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Symptoms, pathogen biology and control of downy mildew of *Brassica* – A minireview.

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Abstract: Downy mildew is a serious constraint, which is caused by the fungus *Peronospora parasitica*. The disease is a widely recorded disease, both on horticultural and agricultural members of the genus *Brassica*. The symptoms caused by the fungus on the seedlings of all common hosts results initially in the development of the discolored spots on the surface of the cotyledons, which may then turn yellow, shrivels and die. The fungus exhibits both sexual and asexual means of reproduction. Asexual spores, conidia, are produced on conidiophores which arise from the aggregation of intercellular mycelium beneath the host epidermis. The fungus differs in a range of cruciferous hosts that it infects. All these and related aspects are discussed in the review. At the end, various control measures to counter the disease are also included.

Key words: *Brassica*; conidiophores; Downy mildew; pathogen biology; *Peronospora parasitica*.

Introduction

Vegetables are edible form of plant tissue. These provide all food nutrients especially minerals and vitamins that is why they are sometimes recommended as daily foods. Although, India is one of the largest producer of vegetables next to China, still the requirement are more than double, both in terms of area and production to meet the demands of growing population. Total production of vegetables is low due to many constraints including diseases. Diseases cause heavy loss to in vegetable production. They are inherent component of agro systems, which must be dealt in continuous and effective manner. Vegetable crops are attacked by various diseases such as rusts, wilts, rots, damping off, powdery mildew and downy mildew. Among them, downy mildew is a serious constraint, which is caused by the fungus *Peronospora parasitica* (pres. Fr.) is the most widely recorded disease on both horticultural and agricultural members of the genus *Brassica*. The disease mainly affects young plants that may, in severe cases, be stunted or killed. With the passage of time, the infection at later stages results in defoliation and reduction in performance and quality of the host plant (Spencer, 1981). It is frequently found on cabbage, kales, cauliflower, on young seedlings as well as moribund leaves of the grown plants and on stored ones (Butler and Jones, 1949).

Natti (1958) reported that the infection is most severe at the seedling stage but the disease may also cause the reduction in the yield of cabbage and turnip leafy greens. According to Lund and Wyatt (1978) the disease causes damage to the cauliflower during storage. The fungus is also common on the oil seed rape, sometimes occurring on 90% of the plants assessed (Dixon, 1975). In cruciferous species, the downy mildew occurs in widely separated localities throughout world (Channon, 1981). The disease in India has been reported by Thind (1942) and Lund and Wyatt (1978).

Symptoms

The symptoms caused by the fungus *P. parasitica* on the seedlings of all common *Brassica* hosts results initially in the development of the discolored spots on the surface of the cotyledons, which may then turn yellow, shrivels and die. At such an early stage of growth, loss of the cotyledon may be fatal. Later infections of the host such as cabbage, cauliflower, turnip, swedge and reddish appear first as small discolored spots and yellowing on the upper surface of the true leaves with sparse patchy growth of mycelium on the lower surface (Spencer, 1981). However, Jenkin (1964) reported that infection and partial or complete, destruction of some leaves might be total expression of the disease in the field. In case of cauliflower, the infection may extend to the curds, both in field (Chorin, 1946) and in storage (Lund and Wyatt, 1978). Cabbage heads may suffer infection in the field and in storage. Extensive grayish black discoloration spreads though the heads and even penetrate the parenchyma of the stem (Gardener, 1920). The stored turnips develop dark discolored zone spreading down from the crown into the steler regions of the root.

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Ramsey *et al.* (1954) reported that roots of raddish may also be attacked by the fungus *P. parasitica* causing brown to black epidermal blotches or streaks extending round the circumference of the root accompanied by slight rusting and cracking. The internal tissue of the root is also explored by the pathogen. Infection of stem and inflorescence of radish may also occur (Spencer, 1981).

