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Biological control of rose powdery mildew (*Podosphaera pannosa* (Wallr.: Fr.) de Bary

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ABSTRACT

Powdery mildew, caused by *Podosphaera pannosa* (Wallr.: Fr.) de Bary (Syn. *Sphaerotheca pannosa var rosae* (Wallr.: Ex Fr.) Lev.), is one of the most important fungal diseases in roses. These are obligate parasites and considered as one of the most distributed and destructive groups of plant pathogens. The symptoms appear on leaves, shoots, buds, thorns, peduncles and flowers as powdery, whitish growth (mycelium, conidiophores and spores) of the mildew fungus. Plants can be severely stunted if they are heavily infected early in the growing season. The disease has been managed mainly by chemical fungicides but increasing public concern over the use of fungicides has made the development of biological control for powdery mildew highly desirable. Recent reports have highlighted the potential of biological control as an alternative strategy for disease management. Several biological control methods such as use of microbial antagonists (fungi, bacterial, yeast and yeast like organisms), botanicals and bioproducts have been found effective against rose powdery mildew fungi. The main objective of this review paper is to summarize the data on the microbial antagonists, bioproducts (anhydrous milk products, oils and compost extracts) and botanicals which have been reported effective for the better management of this plant pathogen.

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The beauty, fragrance and multiple uses of roses as cut flowers or landscape plants have made roses an appreciated crop since ancient times. From an economical standpoint, roses are the most important plants in ornamental horticulture (Hummer and Janick, 2009). Rose belongs to the subfamily Rosideae within the family Rosaceae, most of which are woody perennial shrubs with a basic chromosome number of seven and ploidy levels ranging from 2x to 8x (Wissemann, 2006 and Debener and Linde, 2009).

Rose powdery mildew caused by *Podosphaera pannosa* is the most occurring disease on roses worldwide. It attacks garden roses as well as roses in greenhouses meant for cut flower production. Except for roses, few data exist on the host range of this pathogen. Powdery mildew appears as a whitish powder covering foliage, stems and buds (Rose Magazine Inc., 2011). The fungus is most commonly observed on the upper side of the leaves, but it also affects the underside of leaves and other plant parts including young shoots, stems, buds, flowers and young fruits (Braun, 1995; Horst, 1983 and Gleason, 2014). They seldom kill their hosts but utilize their nutrients, reduce photosynthesis, increase respiration and transpiration, impair plant growth and reduce the yield causing losses between 20 to 40 per cent depending upon the congenial environment for powdery mildew fungus (Agrios, 2005). In Mexico, Gleason (2014) studied rose powdery mildew and identified the pathogen as *Podosphaera pannosa (Syn. Sphaerotheca pannosa var rosae).* Cook *et al.* (1997) could not distinguish the anamorphs of *Sphaerotheca* and *Podosphaera* by observing conidial surfaces with scanning electron microscopy. ITS data (Takamatsu *et al.*, 1998) and the combination of morphological data with ITS sequencing (Saenz and Taylor, 1999) supported the theory that both genera are congeneric. It was concluded that all *Sphaerotheca* species belong to the *Podosphaera* genus. The fungus previously identified as *S. Pannosa* (Wallr.: Ex Fr.) Lev. is now called *Podosphaera pannosa* (Wallr.: Fr.) de Bary (fam. Erysiphaceae, tribe Cystotheceae) (Braun and Takamatsu, 2000 and Braun *et al*., 2002). To investigate the evolutionary history of Erysiphaceae tribe Cystotheceae, ITS sequences were investigated by Takarnatsu *et al.* (2000). The authors suggest that the Cystotheceae were originally arbor-parasitic and transition to herb-parasitism may have occurred on at least two independent occasions. This transition is believed to have occurred in the Rosaceae.

The two main methods for disease control currently available in crop production are repeated application of fungicides and the use of cultivars resistant or tolerant to powdery mildews. However, both methods have their own limitations. Public attitude and environmental concerns towards the use of pesticides as well as the development of powdery mildew strains resistant to different fungicides have reduced the appeal of chemicals. Moreover, in some countries a number of fungicides effective against powdery mildew are no longer registered for greenhouse production due to restriction in pesticide usage. Scanning of literature revealed that the pathogen host interaction (PM/rose) causes huge amount of pesticides volume upto 40 per cent applied to rose crop to combat this disease (Tjosvold and Koike, 2001). All these constrain associated with the use of fungicides and resistant cultivars have lead to the search of alternative methods to control powdery mildews. Biological control, a phenomenon based on the antagonism between micro-organisms, is considered as an alternative to prevent or suppress powdery mildew in roses.

Biological control :

The efficacy of microbial antagonists and use of non-fungicide products such as bioproducts and botanicals have extensively been studied, especially in greenhouse production (Table 1).

