

COLLAR ROT DISEASE OF CROSSANDRA INDUCED BY *SCLEROTIUM ROLFSII* AND ITS MANAGEMENT: A CRITICAL REVIEW**P. Arunasri, T.V. Chalam, N. P. Eswara Reddy and S. Tirumala Reddy**Department of Plant Pathology, ANGRAU, Tirupati - 517 502,
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Crossandra [*Crossandra infundibuliformis* (L.) Nees.] is an economically important ornamental flower plant and is commercially grown in about 719 ha in Andhra Pradesh with an annual production of 503 t. Out of this, majority of the area is in Chittoor and the casual organism was identified as *Sclerotium rolfsii* Sacc. and the disease was named as collar rot (Harinath Naidu, 2000). The symptoms observed were shrunken and brown coloured bark which first appear on the collar region later spreading to roots. When the bark was peeled off, the internal tissue revealed brown to black discolouration with rotten roots. Yellow to pink discolouration followed by shedding of leaves was observed leading to drying of plants.

S. rolfsii is a polyphagous soil borne pathogen infecting over 500 plant species worldwide causing huge losses. Though the fungus is seed and soil borne, soil borne inoculum is more important in causing infection and disease development. For the soil-borne pathogens, use of fungicides is not practical due to exorbitant cost and environmental hazards involved. Hence, integrated management of the disease using bio-control agents and chemicals is the best alternative (Ramarethinam *et al.*, 2001). This paper reviews the literature on *Sclerotium rolfsii* inducing collar rot disease of crossandra and its management.

COLLAR ROT PATHOGEN

The pathogen, *Sclerotium rolfsii* Sacc. is distributed in tropical and sub-tropical regions of the world where high temperatures prevail. The fungus has a wide host range of 500 species in about 100 families including groundnut, green bean, lima bean, onion, garden bean, pepper, potato, sweet potato, tomato and water melon (Aycock, 1966). The teleomorph of *S. rolfsii* was first placed in *Corticium centrifugum* (Lev.) Bres. Later *Corticium rolfsii* was proposed to be the basidial state of *S. rolfsii* by Curzi (1931). Talbot (1973) suggested that the basidial state of *S. rolfsii* belonged to the genus *Athelia*.

The fungus *S. rolfsii* produces abundant white fluffy, branched, septate mycelium with clamp connections only on the main hyphae, which spread like a fan. Small white tufts were formed on mycelium which later give rise to smooth, hard and dark brown sclerotia. Sclerotia may be spherical or irregular in shape and at maturity resemble the mustard seed (Taubenhaus, 1919 ; Barnett and Hunter, 1972; Mahmood *et al.*, 1976 ; Boonthong and Sommart, 1985 ; Harinath Naidu, 2000 and Mohan *et al.*, 2000). The structure of sclerotia was studied by several workers using scanning electron microscopy. Each sclerotium is made up of three layers of an outer rind, a middle cortex and inner medulla. The sclerotial development stages *viz.*, sclerotial initial, development and maturity were studied by Flora Zarani and Christias (1997). Sclerotial size was reported to be varied from 0.1 mm to 3.0 mm (Om Prakash and Singh, 1976 ; Ansari and Agnihotri, 2000 and Anahosur, 2001).

DISTRIBUTION AND ECONOMIC IMPORTANCE OF *SCLEROTIUM ROLFSII*

The pathogen attacks more than 500 species of plants including vegetables, flowers, cereals, forage plants and weeds. Some of the common hosts include legumes, crucifers, tomato, chrysanthemum, peanuts and tobacco in which the pathogen causes foot rot or root rot (Anahosur, 2001). The pathogen causes a great economic loss in various crops. In groundnut, it caused 25 per cent of seedling mortality in the cultivar JL-24 at Parbhani (Ingale and Mayee, 1986). Thiribhuvanamala *et al.* (1999) observed that 30 per cent of crop loss in tomato was due to *S. rolfsii*. Harinath Naidu (2000) reported that *S. rolfsii* caused 40-50 per cent mortality in crossandra in Chittoor district of Andhra Pradesh.

SYMPTOMATOLOGY

The fungus *S. rolfsii* induces a variety of symptoms such as seed rots, seedling blight, collar rot, stem rot, wilt in different host plants. The major symptoms on certain important crops are presented in the Table 1.

