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Management of Fruit Rot of Brinjal Caused by *Phomopsis vexans*

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A B S T R A C T

A few reviews on control of *Phomopsis vexans* of brinjal are reported in the literature. This review is added with recent research work, pertaining to practical applications besides the academic importance. The review includes the diseases caused by *Phomopsis vexans*, yield losses and methods of control. Although control methods like mechanical, chemical, biological and integrated are discussed here, it would be apt to recommend and practice the biological methods of control in the changing climate scenario, drudgery in mechanical methods and to maintain the safe environment. The plant extracts like neem oil, neem cake, plant leaf extracts, plant derived compounds like Nimbidine or bio-fungicides like species of *Trichoderma* would be the better options for control of *Phomopsis vexans* of brinjal and thus to achieve potential fruit yield.

Introduction

Brinjal (*Solanum melongena* L.) belongs to family Solanaceae. It is the most important vegetable in India (Sekara *et al.*, 2007) and described as "king of vegetables" due to its wide usage in Indian foods (Choudhary and Gaur, 2009; Singh *et al.*, 2014). Area, production and productivity of brinjal have increased over the years, although increment in productivity remained relatively less over the years (Anon, 2015 and NHB, 2017). Globally, India stands 2nd in brinjal production; and in India, brinjal constitutes 8.1 per cent of vegetable production (Anon, 2012; Anon, 2013; Anon, 2015). Presently, brinjal ranks 4th important vegetable crop in India after potato, onion and tomato. Brinjal is cultivated in an area of 0.72 million ha with a production of 12.32 million tones and productivity of 16.95 t ha^{-1} during the year 2016-17 (NHB, 2017). Although, the productivity of brinjal in India has increased, it is far less than the productivity in a few other countries *viz.*, China, Japan, Turkey, Egypt and Italy (Anon, 2012). Such lower production could be attributed to several environmental, edaphic and plant factors. Among the various production constraints in brinjal, diseases are the prominent factor in determining the fruit production (Ali *et al.*, 2012; Bhatti *et al.*, 2013). The predominant diseases of brinjal those reduce the fruit yield are (i) *Phomopsis* fruit rot (Das and Sharma, 2012; Islam and Meah, 2011; Ghosh, 2017), (ii) *Phomopsis* blight, (iii) damping off, (iv) little leaf and (v) viral leaf yellowing.

The little leaf of whole plant under severe infection or braches at the initial stages appears as bushy leaves arising from a single node due to highly reduced leaf size with reduced internode length. The little leaf incidence was relatively low, varying from 2.4 to 12.5 per cent among 25 varieties (Bhushan and Samnotra, 2017). However, Rathnamma (2014) reported a higher little leaf incidence from 20.1 to 34.6 per cent. Such incidence lead to an estimated loss of fruit yield ranging from 67.2 to 100.0 per cent especially when crop infected at younger stages due to reduced fruit number per plant (Chakrabarti and Chowdhury, 1979; Rangaswamy and Mahadevan, 2002; Kevin, 2006). Another disease, viral leaf yellowing found to cause yield loss from 9.51 to 27.0 per cent (Singh and Singh, 1975).

The damping off, *Phomopsis* blight and fruit rot are caused by the *Phomopsis vexans* (Udayanga *et al.,* 2011; Jayaramaiah *et al.,* 2013) and was first reported from Gujarat in 1914 and then from almost all the states wherever brinjal is grown (Rangaswamy and Mahadevan, 2002). *Phomopsis vexans* primarily infect the seed coat (2%), cotyledons (4 %) and embryo axis (4 %) and attacks all the above ground plant parts (Thippeswamy *et al.,* 2005).

The damping off occur both in nursery and seedling stage will show symptoms of soft, water soaked and rotting of stem / root portion of the tissue at collar region of seedling. Such seedling rot caused by *Phomopsis vexans* (rot of seedlings) is due to lack of translocation of food material from leaf to roots, loss of mechanical support and consequent plant death (Singh, 1992; Ashrafuzzaman, 2006). Such pre and post emergence damping off can be effectively controlled by seed treatment with carbendazim (Mohanty *et al.,* 1994; Kaushal and Sugha, 1995) and combination of carbendazim + thiram (Kaushal and Sugha, 1995). Another study showed seedling rot (7%) and fruit rot (21%) caused by *P. vexans* leading to yield losses of 15-50 per cent (Das, 1998).