Antagonists:

The potential of mycoparasites to control powdery mildew depends on their intrinsic properties and environmental conditions (Toppo and Tiwari, 2015). Verhaar *et al.* (1999a) studied the effectiveness of mycoparasites to control rose powdery mildew under selected environmental conditions. Isolate of *Ampelomyces quisqualis*, *Aphanocladium album*, *Sporothrix rugulosa*, *Tilletiopsis minor* and *Veriticillium lecanii* were tested at four relative humidities (RH) levels *i.e.* 100, 90, 80 and 70 per cent. Most mycoparasites lost their effectiveness rapidly below 100 per cent RH, but one isolate of *V. lecanii* achieved over 80 per cent mildew control at 90 per cent RH. The fungi can thrive under dry conditions, whereas most biocontrol agents require relative humidity above at least 70 per cent (Hajlaoui and Belanger, 1991). Mycoparasitism of powdery mildews by *Ampelomyces* spp. is one of the best known mechanisms of fungal antagonism. Hyphae of *Ampelomyces* penetrate the hyphae of powdery mildews, continue their growth internally and produce their pycnidia in the cells of the hyphae, conidiophores and immature cleistothecia of their fungal hosts (Kiss, 2003). An isolate of *Ampelomyces quisqualis* selected in the Hebrew University of Jerusalem (Sztejnberg *et al*., 1989) has been formulated as water dispersible granules and commercialized by Ecogen Inc. under the trade name of AQ10. Four commercially formulated biological control products, containing *Gliocladium catenulatum* (Prestop WP), *Trichoderma harzianum*

(Plant Shield) and *Bacillus subtilis* [Serenade (wettable powder) and Rhapsody (liquid)] were evaluated for control of rose powdery mildew (*Podosphaera pannosa*). Both *G. catenulatum* and *B. subtilis* provided significant control of rose powdery mildew (Janice *et al.*, 2011). Another antagonist of rose powdery mildew is *Aphanocladium album*, but this fungus has received little attention so far (Verhaar *et al.*, 1999b).

Yeast and yeast-like fungal antagonists such *Pseudomyza flocculosa* (syn. *Sporothrix flocculosa*), *Pseudomyza rugulosa* (syn. *Sporothrix rugulosa*) and *Tilletiopsis pallescens* has been described against rose powdery mildew. *Pseudomyza flocculosa* showed more rapid colonization of powdery mildew colonies than *P. rugulosa* and was less affected by unfavourable climatic conditions (Hajlaoui and Belanger, 1991). *P. flocculosa* showed better management of rose powdery mildew due to the production of antibiotics (Hajlaoui *et al.*, 1994). The yeast like fungus *Pseudomyza flocculosa* gave better control of powdery mildew in rose cultivars "Samantha" and "Preference" than fungicides (Belanger *et al.*, 1994).

Tilletiopsis spp. are common phyllosphere yeasts belonging to the Sporobolomycetaceae (Elad *et al.*, 1996). *Tilletiopsis* spp. do not seem to penetrate the powdery mildew fungus, antibiosis appears to be the primary mechanism (Urquhart and Punja, 1997). Spore suspension of *T. pallescens* reduces 78-94 per cent conidia formation of rose powdery mildew on treated plants and was used as a potential biological control agent against rose powdery mildew (Ng *et al.*, 1997).

V. lecanii showed better control of rose powdery mildew than *Ampelomyces quisqualis*, *Aphanocladium album*, *Pseudomyza rugulosa* and *Tilletiopsis minor* (Verhaar *et al.*, 1999b). *Verticillium lecanii* act by the mechanism of the hyperparasitism, but recent studies showed that antibiosis also plays an important role in this interaction (Kiss, 2003).

Bioproducts and botanicals:

Different bioproducts such as anhydrous milk fat (AMF) and soybean oil (SBO) emulsions were effective and could be used as alternative methods for managing the powdery mildew of rose (Chee *et al.*, 2011). Foliar application of compost tea showed better control of rose powdery mildew compared with the fungicides (Seddigh *et al.*, 2014). The extract of grape fruit was applied as spray to rose plants in concentrations from 0.017 to 0.099 per cent. Grapefruit extract at concentration 0.066 per cent was as effective as triforine (standard) applied at 0.027 per cent against rose powdery mildew (Wojdyla, 2001).

Conclusion :

Excess use of the chemical fungicides for the management of powdery mildew is hazardous to the environment as well as to the human health. The intensive use of chemical fungicides leads to the development of new resistant strains of pathogens and

Table 1 : Biocontrol agents, bioproducts and botanicals used effectively against rose powdery mildew

Methods	References
Biocontrol agents	
Ampelomyces quisqualis	Kiss, 2003 and Verhaar *et al.*, 1999b
Aphanocladium album	Verhaar *et al.*, 1999b
Pseudomyza flocculosa	Belanger *et al.*, 1994; Hajlaoui and Belanger, 1991 and Hajlaoui *et al.*, 1992
Pseudomyza rugulosa	Hajlaoui and Bélanger, 1991 and Verhaar *et al.*, 1999b
Tilletiopsis minor	Verhaar *et al.*, 1999b
Tilletiopsis pallescens	Ng *et al.*, 1997
Tilletiopsis washingtonensis	Hajlaoui and Belanger, 1991
Verticillium lecanii (Zimm.) Viegas	Verhaar *et al.*, 1999 and Kiss, 2003
Gliocladium catenulatum	Janice *et al.*, 2011
Trichoderma harzianum	Janice *et al.*, 2011
Bacillus subtilis	Janice *et al.*, 2011
Bioproducts and plant extract	
Anhydrous milk fat (AMF)	Chee *et al.*, 2011
Soybean oil (SBO)	Chee *et al.*, 2011
Extract of grape fruit	Wojdyła, 2001 and Waghmare *et al.*, 2011

enhances the danger of epiphytotic situations worldwide. Therefore, alternative control measures for powdery mildew need to be developed in order to reduce the dependency on these fungicides. Among these alternatives are those referred to as biological control. A variety of biological controls are available for use, but further development and effective adoption will require a greater understanding of the complex interactions among plants, people and the environment.

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