Table-1 Major symptoms of diseases caused by *S. rolfsii* on certain important crops

Crop	Symptoms	References
<i>Amorphophallus campanulatus</i> Blume	Collar rot	Gogoi <i>et al.</i> (2002)
<i>Arachis hypogaea</i> L.	Seedling blight, collar rot, wilt, root rot, stem rot and pod rot	Mayee and Datar (1988), Narain and Kar (1990)
<i>Eleusine coracana</i> Gaertn.	Drying of leaves, disintegration of roots, rotting of tissues of collar region	Narain and Kar (1990)
<i>Solanum melongena</i> L.	Collar rot	Amar Singh and Dhanbir Singh (1994)

Harinath Naidu (2000) described the collar rot symptoms on crossandra [*Crossandra infundibuliformis* (L.) Nees.] incited by *S. rolfsii*. The infected plant showed shrunken and brown coloured bark first on the collar region that later spread to roots. When the bark was peeled off, the inner tissue showed brown to black discolouration. The roots of the affected plants were found rotten. Yellow to pink discolouration of leaves followed by shedding and ultimately leading to drying of plants was also observed.

ISOLATION AND MAINTENANCE OF THE PATHOGEN

S. rolfsii can be isolated from different plant parts *viz.*, diseased seed and seedlings (Uma Singh and Thapliyal, 1998), stem (Kajal Kumar and Chitreswar Sen, 2000), collar region (Rajalakshmi, 2002), root (Harinath Naidu, 2000), tubers (Anahosur, 2001) and fruit (Mohan *et al.*, 2000). Potato Dextrose Agar (PDA) was found to be best supporting medium for *S. rolfsii* (Hari *et al.*, 1991 and Harinath Naidu, 2000).

PATHOGENICITY TESTS

Artificial inoculation of the plants with the pathogen was done by different methods. Soil inoculation by the pathogen was studied by several workers: Kajal Kumar and Chitreswar Sen (2000) and Anahosur (2001). Seedling root dip in inoculum was used to induce sclerotial wilt in bell pepper (Anitha Chowdary, 1997). Rajalakshmi (2002) inoculated crossandra plants by placing five sclerotia per plant at collar region.

BIOLOGICAL CONTROL OF COLLAR ROT

Anitha Chowdary (1997) isolated mycoflora from the rhizosphere of bell pepper antagonistic to *S. rolfii* which included *Aspergillus flavus*, *A. niger*, *Cladosporium* sp., *Fusarium* sp., *Penicillium* sp., *Rhizopus* sp., and *Trichoderma viride*. The rhizosphere mycoflora of ginger viz., *Rhizopus* sp., *Aspergillus carneus*, *A. niger*, *A. fumigatus*, *A. flavus* (Sclerotial stage), *Eupenicillium javanicum* ITCC No. 4.595, *Eupenicillium javanicum* ITCC No. 4.596 and four isolates of bacteria (B₁, B₂, B₃ and B₄) were found to be antagonistic to *Pythium aphanidermatum*.

Pandey and Upadhyay (2000) isolated rhizosphere fungi of pigeonpea on Martin medium viz., *Aspergillus niger*, *A. fumigatus*, *Penicillium* sp., *Fusarium udum*, *Pythium* sp., *Rhizopus* sp., *Trichoderma harzianum*, *Gliocladium virens* and bacteria were isolated on soil extract agar medium which included 3 isolates B₁, B₂ and B₃. Anahosur (2001) isolated antagonists like *Trichoderma* sp., *Gliocladium virens* and *Pseudomonas fluorescens* from rhizosphere soil of sunflower infected with *S. rolfii*. The potential for the use of fungal antagonists as bio-control agents of plant diseases was suggested more than 70 years ago by Weindling (1932), who was the first to report the parasitic activity of *Trichoderma* spp. against *Rhizoctonia solani* and *S. rolfii*. Morton and Stroube (1955) screened the antagonistic fungi, bacteria and actinomycetes against *S. rolfii* of soybean by dual culture technique. Muthamilan and Jeyarajan (1992) tested antagonism of *T. viride*, *T. harzianum* isolates and *Laetisaria arvalis* against *S. rolfii* by dual culture on PDA. They observed a reduction of 68.7 per cent in sclerotial production in presence of *T. viride* isolate 2. In dual culture, out of 11 isolates of *T. harzianum*, three isolates viz., T₈, T₁₀ and T₂ were found effective against groundnut isolate of *S. rolfii* and they over grew the pathogen up to 79-92 per cent (Kajal Kumar and Chitreswar Sen, 2000).