The *Phomopsis* blight symptoms are grey to brown circular spots on the leaves or stem, which eventually becomes yellow and dry and at severe conditions as cankers on petiole and stem. While *Phomopsis* fruit rot is the water soaked lesions on fruit. The *Phomopsis* blight will be noticed from 25 to 28 days after inoculation and fruit rot incidence from 45 to 55 days after inoculation of *P. vexans,* these incidences vary with geographic location, soil type and weather (Meah *et al.,* 2002; Ali *et al.*, 2017). In Karnataka, Mahadevakumar and Janardhan (2015) reported a wide range of *Phomopsis* blight from 7.7 to 30.5 per cent with fruit rot ranging from 21.0 to 64.6 per cent. Jayaramaiah *et al.,* (2013) reported that *Phomopsis vexans* cause leaf blight to the extent of 5 to 23 per cent and fruit rot to the extent of 30 to 60 per cent. Recently Mahadevakumar *et al.,* (2017) reported leaf blight incidence (8 to 25 %) and fruit rot incidence (15 to 62 %) caused by *P. vexans*. In another recent study, the *Phomopsis* blight incidence ranged from 8.81 to 23.85 per cent among 25 genotypes (Bhoshan and Samnotra, 2017). *Phomopsis* fruit rot may go as high as 12.5 to 85.0 per cent depending on variety (Pandey *et al.,* 2002). The fruit rot disease incidence varies with different isolates or locations. For instance, fruit rot incidence varied from 20.0 to 55.8 per cent depending on the isolate of *P. vexans* in brinjal (Akhtar and Chaube, 2006). Such a high degree of disease incidence would lead to huge losses in fruit yield.

Yield losses due to *Phomopsis vexans*

Under normal weather conditions, fruit rot caused by *Phomopsis vexans* lead 12 to 25 per cent yield loss due to flower drop and fruit rot (Kannan *et al.,* 1998). It reduces yield and marketable value of the crop from 20 to 50 per cent (Panwar *et al.*, 1970; Jain and Bhatnagar, 1980; Kaur *et al* 1985; Das, 1998; Khan, 1999; Thippeswamy *et al.*, 2005; Akhtar *et al.*, 2008; Beura *et al.*, 2008; Pandey, 2010; Jayaramaiah *et al.*, 2013). Such a huge loss in fruit yield due to *Phomopsis* fruit rot was attributed to decreased fruit number (34.8 %) and fruit weight (17.0 %) as reported by Kidasha (2010) and due to poor seed germination and plant stand due to *Phomopsis* infection (Thippeswamy *et al.*, 2005). Loss in fruit yield was as high as 70 % due to *Phomopsis vexans* (Chistina, 2002). Therefore, management of *Phomopsis vexans* is very important to increase the brinjal productivity and production.

Management of *Phomopsis vexans*

Seeds are the main source of infection of *P. vexans* and serves as substrate for survival of fungus until next season (Vishunavat and Kumar, 1993; Pan and Acharya, 1995) or even up to 14 months (Kalda *et al.*, 1977). The soil borne spores of *P. vexans* generally dispersed by rain splashes, and through rotten parts and insects (Singh, 1992; Mahadevakumar and Janardhan, 2016). The *Phomopsis vexans* causes poor seed germination, damping-off and lesions on leaf, stem and fruit, both in the field and after harvest (Chaudhury and Kalda, 1968; Das, 1998) and the severity of disease caused by *P. vexans* is increasing over the years. *Phomopsis* blight occurs at seedling stage in nursery as well as in transplanted crop. The symptoms are small circular spots develops on leaves, turn grey later with light coloured centre. On stem, the symptoms include brown or dark sunken lesions slightly above the soil surface and may result in cankers and eventual seedlings death. On fruit surface a pale, sunken, oval areas are observed and these symptoms enlarge and become depressed (Ronald, 2009). Hence, there is a need to screen and identify genotypes for disease resistance in crop improvement and or to adopt appropriate control measures for immediate purposes (Mahadevakumar and Janardhan, 2016). The common methods are cultural, chemical, biological and integrated control.

