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Murali V
Assistant Professor, Department of Agronomy, College of Horticulture, SKLTSHU, Telangana, India

Prashanth Kumar A
Scientist (Plant Pathology), JVR Horticultural Research Station, SKLTSHU, Telangana, India

Rajasekhar B
Assistant Professor, Department of Entomology, College of Horticulture, SKLTSHU, Telangana, India

Gajanand P
Assistant Professor, Department of Agricultural Extension, Horticultural Polytechnic College, SKLTSHU, Telangana, India

Corresponding Author:
Murali V
Assistant Professor, Department of Agronomy, College of Horticulture, SKLTSHU, Telangana, India

Bio-rational methods of managing collar rot (*Sclerotium rolfsii*) disease incidence and black thrips (*Thrips parvispinus*) infestations on chilli (*Capsicum annum* L.)

Murali V, Prashanth Kumar A, Rajasekhar B and Gajanand P

Abstract
Chilli production in Telangana state was recently impacted by collar rot disease incidence and black thrips infestation. The extents of crop losses were up to 16-80% with collar rot and total crop loss with black thrips severe infestations. There were no current recommendations of the package of practices for the successful management of these two deadly diseases and pests, impacting the livelihoods of chili growers in Telangana state. This article reviews the collar rot disease pathogenicity, disease spread, black thrips life cycle, damage symptoms, and management using bio-rational methods.

Keywords: Chilli, collar rot, black thrips, symptoms, bio-rational methods

Introduction
Chilli (*Capsicum annuum* L.), the hot pepper is one of the most valuable commercial spice crops of India that generate higher revenues for the producers. More than 400 varieties of chilli are in cultivation worldwide, and India is the world's largest producer, consumer, and exporter of chill. The Telangana state (TS) is the second largest producer of chillies, cultivated in 85,000 ha with an average productivity of 3859 kg/ha (Spice board, 2021) [20]. Chilli crop is infested by a number of insects and nematode pests; diseases caused by bacterial, fungal, viral organisms. Among the diseases, Collar rot is becoming a severe disease in different chilli growing states of India. The extent of yield losses with Collar rot ranging from 16-80 per cent was reported by many researchers (Daunde *et al.*, 2020) [8]. Added to the Collar rot, a recently new invasive insect pest, black thrips (*Thrips parvispinus*) originated from Indonesia becoming resurgent in many chilli growing states in India. Recent joint diagnostic surveys conducted by the Sri Konda Laxman Telangana State Horticultural University (SKLTSHU), Mulugu, TS, Indian Institute of Horticultural Research (IIHR), Bangalore, and Directorate Plant Protection Quarantine & Storage (DPPQ&S), Faridabad, India inferred that Black thrips becoming pandemic to chilli crop in Telangana (Anitha *et al.*, 2021) [3]. The insect pest developed resistance against pesticides and farmers losing hopes in different districts of Telangana ploughing the fields at flowering stage itself causing total crop loss. About 20 chilli farmers of Mahabubabad district, TS, committed suicide in 2021 crop season as they incurred Rs 80,000-100,000 per acre on raising the chilli crop was lost (Down To Earth 2022) [9]. Chilli farmers opined that the current insect pest and disease management practices did not help in managing the outbreaks and posing scientists to formulate alternative bio-rational measures. The precise usage of the term bio-rational is difficult, it inherently different from conventional pesticides and has lower risks associated with their use (Horowitz *et al.*, 2009) [12]. Thus bio-rational methods refer to the utilization of natural substances, botanicals, substances of animal origin, bio-pesticides, insect growth regulators, and semi chemicals which have limited or no adverse effects on environment or beneficial organisms. This article reviews the work done on different bio-rational methods in the management of devastating newly emerged pest "black thrips (*Thrips parvispinus*)" and "Collar rot (*Sclerotium rolfsii*)" disease limiting chilli production worldwide.

Collar rot - *Sclerotium rolfsii* (*S. rolfsii*) *disease*
The collar rot of the solanaceous group of plants is an aggressive soil and seed-borne disease caused by the basidiomycete fungus *Sclerotium rolfsii*.