Pranab Dutta and Das (2002) studied the antagonistic potential of *T. harzianum*, *T. viride* and *T. koningii* against tomato isolate of *S. rolfii* by dual culture technique. They observed that the three antagonists reduced the growth of the pathogen by 61.5, 59.1 and 57.2 per cent, respectively and sclerotial production by 94.2, 86.8 and 84.1 per cent, respectively. Rajalakshmi (2002) observed 37.5 to 41.3 per cent reduction in growth of mycelium of groundnut, tomato and crossandra isolates of *S. rolfii* by *T. viride* and *T. harzianum*. She also observed significant reduction in sclerotial production by the antagonists in dual culture.

Rajeev Pant and Mukhopadhyay (2001) studied the mechanisms of biocontrol viz., antibiosis, competition, mycoparasitism or other form of direct exploitation of *G. virens* and *T. harzianum* on *S. rolfii*. They observed infrequent coiling of hyphae of *T. harzianum* around *S. rolfii* hyphae resulting in coagulation of protoplasm and shrunk hyphae leading to lysis. Dube (2001) described the mechanisms of disease suppression by rhizobacteria. He stated that rhizobacteria antagonize soil borne pathogens through production of antibiotics or lytic enzymes (chitinase) and through competition for nutrients, notably iron as well as by inducing systemic resistance in the plant against subsequent infection by pathogens.

EFFECT OF CHEMICAL FUNGICIDES AGAINST COLLAR ROT

Bhardwaj et al. (1983) evaluated *in vitro* the efficacy of thiophanate- methyl at 100 µg/ml against two strains of *S. rolfii* and found that potato isolate was more sensitive to thiophanate-methyl than rice isolate. Anitha Chowdary (1997) evaluated *in vitro* sensitivity of bell pepper isolate of *S. rolfii* to captan, thiram @ 25, 50, 100, 250, 500 and 1000 ppm and propiconazole @ 10, 20, 25, 50, 100, 250 and 500 ppm. She reported that propiconazole at a concentration of 250 ppm was effective in complete inhibition of *S. rolfii*.

Pranab Dutta and Das (2002) studied *in vitro* efficacy of thiram and mancozeb at 0.1 per cent concentration against tomato isolate of *S. rolfsii* and reported that thiram had inhibited 70.3 per cent of mycelial growth and 96.5 per cent of sclerotial production of *S. rolfsii*. Narayana Bhat and Srivastava (2003) evaluated *in vitro* efficacy of captan, thiophanate-methyl and propiconazole at 250, 500 and 1000 ppm concentrations against *S. rolfsii*. They found that propiconazole was effective even at 250 ppm concentration against *S. rolfsii*.

COMPATIBILITY STUDIES OF BIOAGENTS WITH FUNGICIDES

Vidhyasekaran and Muthamilan (1995) reported that thiram and carbendazim were not inhibitory to *P. fluorescens* in *in vitro* conditions.

Deepak Kumar and Dubey (2001) tested the compatibility of *T. harzianum* and *G. virens* with benomyl, carbendazim, thiophanate-methyl, carboxin at 0.025 and 0.05 per cent and thiram and captan at 0.05 and 0.01 per cent concentration. They found that thiram, carboxin and captan were least effective on the antagonists.

Dubey and Patel (2001) evaluated the compatibility of *G. virens* and *T. viride* with carbendazim, thiram, carboxin, captan and thiophanate - methyl at 0.2, 0.1, 0.05, 0.02 and 0.01 per cent concentrations. Thiophanate - methyl was found to be more compatible. Rajeev Pant and Mukhopadhyay (2001) evaluated the effect of carboxin, @ 10, 25, 50 µg a.i / ml ; thiram @ 25, 50, 75 µg a.i / ml and carbendazim @ 1, 5, 10 µg a.i / ml concentrations on the growth of *G. virens* and *T. harzianum*. Carboxin had no effect on both antagonists at all the concentrations. Carbendazim was found to be highly inhibitory to them. Ramarethinam *et al.* (2001) reported that propiconazole was highly inhibitory to *T. viride* even at 100 ppm concentration.

