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Anthracnose of chilli: A review

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Abstract
Capsicum annum L. is a fourth grown crop in the world. Anthracnose is the most common disease in chilli. *Colletotrichum spp*. that causes anthracnose disease in chilli crops. Due to anthracnose up to 50% yield loss was reported in different countries and especially in Thailand 10 to 80% yield loss was reported. *Colletotrichum* spp. it causes severe infection in chilli and mostly it infection occur on fruit, stem and leaf. It may cause die back and ripe fruit rot. Anthracnose causes dark sunken lesion with concentric ring spot and dieback of stem started on tip of the plant and move downward and spotting occurs in ripe fruit. Sickle shaped and hyaline conidia produced by acervuli. The pathogen can survive on seed in form of microsclerotia and acervuli and 27 °C temperature with relative humidity are required for the growth of the pathogen. crop spacing, crop rotation, disease-free transplanting, mulching, use of resistant varieties and use of botanical (Garlic Bulb Extract, Tulsi leaves extract, crude plant extracts), Bioagent (*Trichoderma viride, Pseudomonas fluorocence*), chemical (Amistar, Headline, M - 45, Blue copper, Score) are also effective ways to control the anthracnose of chilli.

Keywords: Anthracnose, botanical, bio-agent, chemical, chilli, *Colletotrichum capsici*

Introduction
Capsicum annum L. (Chilli) is a key ingredient in the cuisines of tropical and subtropical countries, as well as the world's fourth most grown crop. Chillies are grown in over 400 different kinds all over the world. “Carolina Reaper" is the hottest cultivar which has approximately a pungency is 2.2 million SHU which was proved by West Indian grower Ed Currie (Scoville Heat Units; Pucker Butt Pepper Company, 2013) [42]. Chillies (*Capsicum spp.*), a major economic crop around the world, are one of these hosts (Poulos, 1992) [41]. Chilli’s berries are botanically classified as vegetables and are often referred to as berries (Saxena *et al.*, 2016) [46]. (Makari, 2009) [34] said that *Capsicum annum* L., often known as the chilli pepper, is a popular and extensively produced vegetable across the world, but it is especially popular in Asia. However, in tropical and subtropical locations, anthracnose disease is a serious challenge for chilli productivity reported by (Sharma *et al*., 2005) [49]. In India, the chilli pepper is a popular commercial crop. Chilli is grown extensively in Andhra Pradesh, Punjab, Haryana, Orissa, Maharashtra, Uttar Pradesh, West Bengal, Karnataka, Rajasthan, Gujarat and Tamil Nadu (Sahitya *et al*., 2014) [45].
Colletotrichum is a significant plant pathogen that causes anthracnose in tree fruits, perennial crops, vegetables, legumes and cereals among other hosts (Bailey and Jeger, 1992) [13]. It was at Coimbatore, in the Madras Presidency, where chilli anthracnose was first discovered in India (Sydow, 1913) [57]. Disease was already discovered in all of the world's chilli-growing regions, creating a significant bottleneck in the industry. Pepper anthracnose is caused by the four *Colletotrichum* species: *Colletotrichum capsici*, *Colletotrichum gloeosporioides*, *Colletotrichum acutatum*, and *Colletotrichum coccodes*, which have been recognised as the causal agents in many places. According to Hadden and Black (1987) [17]. *Colletotrichum capsici* and *Colletotrichum gloeosporioides* are the most prevalent species. Anthracnose, which is one of the most dangerous fungal diseases of chillies in Asia. *Colletotrichum capsici* is a significant disease in chilli crop producing areas in Thailand, according to (Than *et al*., 2008 and Montri *et al*., 2009) [58, 36].
This disease creates huge devastation to ripe fruits in the field by causing symptoms on the leaves, stems, and fruits. Furthermore, this disease causes significant damage to chilli fruit during postharvest storage reported in 2003, by Mehrotra and Aggarwal. Concentric rings of acervuli on sunken necrotic tissues with are typical anthracnose signs on chilli fruits. The marketability of fruits with imperfections is diminished (Manandhar *et al*., 1995) [35]. Anthracnose disease occurs on fruits and foliage as tiny circular dots that merge into big

elliptical patches. Defoliation of damaged plants happens under extreme circumstances.

