Applied Ecology and Environmental Sciences, 2021, Vol. 9, No. 2, 172-176
Available online at http://pubs.sciepub.com/aees/9/2/8
Published by Science and Education Publishing
DOI:10.12691/aees-9-2-8

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

Sonawane V.B.[1], Shinde H.P.[2,*]

[1]Department of Botany, MVP Arts Commerce & Science College, Nandgaon, Dist. Nashik, Maharashtra
[2]Department of Botany, K.V. N. Naik Arts Commerce & Science College, Nashik, Maharashtra
*Corresponding author: shindehemant79@gmail.com

Received November 26, 2020; Revised December 30, 2020; Accepted January 13, 2021

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 capsteam; 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.*

Cite This Article: Sonawane V.B., and Shinde H.P., "Anthracnose Disease of *Capsicum annuum* L. and Its Bio Control Management: A Review." *Applied Ecology and Environmental Sciences*, vol. 9, no. 2 (2021): 172-176. doi: 10.12691/aees-9-2-8.

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 *Gloeopsorium piperatum* and *Colletotrichum nigrum*. Disease is known to be caused by different *Colletotrichum* species complex *viz., C. capscii, 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 (*Azadirachia 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 (*Cymbopogon nardus*) along with biocontrol agents like *Trichoderma harzianum*, *T. viride* and *Pseudomonas flourescens* 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*), koromcha (*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 chili. 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 *Colletoreichum 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 efficiency of bio-fungicides like *Trichoderma* sp. and *Pseudomonas fluorescens* on seedling emergence, vigour and health of infected chilli seeds *Capsicum annuum* by *Colletotrichum capsicii.* 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 capsicii.* 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 capsaicin content were observed with application of *Methylobacterium populi* as compared to control; that highlighted native *M. populi* ($PPFM_6$) 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.

References

[1] Saxena, Amrita, Raghuwanshi, Richa, Gupta, Vijay Kumar and Singh, B. Harikesh. Chilli Anthracnose: The epidemiology and management. *Front. Microbiol.* 7: 1527. 2016.

[2] R. S. MacNeish. Ancient Mesoamerican civilization. *Science* 143, 531-537. 1964.

[3] B. Pickersgill. Genetic resources and breeding of *Capsicum* spp. *Euphytica*, 96 (1): 129-133. 1997.

[4] B. Kumar Indian Horticulture database Ministry of agriculture, Government of India 85 institutional area sector 18 Gurgaon - 122 015. 2011.

[5] A.K. Shah. *Factsheets for farmers; Nepal;* knowledge based integrated sustainable agriculture and nutrition USAID Kisan project 2013.

[6] S. U. Lakshmi, R. Deepthi, D. Pedda, P. Suneetha and M.S.R. Krishna. Anthracnose, a Prevalent Disease in Capsicum. *Research Journal of Pharmaceutical, Biological and Chemical Sciences RJPBCS5* (3), Page No.1583-1604. ISSN: 0975-8585. 2014.

[7] May Moe Oo and Oh Sang-Keun. Chilli anthracnose. (*Colletotrichum sp.*) Disease and its management. Approach. *Korean Journal of Agricultural Science*, 43(2): 153-162. ISSN (Print): 2466-2402. ISSN (Online): 2466-2410. 2016.

[8] N. Tong, P.W. Bosland. *Capsicum tovarii*, a new member of the *Capsicum* complex. *Euphytica*, 109(2): 71-72. 1999.

[9] P.W. Bosland, E.J. Votava. Peppers: Vegetable and Spice Capsicums. *CAB International*, England, p.233 2003.

[10] G. J. H. Grubben and El. T. I. Mohamed. "*Capsicum annuum* L.," in PROTA 2: Vegetables/Légumes, eds G. J. H. Grubben and O. A. Denton (Wageningen: PROTA), 154 163. 2004.

[11] J.A. Osuna-García, M.W. Wall, C.A. Waddell. Endogenous levels of to copherols and ascorbic acid during fruits ripening of New Mexican-type chilli (*Capsicum annuum* L.) cultivars. *Journal of Agricultural and Food Chemistry*, 46(12):5093-5096 1998.