IN VIVO STUDIES ON COLLAR ROT DISEASE

Seed treatment (or) seedling treatment

Muthamilan and Jeyarajan (1992) found that seed treatment with captan @ 4 g/kg seed significantly decreased root rot of groundnut caused by *S. rolfsii*. Dip treatment (3 g/litre water) or seed dressing (3 g/kg seeds) with thiophanate-methyl, carboxin and thiram were evaluated for their effectiveness in controlling soil borne pathogens of stevia viz., *S. rolfsii*, *Macrophomina phaseolina*, *Fusarium oxysporum*, *F. semitectum*, *F. solani* and *R. solani*. Thiophanate-methyl was found to be effective in controlling these pathogens (Hilal and Baiuomy, 2000).

Charde *et al.* (2002) found that seed treatment with propiconazole and hexaconazole were superior in checking stem rot of groundnut caused by *S. rolfsii* and increasing the shoot and root length. Corm treatment with captan @ 0.2% significantly reduced collar rot of elephant's foot yam incited by *S. rolfsii* (Gogoi *et al.*, 2002). Seedling root dip in mancozeb (0.1%) and thiram (0.1%) effectively reduced collar rot of tomato caused by *S. rolfsii* (Pranab Dutta and Das, 2002). Seed treatment of soybean with hexaconazole and propiconazole inhibited *S. rolfsii*. These fungicides were found to be absorbed by roots and translocated to shoot and leaf (Tajane *et al.*, 2002).

Soil treatment

Mishra and Bais (1987) found that soil treatment with thiram (2000 ppm) minimized pre and post-emergence mortality of barley caused by *S. rolfsii*. He also evaluated the efficacy of hexaconazole (0.1% and 0.2%), carbendazim (0.2%), and thiophanate-methyl (0.2%) under *in vivo* conditions against *S. rolfsii* of gram and sunflower. Hexaconazole was found to be highly effective followed by carbendazim and thiophanate-methyl .

Charde *et al.* (2002) reported that soil treatment with propiconazole and hexaconazole effectively reduced stem rot of groundnut caused by *S. rolfsii*.

Gogoi *et al.* (2002) reported that soil-drenching with captan (0.2%) resulted the lowest collar rot incidence of elephant's foot yam caused by *S. rolfsii*.

EFFICACY OF ANTAGONISTS AGAINST COLLAR ROT PATHOGEN

Seed (or) seedling treatment

Muthamilan and Jeyarajan (1992) found that the seed pelleting with *T. harzianum* of 5×10^9 conidia / ml as the best treatment in controlling root rot of groundnut caused by *S. rolfisii* and seed treatment with *P. fluorescens* was found to be effective in controlling collar rot of groundnut incited by *S. rolfisii*. Hari Narayana (1999) evaluated the efficacy of seedling root dip in *T. viride* and *P. fluorescens* in controlling sclerotial wilt of bell pepper incited by *S. rolfisii*. Seedling root dip in *T. viride* was found to be superior.

Seed treatment with *P. fluorescens* and *P. putida* effectively reduced sclerotium rot of sunflower caused by *S. rolfisii* (Rangeshwaran and Prasad, 2000). Anahosur (2001) reported that tuber treatment with *T. harzianum*, *T. viride*, *G. virens*, and *P. fluorescens* @ 10 g/kg of tuber effectively controlled wilt of potato caused by *S. rolfisii*. Gogoi et al. (2002) reported that corm treatment with *T. harzianum* and *B. subtilis* significantly reduced collar rot of elephant's foot yam incited by *S. rolfisii*.

Soil application

Biocontrol by adding large amounts of *Trichoderma* preparations on solid media (ground annual ryegrass seed) for field control of *S. rolfisii* were reported. Mixing of wheat bran culture of *T. harzianum* (Th-2), *T. viride* (Tv-2) and *Gliocladium* sp. @ 10 g/kg soil reduced the seedling mortality by 12.71, 14.72 and 17.98 per cent, respectively, in brinjal due to collar rot caused by *S. rolfisii* (Amar Singh and Dhanbir Singh, 1994). Application of *T. harzianum* inoculum to soil at the time of sowing was better than other treatments including seed treatment with antagonist in controlling root rot of groundnut caused by *S. rolfisii* (Muthamilan and Jeyarajan, 1996).