Mechanical / cultural methods

The *Phomopsis vexans* is soil as well as seed borne, survives on seed surface and inside the seed, and disseminated through rain splash (Khalil *et al.*, 2013; Mahadevakumar and Janardhan, 2016). Several mechanical / cultural methods are reported for control the *Phomopsis vexans* as detailed below.

(i) Use of healthy seed found to show higher seed germination of 84.8 per cent with lower damping off incidence (1.75 %) and seedling blight (3.5 %) as against diseased seed (28.0 % seed germination, 30.25 % damping off and 26.25 % seedling blight). Therefore, it is appropriate to collect the seeds from healthy plants (disease-free) and use for sowing (Islam and Meah, 2011).

(ii) Use of resistant varieties is one of the most effective methods of disease control as the chemical control will not be effective in all the weather conditions. In India, sources of resistance have been identified (Datar and Ashtaputre, 1988). Although no resistant genotypes are available for *Phomopsis* fruit rot among 36 genotypes tested (Pandey *et al.*, 2002), a few relatively resistant (with least fruit rot incidence) varieties of brinjal *viz.*, Pant Samrat, Florida beauty, Florida market, PB-30, BC-1, JC-2, KS-352 have been reported against *Phomopsis* blight. However, the wild species resistant to *Phomopsis* blight viz., *S. nigrum, S. xanthocarpum, S. gilo, S. testiculam, S. khasianum* and *S. torvum* can be utilised in breeding programme for development of resistant varieties to *Phomopsis* blight and fruit rot (Kalda *et al.,* 1976; Agrawal *et al.,* 2000). The *Phomopsis* blight caused by *Phomopsis vexans* is highly heritable (Bhardwaj *et al.,* 2014). In this direction, Khalil *et al.,* (2013) have proved the possibility of achieving tolerance by crossing between tolerant and susceptible brinjal genotypes and selection in F_4 generation. Recently, Karmakar and Singh (2017) have developed moderately resistant lines for fruit rot resistance from interspecific crosses between susceptible cultivated variety (*S. melongena;* susceptible) and wild species (*S. gilo;* resistant). Disease free varieties namely, Pusa bhairabi and Pusa cluster were recommended for cultivation to avoid the *Phomopsis* blight and fruit rot (Singh *et al.,* 2014). Further, hybrids observed to show less incidence of *Phomopsis* blight compared to farmer-collected seeds (Mahadevakumar *et al.,* 2017).

(iii) Hot water treatment has been one of the physical methods recommended to reduce the disease infection without affecting the seed viability. In this regard hot water treatment of seeds at 50 ^{0}C for 30 min or 56 ^{0}C for 15 min can be used to control the disease incidence, as the fungus is sensitive to high temperature (Islam and Meah, 2011; Singh *et al.,* 2014). The disease infection and spread are highly influenced by weather conditions. The incidence of *Phomopsis* blight was high during humid conditions (Mahadevakumar *et al.,* 2017). The temperature of 25 ^{0}C and pH 5.5 were optimum for the best growth of *P. vexans* on PDA culture media in 7 days at 12/12 D/N and; the spore formation was decreased by 30 ^{0}C and reached to zero by 35 ^{0}C (Islam *et al.,* 2009). This could explain the seed treatment with hot water treatment at 50 ^{0}C for 30 min. The light, 12/12 D/N was the best for sporulation and growth of *P. vexans* and continuous light or continuous dark and U.V. light reduces the growth and sporulation of *P. vexans* (Islam *et al.,* 2009), suggesting that the light is essential for growth and sporulation of *P. vexans*. Further, pH of 4.0 to 7.0 is an optimum but maximum growth and sporulation will occur at 5.5 pH (Islam *et al.,* 2009).

(iv) The survived fungus in soil, seed and debris of brinjal will be carry forwarded to the next generation or next season, hence burning of crop debris and burying them by deep ploughing would help to reduce disease incidence (Singh, 1987).

