn) Schroet), hard rot (Rhizoctonia sp. Kuhn), leak rot (Rhizopus nigricans Ehrenb.) and anthracnose (Colletotrichum acutatum Simmonds) are major obstacles in maintaining or increasing production levels (Stevens, 1925, Demaree, 1942, Anderson, 1946 and Jarvis, 1962). In the recent past, leather rot (Phytophthora cactorum) has been observed as a serious limiting factor in cultivation of strawberry. The disease affects both the fruit quality and quantity. In this chapter, biology, epidemiology and management of the disease have been discussed.

Occurrence and Economic Importance

Leather rot (P. cactorum), a most destructive fungal disease of strawberry, was reported for the first time from southern Mississippi Valley by Rose (1924). Growers in southern states referred it as “Water Soak”. Subsequently, it was reported from United States (Stevens, 1925), England (Beaumont and Hodson, 1931), Illinois (Anderson, 1946), Germany (Schmidle, 1956), Chicago (Wright et al., 1964), California (Wright et al., 1966), Moscow (Pristanskav, 1974), Leningrad region (Andreeva, 1977), Taiwan (Kao and Leu, 1979), Hungary (Marton, 1981), Ohio (Ellis and Grove, 1983), Europe (Duncan, 1990), Japan (Osada et al., 1993), Mexico (Castro et al., 1993) and Korea Republic (Lim et al., 1999). However in India, it was first reported by Bhardwaj et al. (1998) from Paonta Valley of Himachal Pradesh.

Fruit rots cause direct losses in the economic gains. Stoddard et al. (1924) reported about 25 per cent loss due to fruit rots caused by species of Phytophthora, Rhizoctonia, Pezizella and Botrytis. Leather rot (P. cactorum) caused 10-50 per cent fruit loss in southern Mississippi (Rose, 1924), while up to 50 per cent losses in southern Illinois (Anderson, 1946) and 20-30 per cent losses in Ohio (Ellis and Grove, 1983). Heavy losses
due to leather rot were also observed from Europe (Duncan, 1990).

**Symptomatology**

The pathogenic fungus (*P. cactorum*) infects strawberry fruits from fruit formation stage to full maturity. The disease is characterized by softening of the tissues, which become tough, leathery and discoloured and develop a marked bitter taste. In very young fruits, all the affected areas turn brown, shading off into the normal green at the edges. In older fruits, the center of the spot is brown surrounded by a dark brown to purple zone. Ripe fruits show no colour change except slight darkening over the affected spots. In markets, a superficial growth of the causal fungus, rare in the field, is frequently seen (Rose, 1924 and Stevens, 1925). However, Bhardwaj *et al.* (1998) observed superficial growth of the fungus on fruits in a field under high humid conditions.

**Isolation and pathogenicity**

Various workers have devised different techniques for isolation of *Phytophthora* spp. from sick soil and affected plant parts including fruits. The baiting method for isolation of *Pythium* and allied genera was first described by Blackwell (1944) for *Phytophthora*. Fruit baits were also used for isolation of *Phytophthora* (Newhook, 1959 and McIntosh, 1969). *P. cactorum* was isolated from shrivelled brown tissues of strawberry fruits by various workers (Beaumont and Hodson, 1931, Niemoller, 1956, Schmitthenner, 1973, Castro *et al.*, 1993, Maltoni *et al.*, 1995 and Sharma, 1998).

Rose (1924) placed healthy berries in pans containing about % inch of water together with a few leather rotted berries. After one hour, berries were transferred to sterilized pan and it resulted in 100 per cent infection. Some workers proved the pathogenicity of fungus, *P. cactorum* by inoculating the fungus on immature and mature fruits of strawberry (Ellis and Grove, 1983, Castro *et al.*, 1993, Maltoni *et al.*, 1995 and Sharma, 1998).

Immature (green) and mature berries were inoculated with agar plugs or zoospore suspension and incubated in damp chamber lined with moist paper toweling. Berries developed leather rot symptoms within three days. Wound inoculated watermelon, tomato, lemon, nectarine, apple and potato decayed within six days in varying degrees (Wright *et al.*, 1966). Temperature influenced the leather rot incubation period under laboratory conditions. The optimum temperature for leather rot development was 22°C.