The sclerotia and mycelium of the fungus can spread rapidly and may infest the entire field due to its prolific growth rate. Different strategies to manage collar rot failed due to melanized resting bodies and prolonged resting of pathogens in vivid soil and environmental conditions. Collar rot is an emerging disease that may incite 16–80% mortality of chilli seedlings under favourable environmental conditions of heavy rainfall and high soil temperature (25–30 °C). *S. rolfsii* usually attacks the collar region of plants, hence the name collar rot. Because of the highly competitive saprophytic survival ability, in recent years, S. *rolfsii* is becoming more prevalent in agricultural areas where sudden rainfall increases soil moisture for longer periods combined with warm temperatures. With the availability of such a large range of natural hosts, *S. rolfsii* could even survive in dry climatic regions and continue to persist in the soil for prolonged periods even after several crop rotations. Alternate wetting and drying, following periods of warm temperatures enhanced the germination of sclerotia (Punja 1985) [18].

Table 1: Successful bio-rational methods for collar rot disease management in different crops.

Crop	Disease/Quality	Bio rational method	Reference
Chilli	Enhanced Seed quality and Yield	Seed bio-priming with *Pseudomonas. fluorescens*	Ananthi *et al.*, 2017 [1]
Chilli	*Rhizoctonia solani* and *Sclerotium rolfsii*	*Pseudomonas spp*	Kotasthane *et al.*, 2017 [25]
Peppermint	Collar rot	*Trichoderma harzianum* + *Pseudomonas fluorescens*	Muthukumar and Venkatesh, 2014 [16]
Chilli	Dry root rot	Addition of vermicompost and application of *Trichoderma harzianum*	Madhavi B and Bhattiprolu S.L. 2011 [6]
Tomato	Collar rot	*Trichoderma viride soil application.*	Faheem *et al.*, 2010 [10]
Chickpea	Collar rot	Foliar sprays of *Pseudomonas fluorescens* and *Trichoderma. harzianum*	Mourya *et al.*, 2008 [16] Anil *et al.*, 2017 [2]

The bio-fertilizers used in the bio-rational approach generally composed of *Azotobacter*, *Azospirillium*, *Bradyrhizobium*, *Rhizobium*, and bio-pesticides such as *Trichoderma*, *Pseudomonas* spp were found to suppress soil-borne diseases through antibiosis, mycoparasitism, nutrition and space competition, production of toxic metabolites and siderophores. Bio-rational methods are low-cost, self-manageable, long-lasting, and hold high antifungal activity as compared to chemical fungicides (Bhattacharjee and Dey 2014) [5].

Black Thrips -*Thrips parvispinus* (*T. parvispinus*) insect pest

Thrips parvispinus is a cosmopolitan devastating invasive tiny insect pest belonging to the order Thysanoptera. It is a polyphagous pest, infesting a number of fruit, vegetable, and ornamental crops including Beans, Brinjal, Rose, Anthurium, Chrysanthemum, Dipladenia, Gardenia, Dahlia, Mango, Pepper, Potato, and Onions. Black thrips infestation was observed in different chilli growing areas of Andhra Pradesh, Chhattisgarh, Karnataka, Kerala and Tamil Nadu (Rachana R.R. and Shylesha A.N, 2021) [19]. This shows black thrips had wider adaptability to feed on a variety of host plants and breed in diverse agroecosystems. Thrips life cycle had five distinct stages, starts with an egg and then passes through two foliar-feeding nymphal stages (First and second instar larvae) followed by two non-feeding soil-inhabiting stages (Pre-pupa and Pupa). The lifecycle completes the emergence of flying adults from pupae. The stadia of each growth stage were 4.79, 1.36, 3.54, 1.08, and 1.96 days respectively. Males of black thrips are short-lived (8.55 days) while females had more longevity (13.68 days), the nymphs are small, linear-shaped, easily fragile abdomen with yellow colour. Adults exhibit sexual dimorphism; females are brownish-yellow, and males are uniformly yellow. Both nymphs and adult damage the younger leaves, flower buds, and fruits. The lifecycle completes in about 13 to 15 days and the doubling time was 4.57 days (Hutasoit *et al.*, 2017). The infested leaves develop silvery white patches, crinkles, and upward curling with elongated petioles. During the initial stages of infestation, plants show stunted growth, buds become brittle and drop down. In severe cases of infestation, flower production, fruit set were stopped, which necessitate the chilli growers to plough back the crop. Excessive use of organophosphates, neonicotinoids, pyrethroids, spinosyns, avermectins, chlorenapyr and tetranoic acids derivatives insecticides lead to resistance development in chilli thrips (Arisz-bal *et al.*, 2016). Unlike Integrated Pest and Disease Management measures, bio-rational methods of pest and disease management employ a combination of organic manures and bioagents - biofertilizers, biopesticides, parasitoids (Horowitz *et al.*, 2009) [12]. The immobile soil-inhabiting stages pre-pupa and pupal stages were found to be most susceptible to soil-inhabiting pathogens such as nematodes, *Heterorhabditis bacteriophor*a (VS strain), and *Steinernema feltiae* (SN strain) and Entomopathogenic fungi, Beauveria *bassiana* (WG-11) and *Metarhizium anisopliae* (WG-02) strains (Gulzar *et al.*, 2021) [11].