(v) Use of lower dose of nitrogen with higher rates of phosphorus and potassium are also useful in control of *Phomopsis* vexans to certain extent (Sugha and Kumar, 2003).

(vi) Practice of crop rotation is another mechanical method. Although brinjal is the significant host for *Phomopsis vexans*, the fungus is capable of growing well on number of alternate host plants such as cauliflower, carrot, beet-root and solanaceae weeds (Anon, 2017). Therefore, choice of crop for crop rotation to reduce the inoculum should be taken care.

Chemical control

Compared to the mechanical methods which are drudgery, chemical control measures have been widely adopted with time owing to their high efficiency in controlling the diseases in addition to ease of application either as seed treatment or foliar application. Most common fungicides used for seed treatment and foliar spray are, Carbendazim (bavistin), Dithane M-

45 (Mancozeb), Dithane Z-78 (Mancozeb) and Copper oxychloride (blitox-50) (Singh and Chakrabarti, 1982; Mohanty *et al.*, 1994; Kaushal and Sugha, 1995; Pandey, 2010a; Singh *et al.*, 2012; Vinodkumar, 2012; Das *et al.*, 2014; Singh *et al.*, 2014; Rohini *et al.*, 2015; Chaukhe *et al.*, 2017; Jakatimath *et al.*, 2017; Priya Reddy *et al.*, 2017). Confirming the results of other workers, Beura *et al.*, (2008) and Phansawan *et al.*, (2015) found that carbendazim provided the best control of *Phomopsis vexans* and maximising the yield. Chaukhe *et al.*, (2017) showed that foliar spray of carbendazim (0.1 %) at the onset of disease incidence and twice thereafter at 15 day interval gave highest fruit yield by controlling the *Phomopsis* rot with a meagre fruit rot incidence of only 10.35 per cent as against 33.66 per cent in control. Further, it was confirmed through laboratory study wherein, carbendazim completely inhibited the mycelia growth of *Phomopsis vexans* (Mohanty *et al.*, 1994; Priya Reddy *et al.*, 2017) as the sensitivity of *Phomopsis* spore germination to the fungicide was high (Sugha and Kumar, 2003).

Several chemicals have been tested and recommended for seed treatment with bavistin (1g kg^{-1} seed) or seedling treatment (0.05% solution) for 30 minutes or foliar spray (0.05%) at 10 to 15 days interval for control of *P. vexans* effectively (Pandey, 2010a). Seed treatment with thiram (2 g kg^{-1} seed) protects the seedling in the nursery stage.

Spraying with Dithane Z-78 (0.2%) or Bordeaux mixture (1%) effectively controlled the *Phomopsis* blight caused by *P. vexans* in the field (Vinodkumar, 2012). The chemicals like, bavistin (0.1%), vitavax (0.1%), blitox-50 (0.2%), and ridomil (0.15%) proved to be most effective in inhibiting the growth of *Phomopsis* pathogen *in-vitro* and in controlling the disease under field conditions (Singh *et al.*, 2012). Singh *et al.*, (2014) reported that *Phomopsis* blight and fruit rot caused by *P. vexans* can be effectively controlled by spraying zineb (Dithane Z-78) or mancozeb (Dithane M-45) at 2.5 g L^{-1} of water. The fruit rot incidence was reduced from 67.6 per cent in control to 14 per cent in carbendazim and other fungicides *viz.*, propiconazole (0.15%), copper oxychloride (0.3%) and 0.15 % metalaxyl + mancozeb sprayed twice at 15 day interval (Ali *et al.*, 2017).

Fungicides such as carbendazim, mancozeb and captan have reduced seed borne fungi and controlled the fruit rot caused by *Phomopsis vexans* (Thippeswamy *et al.*, 2005). Das *et al.*, (2014) reported that the carbendazim (0.1 %) inhibited mycelia growth of *Phomopsis vexans* by 100 per cent and carbendazim was more effective as compared to the captan, macnozeb and ridomil in inhibition the mycelia growth of *Phomopsis vexans*. However, there are emerging evidences to show that the fungus is becoming resistant against these fungicides (Islam and Sitansu, 1989; Thippeswamy *et al.*, 2006).