The disease development was not observed at 32°C. All apple cvs. and rootstocks were susceptible to isolates 'from apple and strawberry fruits, whereas, rhizomes of strawberry cvs. were severely rotted by strawberry rhizome isolates only, indicating that collar rot of apple and rhizome rot of strawberry were caused by different pathotypes of the fungus, *P. cactorum* (Seemuller and Schmidle, 1979). Sharma (1998) found that fruits of all the developmental stages i.e. immature, mature and ripened berries were infected by the pathogen, however, immature fruits were more prone to infection by *P. cactorum*. Injury to fruits of all developmental stages resulted in rapid establishment of infection and thereby reducing the incubation period in comparison to uninjured fruits. The pathogen did not infect the leaves, stems and runners of strawberry upon inoculation. Paulus (1990) reported that leather rot and crown rot of strawberry are caused by different strains of *P. cactorum*. Crown rot was characterised by an intensive browning and eventual disintegration of the vascular tissues of the crown. Suggestions have been made that infection can occur after penetration through roots, petiole bases and runner tips (Wilhelm and Nelson, 1980). Golebniak and Wachowiak (1999) tested fruits of six strawberry cultivars and found that all
the cultivars were infected.

Biology and Morphology

*Phytophthora* species grow on different kinds of natural, semi-synthetic and synthetic media. Among these, synthetic media have been found to give poor vegetative growth as well as sporangia and oospore formation. Pea meal agar was reported to be the best medium for vegetative growth, sporangia and oospore formation of *P. cactorum* (Bhardwaj, 1976). Garg (1987) reported oat meal agar and corn meal agar as the best media for the growth of *P. cactorum*, the causal agent of collar rot of apple. Sharma (1998) also found oat meal agar to be the best medium for vegetative growth of leather rot pathogen, *P. cactorum*.

*Phytophthora* spp. can grow over a wide range of temperature. Braun and Krober (1958) reported a different temperature requirement of the pathogen under field and laboratory conditions. The optimum temperature for establishment of *P. cactorum* under field conditions have been found 16-21°C, while 25°C for laboratory conditions. Wright et al. (1966) observed that a temperature of 4.4-32.2°C was favourable for *P. cactorum*, while 26.6°C was optimum. Sharma and Bhardwaj (2001) reported 25°C and relative humidity 88.5 per cent to be optimum for sporangia germination of *P. cactorum*.

Nutritional requirement of every fungus varies from species to species and same is true in case of *Phytophthora* species. Lopatecki (1950) reported that growth of *P. cactorum* was greater with ammonium salts as compared to nitrate salts. Sharma and Bhardwaj while studying the nutritional requirement of *P. cactorum* reported maximum sporangia germination in asparagine solution. Christie (1956) reported that *P. cactorum* grew uniformly between pH 4.7 and 7.4, growth being restricted at pH 8.7 and prevented at pH 3. Cameron (1962) reported that no two species of *Phytophthora* had similar pH requirement, for *P. cactorum*, it was 4.5, while *P. illicis* could grow at a pH level of as high as 7.5.

The leather rot fungus grew slowly on potato-dextrose-agar medium, mycelium was white and colony fluffy and slightly radiating. Sporangia were lemon shaped and papillate and measured 28.9-39.8 x 18.0 - 35 μm, while papilla was 3.63-5 μm. The oospores were thick walled and measured 22-24 μm in size. It was distinguished from the *P. nicotianae* causing fruit rot of strawberry by caducous sporangia with short pedicels, by paragynous antheridia and plerotic oospores. The banding pattern of *P. cactorum* when compared with banding patterns of other *Phytophthora* isolates matched with that of *Phytophthora cactorum*. Although this pattern was identical to those of the very closely related species, *P. pseudotsugae* and *P. idaei*. It was unlikely that either would be found on strawberry (Sharma, 1998).

Epidemiology

*Phytophthora cactorum* is a homothallic fungus and produces sporangia and oospores as asexual and sexual phases, respectively. Oospores are highly effective survival structures that allow *Phytophthora* spp. to survive adverse environmental conditions for relatively long periods of time in plant debris and in soil. Germinating oospores were observed in over-wintered mummified fruits within 14 days after placement in water. Sporangia were not recovered from soil, which had been allowed to dry. Some oospores germinated even after drying. Sporangia germinate directly or produce zoospores in soil water. The germ tube penetrates the host tissue and cause infection (Madden et al., 1991).

Moisture/rainfall and temperature are important epidemiological factors favouring development of strawberry leather rot (Rose, 1924, Wright et al., 1964, Wright et al., 1966
and Ellis and Grove, 1983). Rose (1924 and 1926) found leather rot more prevalent in areas that had received large amounts of precipitation or had poor drainage. Andreeva (1977) reported that rainy weather with temperatures of 18-22°C and relative humidity 95-100 per cent favours infection by *P. cactorum* in strawberry. Grove et al. (1985) reported that wetness period and temperature were significant factors influencing the infection of immature strawberry fruits by *P. cactorum* and influencing sporulation of pathogenic fungus on infected strawberry fruits. The effect of temperature was most pronounced at short wetness durations e.g. one hour wetness at 21°C. At the short wetness durations, optimum infection occurred over a relatively short temperature range, whereas at-long wetness periods, high infection occurred over a wide range. A film of free water was required for in vivo sporangial production and the sporulation response was first detected after wetness duration of three hours between 15 and 25°C and optimum was 20°C. At temperatures between 17 and 25°C, two hours of wetness resulted in greater than 80 per cent fruit infection and more than 12 and 6 hours of wetness at 12.5 and 27.5°C, respectively. Increasing rain intensity leads to increased removal of spores from the source and loss of spores through the soil and canopy (Madden, 1997).