Pathogen biology

The fungus exhibits both sexual and asexual means of reproduction. Asexual spores conidia are produced on conidiophores which arise from the aggregation of intercellular mycelium beneath the host epidermis. The project either singly or in groups through stomatal openings. Chou (1970) reported that the hyphae differentiate to form the conidiophores (200-500µm in height) and bear primary and secondary branches, which ultimately bifurcate to form pairs of finely pointed and incurved strigmata bearing single terminal conidium. Davison (1968) studied the process of sporulation and reported that the conidiophores are produced during darkness. McMeekin (1959) studied separately formed spherical oogonia and paragynous anthridia of the fungus. Dickinson and Greenhaldge (1977) reported existence of both heterothallic and homothallic forms of *P. parasitica.* Further investigations revealed that the pathogenic variants of the fungus differ in their ability to parasitize cruciferous hosts belonging to different genera and species (Dickinson and Greenhaldge, 1977).

Oospore formation has been observed when heterothallic isolates differentially virulent on different host species are co-cultivated on a host (Sherriff and Lucas, 1990). Successful production of oospores *P. parasitica* on crucifers and recovery of sexual progeny from crosses between isolates with different host specificity was achieved in laboratory Moss et al (1994).

Infection and disease development

When environmental conditions are suitable, conidia of *P. parasitica* alighting on the surface of a susceptible host from germ tubes from which appressoria develop. Preece et al (1967) found that the contents of the conidium pass into the appressorium from which infection hyphae develop. Chou (1970) while studying the penetration of the pathogen observed that it usually penetrates directly into the epidermal cells and occasionally enters through stomata. The penetration hyphae breaks a hole of 4-5µm in diameter through the cuticle and after entering the host grows initially in the region of middle lamella (Shiraishi and Sakomoto, 1975). Studies on the infection of *P. parasitica* carried out by Kluczewski and Lucas (1982) have revealed that two isolates from cauliflower and oil seed were capable of infecting species other than their original hosts. Acher (1993) reported extreme hypertrophy in tissues of raddish due to the mixed infection of *P. parasitica* and *Albugo candida*. He also observed that a direct correlation exists between the embryo infection and seed transmission.

Oospores undoubtly constitutes an important means of survival of *P. parasitica* over periods of unfavourable conditions (Chang *et al.*, 1964). Further studies on infection and oospore formation by Kluczewski and Lucas (1983) have shown that the isolates of pathogen were capable of forming oospores in 25 out of 47 hosts examined. Infection of *Brassica* seeds with *P. parasitica* and its transmission through seed were reported by Karuna and Kolte (1993). Oospores were also produced under laboratory conditions from pairing between isolates specialized to different host species (Moss *et al.*, 1994).

Host range

The fungus *P. parasitica* differs in a range of cruciferous hosts that it infects. Gardener (1920) found that an isolate of the fungus obtained from turnip was able to infect seedling turnip but unable to infect raddish. Specialization of parasitism in *P. parasitica* may be exhibited to the generic, specific and lower taxonomic levels of the host. Wang (1944) and Chang et al (1964) recognized separate pathogenic varieties of the fungus on species of *Brassica*, *Raphanus* and *Capsella*. Isolates of *P. parasitica* from *Brassica* and *Raphanus* were studied by Dickinson and Greenhaldge (1977).The pathogen behaves differently in different host-pathgencombination which creates problem in determining the exact host ranges for pathogen. The host range of 33 isolates of the downy mildew fungus *P. parasitica* from different *Brassica* hosts of different geograohical originswere assessed on standard of *Brassica* accessions. Isolates from each host species had a distinct host range (Sherrif and Lucas, 1990). Some nine isolates of *P. parasitica* collected from different crucifers assessed on set of 17 different host differentials show that the isolates from oil yielding *Brassica* infected all differentials except *B. alba,* where as isolates from cauliflower leaf did not infect species like *B. carnivata, B. alba, B. chinensis,* and *B. napus.* The host range *P. parasitica* from *B. oleracea,* cabbage and Broccoli crops was also worked out by Mamoru and Fumiyoshi (1996).