Other problem associated with chemical fungicides is their accumulation in different plant parts including the fruit. Further, the chemical control in long run or indiscriminate use lead to residue accumulation in soil, risk of ground water pollution, death of non-targeted flora and fauna, fungicide resistance, death of beneficial soil micro-flora and consumer health (Campbell, 1989; Rajavel, 2000; Avinash and Hosmani, 2012). Therefore, alternatives are indeed essential in the climate change scenario although fungicides combined with cultural control methods are most effective (Howard and David, 2007). To avoid the adverse effects of chemicals, alternative biological agents are emerging as alternative strategies, being widely considered for their low cost, sustainable and eco-friendly features.

Biological control

Application of fertilizers, pesticides, fungicides etc. are in increasing trend over the years to meet the food production requirements for ever-growing population. Such applications lead to environmental pollution and human and animal health hazards. Therefore, there is a need for alternate, eco-friendly measures in place of inorganic chemicals for control of pests/diseases (Kumar *et al.,* 2012). In reference to present discussion on *Phomopsis vexans*, it would be apt to use plant based extracts, plant oils, bio-fungicides etc. or integrated disease management rather than chemical compounds. The biological agents or chemical compounds primarily inhibit the germination and growth of the conidia of *Phomopsis vexans,* resulting in proper seed germination, plant growth with lower PDI and higher fruit yield.

With regard to use of plant based products, Ram *et al.,* (2012) have shown that plant extracts will have anti-microbial activity and such plant extracts found to inhibit the fungal growth in artificial media (Sneha *et al.,* 2016). Lakshmi Nair (2011) reported an effective inhibition of mycelia growth of *Phomopsis vexans* with 30 per cent leaf extract of *Ocimum* and neem leaf. Jadeja (2003) reported that the plant extracts (5 % w/v) of *Datura* inhibited mycelia growth of *Phomopsis vexans* by 80.65 per cent, *Eucalyptus* (53.6 %), *Ocimum* (53.3 %) and neem (51.2 %). *In vitro* medium containing 20 to 30 per cent leaf extract (w/v) of *Ocimum, Azadiracta, Lantana* or *Clerodendron* inhibited the mycelia growth of *Phomopsis vexans* by 44.75 per cent (Lakshmi Nair, 2011). Similarly, other plant extracts, the garlic extract (5 and 10 %, w/v) inhibited the mycelia growth of *P. vexans* (Jakatimath *et al.,* 2017). Seed treatment with botanicals, like garlic (1:1, w/v) or *Allamanda* (1:1, w/v) extract decreased the incidence of seedling blight (Islam and Meah, 2011). The seed treatment with neem leaf extract (100 % w/v) for 30 min completely inhibited the *Phomopsis vexans* infection with a high seed germination percentage of 78.7 per cent (Kuri *et al.,* 2011). Nimbidine, a neem based, eco-friendly and economical product proved effective, although slightly less effective than systemic fungicide like Indofil M-45 and thus it can be used in the management of the *Phomopsis* (Singh *et al.,* 2012). Khanam (2015) reported that spraying *Allamanda* leaf extract (1:2, w/v) or neem leaf extract (1:2, w/v) reduced the per cent disease incidence (PDI) over the control significantly. In a recent study, seed treatment for one hour with neem oil (5 ml kg^{-1} seed) resulted in 94.33 per cent seed germination which was at par to the seed treatment with carbendazim (95.0 %) and the neem oil was at par or better over the carbendazim (0.2 %) both in terms of seedling vigour and disease control (Priya Reddy, 2017). Although, many of the plant extracts are highly useful in controlling the *Phomopsis vexans*, these can be adapted depending on the availability of plant material in bulk.