Soil application of *P. fluorescens* was effective in controlling collar rot of groundnut incited by *S. rolfisii* (Patil et al., 1998). Soil application of *T. harzianum* (20 g / plant) and *B. subtilis* (20 ml/plant) significantly reduced collar rot of elephant's foot yam caused by *S. rolfisii* (Gogoi et al., 2002). Sclerotial wilt of groundnut caused by *S. rolfisii* was effectively reduced (92.58%) when *T. harzianum* was applied @ 10 g/kg soil (Patibanda et al., 2002). Soil application of inoculum of *Trichoderma* spp. at the time of transplanting reduced collar rot of tomato caused by *S. rolfisii* and increased dry mass of root and shoot and yield (Pranab Dutta and Das, 2002).

INTEGRATED MANAGEMENT OF COLLAR ROT

Papavizas (1985) emphasized the importance of integration of *Trichoderma* or *Gliocladium* with compatible fungicides or other practices in controlling soil borne pathogens. Muthamilan and Jeyarajan (1996) reported that integration of *T. harzianum*, *Rhizobium* and carbendazim remarkably reduced the root rot of groundnut caused by *S. rolfisii*. Seed treatment with Vitavax 200 (carboxin 37.5 + thiram 37.5) 75 WP @ 0.2% + *T. harzianum* or *G. virens* effectively controlled seed and seedling rot of soybean caused by *S. rolfisii* (Uma Singh and Thapliyal, 1998).

Seed and soil treatment with *T. harzianum* plus neem cake significantly reduced stem rot of groundnut caused by *S. rolfisii* with increased dry shoot and root weight (Sakthi Kumaran, 2000). Deepak Kumar and Dubey (2001) found that seed treatment with captan or thiram @ 1 g / kg along with *T. harzianum* @ 10^6 spores/ml gave not only good germination but also effective control of collar rot of pea caused by *F. solani* f.sp. *psi*. Integration of *G. virens* and *T. harzianum* with carboxin (0.1%) effectively controlled seed and seedling rot of soybean incited by *S. rolfisii* (Rajeev Pant and Mukhopadhyay, 2001). Gogoi et al. (2002) reported that corm treatment with captan (0.2%) integrated with soil application of *T. harzianum* or *B. subtilis* reduced collar rot of elephant's foot yam caused by *S. rolfisii*. Patibanda et al. (2002) observed effective control of sclerotium wilt of groundnut caused by *S. rolfisii* when seed coating with thiram (0.1%) integrated with soil application of *T. harzianum* @ 4.0 g/kg soil.

Rama Yalla Reddy (2002) found that integrated use of *T. viride*, *P. fluorescens*, commercial neem product Niwaar and thiram for seed treatment of groundnut improved pod yield and controlled soil mycoflora viz., *A. niger*, *Alternaria* sp., *Curvularia* sp., *Fusarium* sp., *Drechslera* sp., *Penicillium* sp., *R. stolonifer*, *Rhizoctonia* sp., *S. rolfsii* and *Verticillium* sp. Duffy et al. (1996) reported that combined application of *T. koningii* and fluorescent *Pseudomonads* effectively controlled take-all on wheat. Rajendran and Ranganathan (1996) reported that combined seed treatment of *T. viride* and *P. fluorescens* reduced the onion basal rot incidence incited by *F. oxysporum* f.sp. *cepae* both in pot culture and in field conditions. Seed treatment with both *G. virens* and *B. subtilis* suppressed *Fusarium* colonisation of cotton root (Xhang et al., 1996). Anith and Manomohandas (2001) reported that combined application of *T. harzianum* and *Alcaligenes* sp. strain AMB8 effectively controlled nursery rot disease of black pepper caused by *P. capsici*. Damping - off of brinjal and tomato was effectively controlled by combined seed treatment with *P. fluorescens* and *T. harzianum* (Vishwakarma et al., 2002).

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