**Disease management**

The inoculum of leather rot of strawberry survives in plant debris or soil and thus cannot be completely controlled, as soil is a complex structure. Chemicals or the organic amendments added to soil are subjected to various biochemical reactions depending upon temperature, moisture and soil pH. Therefore, for the management of leather rot, multiple strategies comprising methods like use of cultural practices, biological control, fungicides and host resistance have to be followed.

**Cultural methods**

To reduce leather rot epidemics excellent water drainage, good air circulation and exposure to sunlight have been recommended to reduce periods of free moisture on fruit. Weeds in strawberry planting reduce air circulation and prolong wetness periods on fruits; thus weed control may aid in leather rot control. Excessive use of fertilizers (especially nitrogen) stimulates very dense foliage that can extend wetness periods, therefore, proper fertilization based on soil and foliar analysis is recommended. Use of organic amendments or inorganic chemical fertilizers affects the soil ecosystem and thus affects the disease indirectly. In the recent years, much work on disease management has been done through the use of mulches. Straw mulch is highly beneficial for controlling leather rot (Madden and Ellis, 1990) as it keeps off fruit from contacting the soil where the fungus inhabits. It provides a barrier between fruit and standing water and it thus reduces the splashing of water droplets bearing sporangia. They reported that maximum (83%) disease control was achieved by straw mulch followed by sand (64%), soil (53%) and plastic mulch (21%). Legard et al. (1997) reported that for the control of strawberry fruit rots, field sanitation is the most economic method. Sharma (1998) reported that leather rot incidence was greatly reduced with polyethylene and paddy straw mulches as compared to control. Use of polyethylene sheet and paddy straw mulch reduced the fruit rot incidence to 24.67 and 28.02 per cent respectively, as compared to 40.39 per cent in control.

**Soil solarization**

Soil solarization is a non-chemical approach to control soil borne diseases where soil temperature remains high enough to kill the pathogen propagules. This can only be achieved by using thin transparent polyethylene mulch, which transmit most of the solar
radiations that heat the soil (Katan et al., 1976). Mulching with transparent polyethylene sheets during summer generates much heat that helps in controlling soil borne diseases (Katan et al., 1976, Jacobson et al., 1980 and Khandar and Bhowmik, 1990). Hartz et al. (1993) reported that soil solarization; from late July to September for October plantings of strawberry, reduced baited population of P. cactorum and P. citricola when compared with pathogen survival in non treated soil. Solarization controlled annual weeds in strawberry fields and increased strawberry yield by 12 per cent compared with yield of non treated plots. Soil solarization combined with metam sodium, increased yield by 29 per cent, in comparison to chloropicrin fumigation. Cobelli and Antoniacci (1999) evaluated soil solarization as an alternative to methyl bromide fumigation. Cobelli and Antoniacci (1999) evaluated soil solarization as an alternative to methyl bromide fumigation in soils of Italy which were naturally infested with P. cactorum and two different methods of solarization were compared: total field solarization and localized row solarization. Localized row solarization increased strawberry yield 7 to 64 per cent compared with control plots.

Biological control

Biological control is an environment friendly approach of disease management. Various species of Trichoderma have been reported to be antagonistic to many soil borne fungi. These fungi produce a number of volatile and non volatile fungitoxic compounds like trichoviridin, trichodermin, viridin and metabolites containing an isocyanide group (Brian, 1951, Dennis and Webster, 1971, Tarnura et al., 1975 and Ghiselberti and Sivasithamparam, 1990). Similarly, Gliodadium virens is another biocontrol agent, which also produces antibiotics namely, gliotoxin, viridin and glioviridin (Aluko and Hering, 1970 and Howell and Stipanovic, 1983) and all these compounds are inhibitory to most of the soil borne plant pathogens. Gupta (2001) reported different spp. of Trichoderma viz., T. hamatum, T. harzianum, T. viride and T. virens and bacterial antagonists viz., Pseudomonas fluorescens IISR8, P. fluorescens T R K 4 , P. fluorescens 81 and Bacillus sp. effective against leather rot of strawberry in field as well as laboratory conditions.