The other approach could be identification of antagonistic microorganisms those suppresses the activity of pathogen but has growth promoting effect on the plant. For instance, an antagonistic fungus *Trichoderma* sp. the most studied and commercially available, works on the principle that, it competes with *Phomopsis vexans* (mycoparasitism) for nutrition / carbon source by secreting cell wall degrading enzymes. The *Trichoderma* synthesize cellulase and chitinase enzymes those breakdown the cellulose and chitin of fungus (*Phomopsis vexans*) and the derived carbon source will be utilised by the *Trichoderma* and thus inhibit the growth of the pathogen (Sharma and Singh, 2016). *Trichoderma* sp. found to inhibit the radial growth of *Phomopsis vexans* by 67.33 per cent and *Aspergillus* sp. by 38.5 per cent (Lakshmi

Nair, 2011). Das *et al.,* (2014) reported that per cent inhibition of mycelia growth was 84 per cent with *Trichoderma viridae* compared to 78.2 per cent with *Trichoderma harzianum.* Similarly, Ghosh (2017) also reported a lower fruit rot incidence (31.3 %) with *Trichoderma viride* as compared to the *Trichoderma harzianum* (39.6 %). The mechanism of action of *Trichoderma viride* could be secretion of cell wall degrading lytic enzyme and then kills the *Phomopsis vexans* (Ghosh *et al.,* 2015). Further, the bio-control agents like *Bacillus subtilis* produce diffusible and volatile compounds, those lead to structural deformation of pathogen and subsequent death of pathogen (Chaurasia *et al.,* 2005). Jakatimath *et al.,* (2017) reported that fungal bio-agents (*T. harzianum*) was better than bacterial bio-agents in inhibiting the growth of *Phomopsis vexans*.

Antagonistic *Pseudomonas fluorescens* and *Trichoderma harzianum* seed treatment and foliar sprays found effective against *P. vexans* (Srinivas *et al.,* 2005). Seed treatment with bio-fungicide like *Trichoderma* species controls the *Phomopsis vexans* and hence decreases the incidence of seedling blight (Islam and Meah, 2011). Khanam (2015) have shown that spraying *Trichoderma harzianum* at fruiting stage was effective in controlling the fruit rot and at par to or superior to the chemical fungicide, bavistin-50WP, hence *Trichoderma* sp. can be effectively used to control *Phomopsis vexans* to yield on par to that of chemical (bavistin) treatment.

Ghosh (2017) reported that *Trichoderma viride* can serve as bio-pesticide comparable to that of blitax-50 and carbendazim in controlling the *Phomopsis vexans* in addition to stimulating the crop growth, hence it can be used as alternative to chemical fungicide. Therefore, it was suggested that seedling treatment with *Trichoderma viride* suspension (10^7 spores/ml) and consecutive foliar applications at 15 days interval after fruit initiation serve as effective control of fruit rot caused by *Phomopsis vexans*.

Trichoderma viride increased the seed germination, seedling vigour index and plant growth in terms of leaf area, number of leaves, dry weight and plant height (Ghosh, 2017, Priya Reddy, 2017). Ghosh (2017) reported that the *Phomopsis vexans* would cause 100 per cent fruit rot incidence, while addition of *Trichoderma viride* to *Phomopsis vexans* treated fruits showed only 20 PDI and *Trichoderma viride* was better than the *Trichoderma harzianum*. *Trichoderma viride* was on par to the blitax-50, hence *Trichoderma viride* can be used to treat and combat the *Phomopsis vexans* rot of brinjal with less than 36.3 % PDI as against blitox-50 (33.0%). Bio-control agents are natural and environmentally acceptable alternatives to chemical methods. *Trichoderma* sp. also serves as bio-pesticide and bio-fertilizer (Harman, 2006). Further, *Trichoderma* has good capacity to mobilize and uptake of soil nutrients (Chet *et al.,* 1997), which could be competitively, inhibits the pathogen like *Phomopsis vexans*. Further, Rohini *et al.,* (2016) reported beneficial effects of phylloplane colonizing bacteria (PCB) and rhizosphere colonizing bacteria (RCB) to control *Phomopsis* leaf blight of brinjal (*Solanum melongena* L.). Among 16 combinations of PCB and RCB tested, seed treatment with *Pseudomonas fluorescens* (an RCB) followed by foliar application of *B. subtilis* (a PCB) significantly increased root length (6.3 cm) and shoot length (23.2 cm), fresh weight (2.51 g) and dry weight (0.373 g) of seedling. This combination significantly reduced the disease incidence (18.0%) and disease severity (0.54) in comparison with distilled water treated control (91% and 6.0, respectively). They suggested that combined application of bio-control agents is more efficient in improving plant growth and suppressing leaf blight disease caused by *P. vexans* in brinjal as compared to the control and carbendazim treatment. Further, *Trichoderma* secretes growth promoting hormones viz., zeatin, gibberellic acid, gluconic acid, citric acid and fumaric acid (Osiewacz *et al.,* 2002) and have tendency to acidify soil and thus higher productivity (Gomez and Torre, 1994). Srivastava *et al.,* (2015) have shown that the *Trichoderma* is more effective in acidic soils compared to the alkaline soil. These research findings suggest that the *Trichoderma* sp. and other bio-agents could be beneficial in replacing agrochemicals in brinjal cultivation and there is a need to identify isolates or species of such bio-agents for control of fungal infection to reach potential yields of brinjal without environmental hazards.