Anthracnose disease is the most serious restriction to chilli production worldwide, leading in significant productivity losses. The quality and production of fruit are significantly reduced by this fungal disease produced by *Colletotrichum spp*., resulting in low returns to growers. In 2005, Pakdeevaraporn *et al.* [39] investigate that anthracnose has invaded the crop, causing output up to 50% losses. Poonpolgul and Kumphai in 2007 [40] said that *Colletotrichum spp.* which cause in chilli anthracnose and due to this disease 10-80 percent reduce marketable yield in various countries, especially in Thailand. Thailand loses 10-80% of its marketable yield, while Korea loses approximately 13%. This dieback/fruit rot/anthracnose disease affects mature fruits, causing fruit loss both before and after harvest. More than half of all losses in India are caused by pre-harvest and post-harvest losses. Haryana and Punjab (20-60%), as well as Assam (12 to 30%), have reported significant yield reductions (Sahitya *et al*., 2014) [45]. In Maharashtra, yield losses were estimated to be between 8 and 27 per cent and 30 to 76 percent in Tamil Nadu (Bansal and Grover, 1969) [5]. *Colletotrichum spp.* was named one of the ten most infamous diseases in the world by (Dean *et al.* in 2012) [11], causing massive crop losses all over the world. In 1985, Thind and Jhooty [59] reported 12-50% yield loss and 66-84% disease incidence rates.

Materials and Methods

1. Symptoms

Anthracnose refers to a group of plant diseases marked by black, sunken lesions that contain spore. It is derived from a Greek word that means "coal" (Isaac, 1992) [22]. Plants die back and develop leaf spotting at various stages of development. The symptoms of die back first occurs at the tips of the plant's branches and spreads downward, eventually killing the branch. The production of acervuli in sunken necrotic tissues, concentric rings, and a consolidated lesion accompany rotting and fruit spotting in mature chillies. The necrosis of branches from the tip backwards is caused by infection of the developing tips. The necrotic tissues are greyish white in colour, with a black dot in the centre that looks like acervuli. Infection in the pedicel and branch tips causes flower shedding (Chilli Diseases – Vikaspedia).

2. Pathogen

Colletotrichum spp. present taxonomic position is unknown (Sreenivasaprasad and Talhinhas, 2005) [55]. Dean *et al. (2012)* [11], said that *Colletotrichum* is an asexual fungi imperfectii genus that belongs to the Ascomycetes phylum and the Coeleomycetes class. According to (Cannon *et al*., 2000; Freeman *et al.*, 1998; Simmonds *et al.*, 1965) [9, 15, 52], different species of this pathogen can be connected to anthracnose in the same host. In 2004, Kim *et al.* [30] reported that various species infect different areas of the chilli plant; for example, *C. gloeosporioides* and *Colletotrichum acutatum* infect chilli fruits at all stages of growth but not the leaves or stems, which are usually harmed by *C. dematium* and *C. coccodes*. *C. coccodes* caused leaf anthracnose on chilli seedlings for the first time in 1988 on a farm in Korea's Chungnam Province (Hong and Hwang, 1998) [20]. Conidia generated by acervuli, a subepidermal fruiting body, are hooked in shape (Than *et al.*, 2008) [58]. In nature, the sexual ascomycete is scarce. Conidiophores are hyaline, cylindrical, unicellular, or septate, and range in size from 3 to 45 x 2-6 µm. Conidia are hyaline, gluttulate, fusiform with both ends pointed, one-celled and 7-14 µm x 2.5-3.5 µm in size; conidiogenous cells are hyaline, ellipsoidal to subglobose and 6-10 µm x 2.5-4 µm broad, (Shenoy *et al*., 2007) [50].

