Anthracnose Disease of *Capsicum annuum* L. and Its Bio Control Management: A Review

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Abstract *Capsicum annuum* L. is an important tropical and subtropical vegetable and spice crop due to its high consumption, nutritional and cash value to farmers and consumers. It has a specific nutritional value due to presence of biochemical compounds such as capseteum; a volatile fatty oil, capsaicinoids, carotenoids, potassium, folic acid, protein, fiber, mineral elements and vitamins etc. Despite serious threats have been posed by many fungal pathogens to the chili crop worldwide; maximum losses occur in capsicum are due to the Anthracnose disease caused by fungal pathogen *Colletotrichum* sp. The biocontrol management is playing crucial role and promoted widely in control of Anthracnose disease, mainly because of its ability to control variety of fungal diseases and also enhancing the crop production in an environment friendly manner. This review article attempts to highlight an occurrence of Anthracnose disease on an economically important *Capsicum annuum* L. (chilli) along with its biocontrol management strategies.

Keywords: anthracnose, bio control, *Capsicum annuum* L.

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1. Introduction

Chilli (*Capsicum annuum* L.) is one of the most important constituents of the cuisines of tropical and subtropical countries and the fourth major crop cultivated globally. Around 400 different varieties of chilies are cultivated throughout the globe. [1]. Known for over 9500 years, chilli is the native of southern America and was first cultivated in Peru at around 7500 BC. [2]. Chilli is believed to be introduced in India during 17th century by the Portuguese. It was originated in the American tropics and has been propagated throughout the world including the tropics, subtropics, and also temperate regions [3]. The fruit of *Capsicum* has a variety of names, such as ‘chilli’, ‘chilli pepper’ or ‘pepper’ depending on place (i.e., differences between the English-speaking countries) and type of fruits. *Capsicum annuum* L. (Chilli) is one of the most important vegetable and spice crop belonging to family Solanaceae, mostly cultivated for its green and ripe red fruit that has multiple uses such as an indispensable condiment, digestive stimulant as well as flavoring and coloring agent in sauces, chutneys, pickles and other forms of food. In India alone, it is cultivated over an area of 792.1 thousand hectares with an annual production of 1223.4 thousand tones [4].

Although the crop production has found to be declined in recent years; mainly due to the biotic factors, attributed to diseases such as fruit rot, leaf spot, wilt, damping off, etc. the crop is mainly susceptible and attacked by several fungal diseases; the most devastating fungal disease that lowers the annual yield considerably; is anthracnose disease caused by *Colletotrichum* spp. Anthracnose disease usually develops under conditions of high humidity when rainfall occurs after the fruits have started to ripen. The disease is more likely to develop on mature fruits, although it can occur on immature fruits as well [5]. The Anthracnose disease is being managed by chemical control agents; environmental concern calls for the usage of ecofriendly methods. Moreover; Deep insight into plant pathogen interactions is required in order to understand pathosystem of *Colletotrichum*. Also, the molecular approaches for the development of resistant varieties may provide long lasting resistance. Major reports on anthracnose, plant pathogen interactions are still needed. [6]. since no resistant cultivars of chilli have been developed and commercialized, it is very important to develop biological management strategies.

2. Medicinal and Nutritional Importance

Numerous varieties of chilli are grown for vegetables, spices, condiments, sauces, and pickles occupying an indispensable position in Indian diet. However; genus *Capsicum* is described with about 27 species; of which 5 are domesticated and are cultivated in different parts of...
the world; namely; C. annuum, C. baccatum, C. chinense, C. frutescens, and C. pubescens. Among these five species; C. annuum is one of the most common cultivated species worldwide [7,8].

Apart from the explicit importance of the crop in the diet, chilli is also used in other forms like medicines and beverages and also as an ornamental plant in the gardens. Nutrition-wise; these are enriched with high Vitamin A and C content; high iron, potassium, and magnesium content with the ability to boost the immune system and lower the cholesterol levels [9]. Also, it contains numerous chemicals including steam-volatile oils, fatty oils, capsaicinoids, carotenoids, vitamins, protein, fibre and mineral elements [10]. Many of these constituents are important for nutritional value, flavor, aroma, texture and color. These are low in sodium and cholesterol free, rich in vitamins A and C, and are a good source of potassium, folic acid and vitamin E. Fresh green chilli peppers contain more vitamin C than citrus fruits and fresh red chilli has more vitamin A than carrots [11]. The capsaicinoids are alkaloids that make hot chilli pungent. A large number of carotenoids provide high nutritional value and the color to chilli [12,13,14]. The non-pungent varieties are cooked as vegetables or processed with other food items for flavor [15].