[12] G. Britton, D. Hornero-Méndez. Carotenoids and Colour in Fruits and Vegetables. *In*: Tomás-Barberán, F.A., Robins, R.J. (Eds.), Photochemistry of Fruits and Vegetables. *Clarendon Press*, Oxford, England, p.11-28. 1997.

[13] D. Hornero-Méndez, J. Costa-García and M.I. Mínguez-Mosquera. Characterization of carotenoids high-producing *Capsicum annuum* cultivars selected for paprika production. *Journal of Agricultural and Food Chemistry*, 50(20): 57 11-5716. *Indian Phytopath*. 70 (1): 86-90. 2002.

[14] A. Pérez-Gálvez, H.D, Martin, H. Sies, W. Stahl. Incorporation of carotenoids from paprika oleoresin into human chylomicron. *British Journal of Nutrition*, 89(6): 787-793. 2003.

[15] G. E. Welbaum, (ed.). Family Solanaceae in Vegetable Production and Practices. *CAB International Publisher* 2015.

[16] S. Issac. Fungal Plant Interaction. *Chapman and Hall Press*, London, p.115. 1992.

[17] B.D. Halsted. A new anthracnose of pepper. *Bulletin of the Torrey Botanical. Club.*, 18: 14-15. 1890.

[18] J.A. Bailey, M.J. Jeger (Eds.). *Colletotrichum*: Biology, Pathology and Control. Commonwealth Mycological Institute, Wallingford, p.388. 1992.

[19] J.B. Manandhar, G.L. Hartman, T.C. Wang. Anthracnose development on pepper fruit inoculated with *Colletotrichum gloeosporioides. Plant Disease*, 79: 380-383. 1995.

[20] R. Dean, J.A.L. Van, Z.A. Pretorious, K.E. Hammond- Kosack, A. Di Pietro. The top 10 fungal pathogens in molecular plant pathology. *Molecular Plant Pathology*, 13:414-430. 2012.

[21] S. Freeman, T. Katan, E. Shabj. Characterization of Colletotrichum species responsible for anthracnose disease of various fruits. *Plant Dis*, 82: 596-605. 1988.

[22] J.H. Simonds. A study of the species of *Colletotrichum* causing ripe fruit rots in Queenslands, Queensland. *Journal of Agriculture and Animal Science*, 22: 437-459 1965.

[23] P.F. Cannon, P. D. Bridge, E. Monte. Linking the past, present and future of *Colletotrichum* Synstematics. In: Prusky, D., Freeman, S., Dickman, M. (Eds.), *Colletotrichum*: Host specificity, Pathology and Host- Pathogen Interactions. APS Press, St. paul, Minnesota, p.1- 20. 2000.

[24] K.H. Kim, J.B. Yoon, H.G. Park, E.K. Park, Y.H. Kim. Structural modifications and programmed cell death of chilli pepper fruit related to resistance responses to *Colletotrichum gloeosporioides* infection. *Phytopathology*, 94: 1295-1304. 2004.

[25] J.K. Hong, B.K. Hwang. Influence of inoculums density wetness duration, plant age, inoculation method, and cultivar resistance on infection of pepper plants by *Colletotrichum coccodes*. *Plant Disease*, 82(10): 1079-1083. 1998.

[26] K.D. Kim, B.J. Oh, J. Yang. Differential interactions of a *Colletotrichum gloeosporioides* isolate with green and red pepper fruits. *Phytoparasitica*, 27: 1-10. 1999.

[27] H.K. Park, B.S. Kim, W.S. Lee. Inheritance of resitance to anthracnose (*Colletotrichum* sp.) in pepper (*Capsicum annuum* L.) II. Genetic analysis of resistance to *Colletotrichum dematium*. *Hort. Environ. Biotechnol*, 31: 207-212. 1990.

[28] P.P. Than, R. Jeewon, K.D. Hyde, S. Pongsupasamit, O. Mongkolporn, P.W.J. Taylor. Characterization and pathogenecity of *Colletotrichum* species associated with anthracnose on chilli (*Capsicum* spp) in Thailand. *Plant Pathol*, 57: 562-572. 2008.