Epidemiology

Environmental factors like temperature, moisture, light and relative humidity play an important role in the development of downy mildew on *Brassica* and their effect has been worked ouyt by different workers from time to time. Felton and walker (1946) found that in the pre-penetration stage, conidial germination was most rapid at 8-10^{0}C, while penetration of the host by the infection hyphae and formation of haustoria was rapid was at 16^{0}C and 20-24^{0}C, respectively. Similar temperature ranges of 8-16^{0}C for

disease development were reported by Jonnson (1966). However, Nakovo (1972) found that 15-20 ^{0}C was most favourable for the development of disease. Studies on the influence of light, temperature, suscept stage and suscept nutrition on oospore formation indicated that conditions favouring senescence of leaf favoured oospore formation when anthridial and oogonial strains were present (Dorothy, 1959). Lonivity of conidia of several *Peronospora* species under different environmental conditions have been studied wherein under cool dry conditions their survival is longer than under warm and moist conditions (Krobber, 1970). Microclimate like humidity plays a vital role in the disease development by *P. parasitica* in seedlings of *Brassica juncea* (Brain and Jhooty, 1985). Acher (1993) reported that prolonged periods of low temperature (10-25^{0}C) and high relative humidity (60-70%) promoted the downy mildew disease in cabbage.

Control

Brassica plants are highly infected with the downy mildew disease and it is wide spread, various efforts are being made to tackle with it. Cultural practices, breeding resistant varieties as well as fungicidal control are tried for its control. Schmidt (1960) reported that the measures to reduce the relative humidity around plants by adequate aeration and avoidance of dense sowings help to reduce the incidence of downy mildew disease. In addition, the destruction of infected debris and crop rotation helps in the control of the disease (Nakov, 1968). According to Kluczewski and Lucas (1983), it is undesirable to grow vegetable crop in the vicinity of oil seed rape – a suscept to downy mildew which can prove a significant source of infection.

Studies on the mechanism in cruciferous plants to *P. parasitica* were carried out by Wang (1949) who found various degrees of resistance among commercial varieties of *Brassica* but none was highly resistant. Dickinson and Natti (1967) reported sixteen crucifer accession from a total of 330 plants contained one or more resistant varieties. The identified resistance was governed by separately inherited single dominant gene. Crute and Gorden (1985) showed that cauliflower germplasm from NVRS vegetable gene bank varied remarkably in response to inoculation with *P. parasitica*. Patil *et al.* (1989) screened mustard cultivars under natural conditions for their reaction to downy mildew, cultivars RW 351, Pusa Kranti and Seeta were moderately susceptible while local varieties were found susceptible to the disease under natural conditions. Five new sources with major gene for resistance at at cotyledon stage to *P. parasitica* in *Brassica napus* olefera were identified by Nashaat and Rawlinson (1991). Mahajan *et al.* (1991) while screening of cauliflower germplasm line against downy mildew revealed that the line BR2 is immune to *P. parasitica.* However, Yuen (1991) studied resistance in cabbage and reported that open pollinated lines 77 M(3) - 27 and 77 M(3) – 35 showed high levels of resistance.

For chemical control, various fungicides have become available from time to time to combat this disease. Channon and Hampson (1968) have reported that most outstanding fungicides are captafol, daconil and Ppopineb. The success of dichlofluanid was confirmed in the field by Channon *et al.* (1970). When it gave excellent control on the cotyledons of cabbage and cauliflower. Rayan (1977) while studying plants growing in polythene tunnels has reported that prothiocarb incorporated into the soil at 5g m^{-3} before sowing greatly reduces the disease. Similarly prothiocarb also reduced the infection of infected leaves when applied as soil drench, at 50% seedling emergence (Annon, 1974). Considerable success in controlling downy mildew fungi including *P. parasitica* has been achieved with systematic fungicide metalaxyl which was first introduced by Schwinn *et al.*, (1977). Seed treatment with 35% metalaxyl plus 35% captanused against post emergence damping off also controlled *P. parasitica* far more than two weeks from sowing (Crute, 1983). Studies on efficacy of fungicide in controlling of downy mildew of ridge ground revealed that copper oxychloride (0.20 and 0.25%) and ziram (0.25 and 0.20%) gave highest percent disease control (Khaira and patil, 1988). In field trials carried out by Shao and Zheng (1991) a combination of seed treatment and application of 2-3 fungicide sprays at with a systematic fungi peak infection period decreased the infection decreased the incidence of *P. parasitica* on cabbage and increased yield by 10-18%. Smith and Chamberlin (1995) while studying fungicidal activity of N-methionine and its derivatives against downy mildew of *Brassicas* assessed that some of the derivatives were ten times more active.

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