3. Anthracnose and the Pathogen

**Colletotrichum spp.**

The word anthracnose is a Greek word meaning ‘coal.’ It is commonly used for plant diseases which are characterized by dark sunken lesions having spores [16]. Firstly reported from New Jersey, USA, by [17] in 1890 who described the causal agents as *Gloeosporium piperatum* and *Colletotrichum nigrum*. Disease is known to be caused by different *Colletotrichum* species complex viz., C. capsici, gloeosporioides, C. acutatum, C. coccodes, C. boninense and C. truncatum. Though the pathogen survives on infested debris, but disease is also known to be of seed born origin. Anthracnose disease occur in field as pre or post-harvest decay with water soaked, sunken lesions with dark red to light tan lesions have scattered concentric rings of spore masses. Under severe conditions, lesions fuse and conidial masses may occur in concentric rings on lesions. Post-harvest damage is more as infection remains latent in plant cells [18]. Even small anthracnose lesions on chilli fruits reduce their marketable value [19]. It directly reduces the quantity and quality of the harvested yield; small lesions on chilli fruits also affect the profits [19].

*Colletotrichum* is the 8th most important plant fungal pathogenic group [20], are known as broad range pathogens as a single species is capable of infecting diverse hosts and numerous species infect a single host [21]. The pathosystem involves several *Colletotrichum* species associated with anthracnose of same host [22,23]. As per [24]; different species infect chilli plant at different stages. Leaves and stems are damaged by C. coccodes and C. dementium, whereas C. acutatum and C. gloeosporioides infect chilli fruits. However; *Colletotrichum capsicii* is found to be prevalent in red chilli fruits whereas *C. acutatum and C. gloeosporioides cause infection both in young and mature fruits [25,26,27,28].

Many studies have concluded that disease management practices are often inadequate to eliminate the diseases. Breeding to develop the long-lasting resistant varieties has also not been successful due to involvement of multiple *Colletotrichum* species in anthracnose infection. [29] reviewed on the various management strategies for the causal agent of the disease, associated with the chilli Anthracnose caused by *Colletotrichum capsici*. Similarly; [30] studied the effect of different fungicides against *Colletotrichum capsici* caused chilli anthracnose disease. Likewise; [31] reviewed chilli anthracnose, its spread and management and observed that the use of natural antimicrobials, biocontrol agents, resistant cultivars and ozone should be used as on a commercial scale to control post-harvest chilli anthracnose caused by *Colletotrichum* species.

4. Biocontrol Management of Anthracnose

The potential for biological control of *Colletotrichum* species had been suggested as early by [32,33], who stressed the possibilities of biological control of post-harvest fruit disease by using *Pseudomonas fluorescens*. Biological control using microorganism has been studied intensively since not many alternatives to control are available [34]. Health environmental concern, development of resistance in target populations also contributes to developing biological control using natural enemies [35].

Biological control of fruit rot and dieback of chilli with using botanicals have been tested in many laboratories and field trials, showed that the crude extract from rhizome, leaves and creeping branches of sweet flag (Acorus calamus L.), palmorosa (Cymbopogon martinii) oil, *Ocimum sanctum* leaf extract, and neem (*Azadirachta indica*) oil could restrict growth of the anthracnose fungus. [36,37]. Antagonistic bacterial strains were found to effectively control *C. capsici*, the major anthracnose pathogen in Thailand [38]. Several studies using crude plant extracts have also been conducted to access the control of *Colletotrichum* sp. on chilli. [39,40]. Also, it is believed that *Trichoderma* species are able to effectively compete for surface area, thereby reducing pathogen infection success [41,42,43,44]. The other biological control agents that have been tested for efficacy against C. *acutatum include Bacillus subtilis* and *Candida oleophila*. The current management strategies for this fungus comprise the exploitation of cultivar resistance, cultural, chemical, and biological control methods, and preventive strategies such as disease-forecasting models. [45]. [39] studied biological management of fruit rot in the world’s hottest chilli (*Capsicum chinense* jacq.) in Nagaland, India. In vitro studies indicated that *Trichoderma viride* and *Pseudomonas fluorescens* were very effective in inhibiting mycelial growth of the pathogen. Similarly; among the plant extracts, *Allium sativum* (10%) and *Azadirachta indica* (10%) demonstrated the highest inhibition of mycelial growth of *C. gloeosporioides*.
Similarly; [46]; in Nadia, West Bengal; evaluated efficacy of four botanical oils viz., Garlic (Allium sativum), Neem (Azadirachta indica), Polyalthia (Polyalthia longifolia) and Citronella (Cydonia oblonga) along with biocontrol agents like Trichoderma harzianum, T. viride and Pseudomonas fluorescens used in different concentrations. Likewise; an efficacy of some organic materials to manage anthracnose of chilli under natural field condition at Bangladesh was attempted by [47]. Plant extracts of neem (Azadirachta indica), mahogany (Swietenia mahagoni), koromacha (Carissa carandas) and garlic (Allium sativum) applied as foliar spray, singly or in combination; also showed significant impact on disease reduction as well as on yield of chilli. [48], during a review on management of chilli Anthracnose, observed that the modifications in conventionally recommended cultural practices suiting to a particular agro-climatic region will prove helpful in better management of the disease. Similarly; [49], studied an integrated management of Anthracnose and its implications to disease reactions, quality and growth parameters of three genotypes of Chili in Ethiopia. Also, [50] indicated that the use of bio control agent Burkholderia sp. strain TNAU-1 in combination with the fungicides can effectively be employed to control the disease. [51] evaluated the effectiveness of extracts of Bavchi seeds (Psoralea corylifolia), Datura leaves (Datura sp.) and Ghaneri leaves (Lantana camera) as a biocontrol agent against Colletotrichum capsica at different concentrations of 250µl, 500µl, 750µl and 1000µl were tested by poisoned food technique. Their studies conducted during 2015-2017; it was found that Trichoderma viride suppressed the growth of Colletotrichum capsici by 80.00%. Also, methanolic extract of Psoralea corylifolia @ 1000µl showed the highest inhibition against Colletotrichum capsici. Treatment with P. fluorescens (culture filtrate @ 0.5%) + T. viride (culture filtrate @ 0.5%) + methanolic extract of Psoralea corylifolia @ 2% proved highly effective in reducing disease intensity (80%) in chilli under detached fruit bioassay.