[29] Kumar, Praful and Kerketta, Anurag. Chilli anthracnose: A review of causal organism and their managements. *International Journal of Chemical Studies*; 6(1): 1711-1714. P-ISSN: 23498528 E-ISSN: 2321-4902. 2018.

[30] Dubey, Preeti, Chandra, Ram and Gupta, Parikshit. Effect of different fungicides against *Colletotrichumcapsici* caused chilli anthracnose disease. *The Pharma Innovation Journal*; 8(2): 414-416. ISSN (E): 2277- 7695 ISSN (P): 2349 8242. 2019.

[31] Banya, Manju, Garg, Surbhi, and Meena, Narayan Lal. A review: Chilli anthracnose, its spread and management. *Journal of Pharmacognosy and Phytochemistry*; 9(4): 1432 1438. E- ISSN: 2278-4136 P-ISSN: 2349-8234. 2020.

[32] J.M. Lenné, D.G. Parbery. Phyllosphere antagonists and appressoria formation in *Colletotrichum gloeosporioides.* Transactions of the British Mycological Society, 66:334 336, 1976.

[33] M.J. Jeger, P. Jeffries. Alternative to chemical usage for disease management in the post harvest environment. Aspects of Applied Biology, 17:47-57. 1988.

[34] B.K. Duffy, S. Andrew, D.M. Weller. Combination of *Trichoderma coningii* with fluorescent *Pseudomonads* for control of take-all on wheat. *Phytopathology* 86:88-194, 1995.

[35] F.N. Martin, J.E. Loper. Soil borne plant disease caused by *Pythium*spp.: Ecology. Epidemiology and prospects for biological control. *Plant Sci*18:111 181, 1999.

[36] C. Jeyalakshmi, K. Seetharaman. Biological control of fruit rots and die-back of chilli with plant products and antagonistic microorganisms. *Plant Disease Research*, 13:46-48, 1998.

[37] N. Charigkapakorn. Control of chilli Anthracnose by different biofungicides. Thailand, available from Charigkapakorn_18th http://www.arc-avrdc.org/pdf_files/029. pdf (Accessed 24/06/2008). 2000.

[38] W. Intanoo, C. Chamswarng. Effect of antagonistic bacterial formulations for control of Anthracnose on Chilli fruits. *Proceeding of the 8th National Plant Protection Conference*. Naresuan University, Phisanulok, Thailand, p.309 322. 2007.

[39] Ngullie, Marinus, Daiho, Loli and Upadhyay, Digvigay Narayan. Biological management of fruit rot in the world's hottest chilli (*Capsicum chinense* jacq.). *Journal of plant protection research* Vol. 50 (3). 2010.

[40] L. Johnny, U. K. Yusuf and R. Nulit. Antifungal activity of selected plant leaves crude extracts against a pepper anthracnose fungus, *Colletotrichum capsici* (Sydow) butler and bisby (Ascomycota: Phyllachorales). *Afr. J. Biotechnol.* 10, 4157-4165. 2011.

[41] P. Jeffries, I. Koomen. Strategies and prospects for biological control of diseases caused by *Colletotrichum*. *In*: Bailey, J.A., Jeger, M.J. (Eds.), *Colletotrichum*: Biology, Pathology and control. *Commonwealth Mycological Institute*, Wallingford, p.337-357, 1992.

[42] M. Maymon, D. Minz, O. Barbul, A. Zveibil, Y. Elad, S. Freeman. Identification to species of Trichoderma biocontrol isolates according to ap-PCR and ITS sequence analyses. Phytoparasitica, 32:370-375, 2004.

[43] C. Boonratkwang, C. Chamswarng, W. Intanoo, V. Juntharasri. Effect of secondary metabolites from *Trichoderma Harzianum* Strain Pm9 on growth inhibition of *Colletotrichum Gloeosporioides* and Chilli Anthracnose control. *Proceeding of the 8th National Plant Protection Conference.* Naresuan University, Phisanulok, Thailand, p.323-336, 2007.

[44] M.A. Rahman, T.H. Ansari, M.F. Alam, J.R. Moni and M. Ahmed. Efficacy of *Trichoderma* against *Colletotrichum capsici* causing fruit rot due to Anthracnose of chilli (*Capsicum annuum* L.) *The Agriculturists*, 16(2): 75-87. ISSN 2304-7321 (Online), ISSN 1729-5211 (Print) 2018.