Integrated method

Although mechanical, chemicals or bio-agents can be effectively control the *Phomopsis vexans* effectively, the combined or integrated use of all the three methods would lead to higher fruit yields. For instance, healthy seed, treated with garlic or *Allamanda* extract and soil application of *Trichoderma* sp. effectively controlled the seedling blight caused by the *P. vexans* as compared to the bavistin (Islam and Meah, 2011).

Treating brinjal seed with garlic or *Allamanda* plant extract (1:1) along with soil application of *Trichoderma* (7-10 days of incubation) decreased the damping off (27.25 to 0 %) and seedling blight (14.25 to 0 %) with increased seed germination of 89.75 per cent as against 64.5 per cent in control (Islam and Meah, 2011). Combination of fluorescent bacteria (2%) + *Ocimum* leaf extract (20%) + groundnut cake (200 g/ pot) resulted lesser disease incidence (6.0 %) and increased the fruit yield by 29.2 per cent over the Carbendazim (0.1 %) treatment (Lakshmi Nair, 2011). Bavistin 50WP (0.1 %) in combination with micronutrients (Gypsum, ZnO and boric acid) found more effective in controlling fruit rot and resulted in higher fruit yield compared to the bavistin alone (Hossain *et al.,* 2013).

Mulching with paddy straw in addition to the two sprays of carbendazim (0.1%) at 15 day interval decreased the fruit rot incidence by 24.3 per cent compared to the carbendazim alone with consequent in increase in fruit yield by 34.5 per cent in mulching plus carbendazim (Ali *et al.,* 2017).

Application of higher dose of nitrogen increased the disease incidence. However, application of potassium (30 to 60 kg ha^{-1}) decreased the fruit rot to 50.3 %, while application of phosphorus (64 kg ha^{-1}) decreased the disease incidence to 36.4 per cent (Sugha and Kumar, 2003). FYM treated with *T. viride* after soil solarisation, followed by seed treatment of carbendazim @ 0.2 per cent and four foliar sprays of carbendazim @ 0.1 per cent, gave maximum control of fruit rot incidence coupled with maximum yield (Sharma and Razdan, 2012). Therefore, under all possible conditions, it would be apt to practice the integrated in place of chemical fungicides, which are environmentally not safe.

It is concluded as follows

1. Seed treatment with plant extracts of neem leaf (20-30 %), neem oil @ 5 ml kg^{-1} seed effectively controls the *Phomopsis vexans*. However, seed treatment with *Trichoderma viride* (4g to 5 g kg^{-1} seed) would be more effective and easy to practice.
2. While crop cultivation, use of reduced level of nitrogen with higher rates of phosphorus and potassium fertilizer, in addition to use of *Trichoderma viride* or other species of *Trichoderma* (seed treatment; 5 g kg^{-1} seed) would decrease the fruit rot incidence and lead to higher fruit yields.

3. Seedling treatment with *T. viride* spore suspension (10^7spore/ml) and four consecutive sprays of this suspension at the interval of 15 days after initiation of fruits would control fruit rot infection and result in potential fruit yields.

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