3. Molecular characterization with RAPD primers

In 2018 Dhanashri *et al.* [12] are reported that The RAPD approach was used to discover genetic variation between the four isolates of *C. capsici* that cause anthracnose in chillies. To assess molecular variance, a total of 20 primers from the OPA and OPB families were employed. 16 primers out of 20 randomly chosen primers provided 117 scoreable bands. 100 of the 117 bands were polymorphic, with an overall polymorphism rate of 85.47 per cent. The genetic similarity coefficients of four *Colletotrichum capsici* isolates varied from 0.29 to 0.49. Cc1 and Cc2 isolates had the highest genetic similarity of 49 per cent, followed by Cc1 and Cc4 isolates with 44.20 per cent similarity. Cc2 and Cc3 have the least genetic similarity, which is 29 per cent. There were two significant clusters I and II, according to the dendogram created from the pooled data. Cluster I was split into two sub-clusters, IA and IB. IA exhibited 49 percent resemblance when it was divided into two isolates, Cc 1 and 2, which were in the same cluster. Cc4 is one of the isolates in IB. Cluster II has just one isolate, Cc3, which is unique and shows the least resemblance to the other *C. capsici* isolates. Because Cc3 was found in the temporal area (Western Himalayan Region.)

4. Epidemiology

Any disease's intensity and transmission are largely determined by environmental variables. The establishment of disease is aided by favourable host, pathogen, and climatic circumstances (Agrios, 2005) [1]. Chilli anthracnose is a seed and airborne disease that affects germinating seeds and vigour more than other diseases (Saxena *et al.*, 2016) [46]. In 2001, Roberts *et al.*[43] reported by the pathogen grows at 27 °C, 80% humidity, and a 5 to 6 pH ranges in the soil (Roberts *et al.*, 2001) [43]. The severity of the disease is influenced by rainfall duration and intensity, humid, leaf surface moisture, and light. Because the pathogen has a better establishment in terms of germinate, adhesion, and absorption into host tissues, the severity of the illness has been linked to leaf surface moisture reported by (Than *et al.*, 2008) [58]. Chilli anthracnose is a polycyclic pathogen caused by spores of *C. capsici* that survive on and in seed as microsclerotia and acervuli (Montri *et al*., 2009) [36]. The connection between climatic variables such as rainfall intensity and duration, as well as current temperature and humidity, crop geometry, and inoculum dissemination, can contribute to disease development (Dodd *et al*., 1992) [13]. Temperature has a role in the progression of the disease, as does the existence of surface moisture and a competing microbiota (Royle and Butler, 1986) [44].

5. Management

For managing the condition, a combination of several strategies such as chemical management, intrinsic resistance, physical control and biological control has been advised by Agrios (2005) [1]. Because no one management approach could completely eradicate chilli anthracnose, integrated management techniques were used Bailey (1987) [3] and Agrios (2005) [1]. The long time it takes to establish a resistant cultivar and the limited time span that fungicides provide

make this approach of disease control, in particular for anthracnose, even more attractive in 2004 said by Wharton and Diéguez-Uribeondo [62].

It's important to have a good gap between the plants to avoid a dense canopy that makes it difficult to create moisture (Than *et al.,* 2008) [58]. The use of transplants grown from disease-free chilli seeds is another essential approach. It's important to keep the transplanting free of weeds and away from other Solanaceous plants. After every 2–3 years, the crop should be cycled with crops that are just not *Colletotrichum's* hosts (Roberts *et al.,* 2001) [43]. Plastic mulches and rice straw have also been suggested as disease-controlling options (Vos *et al*., 1995) [60].

Garg *et al.* (2014) [16] found resistant varieties (BS20, BS35, BS28, Lankamura Collection, Pant C-1, IC-383072, Taiwan-2, Bhut Jolokia, and Punjab Lal) among the 42 Capsicum spp. types in use in the area, which might be exploited to generate effective resistant varieties by genetic improvement. Two kinds from the Indonesian Vegetables Research Center (Tanjung-2 and Lembang1) were found to be moderately resistant (Setiawati *et al.,* 2008) [48], while five types from the World Vegetables Centre in Taiwan (AVPP1102-B, AVPP1004-B, AVPP0719, AVPP0513 and AVPP0207) were found to be anthracnose resistant (Hasyim *et al.,* 2014) [19]. *Colletotrichum* resistant variant information may also be utilised to look at how resistance is handed down to the next generation in 2008 said by Kim *et al*., [31] as well as to locate and analyse resistance loci (QTL) maps (Lee *et al*., 2010) [32].