[45] P.S. Wharton, J. Diéguez-Uribeondo. The biology of *Colletotrichum acutatum*. *Anales del Jardin Botanico de Madrid*, 61:3-22. 2004.

[46] S. Begum, and P.S. Nath. Eco-friendly management of anthracnose of chilli caused by *Colletotrichum capsici. Journal of Applied and Natural Science* 7(1), 119-123. ISSN: 0974-9411 (Print), 2231-5209 (Online). 2015.

[47] Md. Rashid, Mamunur, Kabir, Md. Humayun, Hossain, Md. Mokbul, Bhuiyan, Md. Rejwan and Khan, Mohammad Ashik Iqbal . Eco-Friendly Management of Chilli Anthracnose (*Colletotrichum capsici*), *International Journal of Plant Pathology* 6(1): 1-11, ISSN: 1996 0719. 2015.

[48] Adluri, Prashanth, Kumar. A Review on Management of Chilli Anthracnose. *Trends in Biosciences* 10(20), Print: ISSN 0974-8431, 3719-3722. 2017.

[49] Handisoa, Serawit and Alemu, Tesfaye. Integrated Management of Anthracnose (*Colletotrichum capsici* (Syd.)): Implications to disease reactions, quality and growth parameters of three genotypes of Chili. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS).* Volume 32(1), 303-315. ISSN (Print) 2313-4410, ISSN (Online) 2313-4402, 2017.

[50] S. Madhavan, P. Adhipathi, R. Velazhahan, V. Paranidharan and M. Karthikeyan. Management of chilli (*Capsicum annuum*) anthracnose using fungicides and biocontrol agents. 2017.

[51] B. P. Birari, R.M. Gade and R. K. Chuodhari. Antifungal efficacy of plant extracts, biocontrol agents against *Colletotrichum capsici* causing anthracnose of chilli. *Journal of Pharmacognosy and Phytochemistry*; 7(5): 1368-1373. E ISSN: 2278 4136 P-ISSN: 2349-8234. 2018.

[52] Indratmi, Dian. Biological control of chili Anthracnose disease with *Rhodotorula Spp*. *Advances in Engineering Research*, Vol. 172, 113-117. *Atlantis Press*. 2018.

[53] Y.N. Priya Reddy, S.S. Jakhar and O.S. Dahiya. Efficiency of bio-fungicides like *Trichoderma* sp. and *Pseudomonas fluorescens*on seedling emergence, vigour and health of infected chilli seeds *Capsicum annuum* by *Colletotrichum capsica. Current Journal of Applied Science and Technology* 35(5): 1-8, ISSN: 2457-1024. 2019.

[54] Katediya, Mukesh Amrutlal, Jaiman, Rakesh Kumar and Acharya, Sanjay Kumar. Management of chilli anthracnose caused by *Colletotrichum capasici. Journal of Pharmacognosy and Phytochemistry*; 8(3): 2697-2701. E-ISSN: 2278-4136 P-ISSN: 2349 8234. 2019.

[55] De Silva, Dilani D., Groenewald, Johannes, Z., Crous, Pedro W., Ades, Peter K., Nasruddin, Andi Mongkolporn, Orarat and Taylor, W. J. Paul. Identification, prevalence and pathogenicity of *Colletotrichum* species causing anthracnose of *Capsicum annuum* in Asia, *IMA Fungus*, 1-32. 2019.

[56] V. Jaiganesh, P. Kiruthika and C. Kannan. Integrated disease management of chilli anthracnose. *Journal of Biopesticides*, 12(1):126-133. 2019.

[57] S. Santosh and M.N. Sreenivasa. Molecular characterization of native pink pigmented facultative methylotrophs of chilli and their induced systemic resistance mechanism in management of anthracnose. *J. Environ. Biol*., 41, 1493-1500. P-ISSN: 0254-8704 E-ISSN: 2394-0379. 2020.

[58] G. N. Agrios. Plant pathology 5th edition. Elsevier Academic press. London. 2005.