Chemical control

Management of plant diseases through chemical fungicides although has many drawbacks but it is still considered to be the best means of plant disease control. Time to time different chemical fungicides have been recommended to control diseases caused by Phytophthora spp. Baines (1939) obtained partial control of the disease caused by P. cactorum by spraying with Bordeaux mixture at dormancy break. Lenzner (1965) reported the effectiveness of a few antibiotics against P. cactorum which includes Aureomycin, Colimycinmethan, sulphanates, Erythromycin, Karamycin monosulphate, Streptomycin sulphate, dihydrostreptomycin sulphate, Terramycin, Tetracyclin, Tyrothricin and thiosulphil. Andreeva (1977) recommended spraying with zineb or polycarbacin (1.8 to 2.4 kg/ha) and 1 per cent Bordeaux mixture against P. cactorum attacking strawberry. Chalandon et al. (1980) reported the effectiveness of Aliette against leather rot pathogen of strawberry when used as preplant dip, soil drench or foliar spray. Ridomil (metalaxyl) and Aliette (aluminium ethylphosphite) were also reported to give about 55-60 per cent control against Phytophthora diseases (Seemuller, 1982 and Madden et al., 1991). Grove et al (1985) suggested the use of broad-spectrum protectant fungicides such as Captan. Thiram or Folpet against P. cactorum. Teodorescu (1992) found fosetyl aluminium (Aliette 80 Pu) and cymoxanil (Curzate 50 WP) most fungitoxic against P. cactorum in strawberries under in
vitro conditions. Washington et al. (1992) also found Aliette to be most effective against leather rot. Fosetyl aluminium and metalaxyl foliar sprays provided 82-96 per cent control of leather rot (Ellis et al., 1998). Sharma (1998) found Ridomil-MZ to be effective against leather rot of strawberry.

Disease resistance

Use of resistant cultivars is the most effective and economical means of plant disease control but the development of cultivars resistant to disease causing agents is a very lengthy process. Ellis and Grove (1983) surveyed different counties in Ohio and found that all strawberry cultivars viz., Earliglow, Guardian, Klondike, Marlate, Midway, Pochahontas, Red Chief, Robinson, Scott and Vespor were susceptible to leather rot. Battistini and Rosati (1991) reported somaclonal variants (Fragaria x ananassa Brighton) as less susceptible to P. cactorum. Olcott-Reid and Moore (1995) screened strawberry cultivars in Arkansas, of which two selections i.e. NC 4052 and USB 301 were resistant, while the remaining i.e. Earliglow, Vantage, Fairfax, Tristar, Gaurdian, Cardinal and Allstar were either susceptible or highly susceptible against leather rot. Chandler exhibited less rot as compared to Fern, Oso Grande, Pajaro and Yalo, which exhibited susceptible reaction. Preliminary evaluation of varietal susceptibility to P. cactorum showed Addie, Ferrara and Ega less susceptible (22-28% dead plants) than Honeoye, Cesena and Dana (61%) (Colombo and Maltoni, 1996). Bartoletti et al. (1998) screened 13 cultivars of strawberry to determine resistance against P. cactorum and found all cultivars were susceptible except Idea and Miranda. Golebniak and Wachowiak (1999) also reported Elsanta, Kent, Korona, Marmolada, Syriusz and Tarda Vicoda to be susceptible to leather rot.

Integrated disease management

Ellis et al. (1998) reported integrated use of metalaxyl and fosetyl- aluminium with straw mulch very effective for the control of leather rot of strawberry caused by P. cactorum. Washington et al. (1999) found that fosetyl aluminium, phosphorus acid, tea tree oil and Trichoderma sp. reduced the incidence of leather rot of strawberries. Sharma and Bhardwaj (2000) reported that Ridomil-MZ (@ 0.25%) + polyethylene sheet gave 74.47 per cent control of leather rot and was followed by Ridomil-MZ + paddy straw mulch with 64.92 per cent disease control. Fruit yield was increased by 97.57 and 90.04 per cent by these treatments.

CONCLUSION

Leather rot is one of the most economically important diseases of strawberry. Though the disease causes enormous losses, yet much study has not been done. Work has till date been done on the symptomatology, epidemiology, pathogen biology and disease management through chemicals. Now the emphasis is being shifted towards the host resistance, host-parasite relationship and biological methods on which a good beginning has been made. Major gaps, which require immediate attention is the identification of acceptable host genotypes, influence of cultural and biological management practices on the disease and existence of variability on the pathogen. Maximum emphasis must be given to the practicability of biological methods for disease control, which will help in the reduction of excessive use of chemicals.

REFERENCES