At the molecular level, various molecular markers are used to assess variability and diversity, including AFLP, RFLP, ISSR, SSR and RAPD. Using AFLP and RFLP markers, (Kang *et al.* 1997) [27] was able to generate a molecular linkage map for the *Capsicum spp.* (chilli), with a strong association to carotenoids and capsaicinoids. A single dominant gene, for example, controls the red colour of capsicum. RFLP markers in molecular research, however, have limitations due to their usage of radioactivity and labor-intensive nature (Kim *et al*., 2004) [30]. Using a combination of molecular diagnostic methods and diverse isolates to learn about the pathogenic variations in the *Colletotrichum* species might be an effective and reliable strategy. Anthracnose pathogens (*Glomerella cingulata, C. acutatum, C. coccodes, C. dematium, C. truncatum*, and *C. gloeosporioides*) have been effectively studied using the random amplified polymorphic DNA polymerase chain reaction (RAPD-PCR) technology in the past (Sharma *et al.,* 2005) [49].

Chilli anthracnose might also be efficiently managed using as a botanical garlic bulb extract and as a bioagent *Trichoderma viride* (Kamble *et al*., 2015) [26]. Several workers had previously documented antifungal fungistatic activity of phytoextracts such as garlic bulb and tulsi leaves extract against a variety of *Colletotrichum spp*. (Shinde and Gawai, 2014) [51]. Several research employing crude plant extracts have also been carried out to investigate *Colletotrichum spp*. control on chillies (Johnny *et al*., 2011 and Ngullie *et al*., 2010) [25, 38]. Anthracnose can also be controlled using *Pseudomonas fluorescens*. *Trichoderma* is a well-known saprophytic fungus that can adapt to a wide range of environments. *Trichoderma's* biological control potential against plant pathogens such as *Colletotrichum*, *Rhizoctonia*, *Alternaria*, *Pythium*, and *Phytophthora* and others is well documented (Jain *et al*., 2012; Begum *et al*.,2008; Imtiaj and Lèe., 2008) [23, 6, 21].

It's not a good idea to rely on a single fungicide because long-term use leads to resistance (Staub, 1991) [56]. Dithane M 22 has long been recommended as a fungicide for disease management (Smith, 2000) [54]. Copper compounds, triazole, benzimidazole and dithiocarbamates compounds are the most commonly suggested chemical fungicides for treating anthracnose disease proved by Waller in 1992 [61]. It has also been treated with newer compounds like as strobilurin-based fungicides like Headline (pyraclostrobin) and Amistar (azoxystrobin). However, there are just a few reports of this class of fungicide successfully reducing this disease in big field experiments (Lewis and Miller, 2003; Chen *et al*., 2009 and Schilder *et al*., 2001) [33, 10, 47]. Fungicides must be used at the right time. Other fungicides shown to be beneficial include Bordeaux combination (0.5 or 1 percent), Dithane M45 0.1%, Cuman L 0.1%, and Blitox 50. Score (difenoconazole - 0.025 percent) outperformed the other fungicides (Tilt, Blue copper, and Saaf), resulting in the lowest disease intensity of 21.13 percent and the maximum fruit production (Katedia *et al*., 2019) [28].

(Dubey *et al.,* 2019) [14] examined by used the Poison food technique to test the different fungicide's effect: Tebuconazole (Folicur 250 EC), Flusilazole (Cursor 40 percent EC), Azoxystrobin (Amistar 23 percent SC), Pyraclostrobin + Metiram (Cabrio Top 60 percent WG) and Kasugamycin (Kasu B 3 percent SL) against *Colletotrichum capsici*. These fungicides were made in two concentrations: 250 parts per million and 500 parts per million. Cabrio Top was found to be superior to conventional chemical fungicides in reducing pathogen mycelia growth, with a percent inhibition of 84.11 percent.

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