Similarly; [52], at Malang, Indonesia, studied the ability of yeast Rhodotorula sp. to inhibit the infection and anthracnose disease on chilli. The inhibition effectiveness was ranging around 35-73% on the bruised chili fruit condition. The Rhodotorula sp. during the field test was effective in controlling the anthracnose disease caused by Colletotrichum acutatum fungi. The effectiveness was shown by the reduction of the visible intensity of the disease. The controlling effectiveness reached 97%.

Also, [53], in Hisar, Haryana, studied efficacy of biofungicides like Trichoderma sp. and Pseudomonas fluorescens on seedling emergence, vigour and health of infected chilli seeds Capsicum annum by Colletotrichum capsici. The use of Trichoderma viride and Pseudomonas fluorescens individually or in combination; was found as an alternative to carbendazim. The study conducted using blotter and pot experiment; revealed that the seed germination was significantly higher (94.7%) with Trichoderma viride treatment compared to all other treatments including controls in blotter method. The disease incidence was found significantly reduced with Pseudomonas fluorescens as compared to the Trichoderma viride and carbendazim in blotter method. [54] studied the efficacy of the cow urine over the fungicides in the management of chilli anthracnose caused by Colletotrichum capsici. Anthracnose disease inhibition of >40% was observed at 5%, >50% was observed at 10% and 20% concentrations in sterilized cow urine. The highest inhibition growth (91.67%) was observed against 20 per cent concentration and 15 days fermented.

Likewise; many researchers studied the eco-friendly management of Anthracnose of chilli, at different states across India. [55,56]. [55] conducted multigene phylogenetic analyses so as to understand the taxonomy and the pathogenicity of Colletotrichum spp. causing anthracnose disease of Capsicum in Asia. The study involved a total of 260 Colletotrichum isolates, associated with necrotic lesions of chili leaves and fruit were collected from chili producing areas of Indonesia, Malaysia, Sri Lanka, Thailand and Taiwan.

[56] observed that the seed treatment with Pseudomonas fluorescens @10 g/kg of seeds, seed treatment with Bio protectant, foliar application of Salicylic acid @ 50 ppm on 40 days after transplanting (40 DAT) and foliar application of Potassium silicate @ 3 % on 60 DAT recorded the minimum disease incidence and significantly decreased the disease severity, increased the growth and yield parameters.

Further; [57] worked out biocontrol efficiency of native pink pigmented facultative methylotrophs (PPFMs) of chilli for management of disease through induced systemic resistance mechanism under pot culture experiments. Significantly lesser disease incidence, more yield and more capsicin content were observed with application of Methylobacterium populi as compared to control; that highlighted native M. populi (PPFM) of chilli as an effective plant growth promoter, exhibiting significant biocontrol efficiency against C. capsici.

5. Conclusion

The reduction in the chilli production and the drop in fruit quality have further intensified the need for developing a sustainable approach for controlling the spread of the disease. No single management technique has been found to efficiently control the disease. Generally, using a combination of the different strategies like chemical control, biological control, physical control and intrinsic resistance has been recommended for managing the disease. Thus, the application of biocontrol strategy for anthracnose disease management has been emerged up as a sustainable approach required for restoring the lost homeostasis of the environment. [1,58]. Therefore, the farmers may be advised to take an integrated approach, which should to raise a profitable production without polluting the environment and adding toxins in the food chain. This review article will be helpful to the researchers for better understanding.

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