A grape farmer Padma Shri awardee Chintal Venkata Reddy (popularly known as CVR), Rangareddy district of TS has patented the subsoil application (European Patent EP 2272313A1) along with irrigation water thrice at flowering stage in grapes resulted in higher grape yields and quality fruits. He did successful experiments with CVR methods in wheat, paddy, maize, sugarcane, vegetables and grapes. He further refined subsoil application with mixing of castor oil and soil solution foliar sprays on plants in preventing pest and disease attack on a number of crops. Entomopathogenic fungi such as *Beauveria bassiana, Isaria fumosorosea, Metarhizium spp* were found to be promising in managing chilli thrips (Steven *et al.*, 2013) [21].

Table 2: Successful bio- rational methods for chilli thrips different crops

Crop	Pest	Bio rational method	Reference
Sweet pepper	Black thrips	*Menochilus sexmaculatus* and *Coccinella transversalis* and an entomophagous fungus, *Lecanicillium lecanii* was identified as the potential natural enemy.	Prabaningrum *et al.*, 2008 [17]
Chilli	Black thrips	*Pseudomonas fluorescence*- NBAIRPFDWD @ 20 g/l or *Bacillus albus*-NBAIR-BATP @ 20 g/l sprays focusing on flowers and fruits	ICAR- NBAIR, 2021 [14]
Tomato	Thrips	Foliar sprays of *Pseudomonas fluorescens* + neem oil	Vasanthi *et al.*, 2017 [24]
Chilli	Aphids, Thrips, Mites	Farmyard manure (FYM) + Neem cake (NC) and *Pseudomonas fluorescens* + entomopathogenic fungal formulations *Beauvaeria. bassiana*	Chinnaiah *et al.*, 2016 [7]
Chilli	Thrips, Green peach aphids, and Chilli mites	*Pseudomonas fluorescens* + Naphthalene acetic acid + neem oil	Sujay *et al.*, 2010 [22]
Roses	Chilli thrips	*Beauveria bassiana* GHA (BotaniGard ES), *Metarhizium brunneum* F52 (Met-52 EC) Entomopathogenic fungi, horticultural oils (Neem oil, SuffxOil-X).	Arisz-bal *et al.*, 2016

Conclusion

Major chilli pathogen collar rot and insect pest black thrips threatened chilli production in the Telangana state. Despite farmers' adoption of chemical control with a new class of fungicides and insecticides did not result in successful control. There were no current recommendations for a package of practices; chilly farmers are in distress as the incidence of black thrips and collar rot devastated the crop. The bio-rational methods are low-cost and environmentally friendly, and any positive outcome will enhance chilli cultivation and improve the livelihoods of the farmers in the state. There is an urgent need to formulate alternate measures using different bio-rational methods to check crop losses.

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