



Eco Friendly Management of Alternaria Blight Disease: A Review

**Bhaskar Deka^{a+++}, Gunadhya Kumar Upamanya^{b#}
and Randeep Malla Buzar Baruah^{a++}**

^a Department of Plant Pathology, College of Agriculture, AAU, Jorhat, India.

^b Department of Plant Pathology, SCS College of Agriculture, AAU, Dhubri, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/ajaar/2024/v24i10554>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/124912>

Review Article

Received: 05/08/2024

Accepted: 07/10/2024

Published: 17/10/2024

ABSTRACT

The World is passing through a critical phase of climate change and its effect on the ecosystem. It can be related to growing plant diseases that are becoming more and more important because of the losses they cause. So controlling plant disease is very crucial looking at the growing population and availability of arable land. Alternaria leaf spot or leaf blight caused by different species of Alternaria is a major threat to growing crops mostly vegetables. It can lead to yield losses ranging from 20% to 80% worldwide. Chemical fungicides have been effectively managing this disease, but their extensive use has raised concerns due to adverse impacts on environmental and human health. There is an increasing demand for sustainable and eco- friendly management to combat the disease. Some emerging approaches offer promising alternatives to chemical control like the use of biocontrol agents (e.g., *Trichoderma spp.*, *Pseudomonas*), plant-derived products (e.g., neem

⁺⁺ M.Sc(Agri) Scholar;

[#]Associate Professor;

^{*}Corresponding author: Email: dekabhaskarj379@gmail.com;

Cite as: Deka, Bhaskar, Gunadhya Kumar Upamanya, and Randeep Malla Buzar Baruah. 2024. "Eco Friendly Management of Alternaria Blight Disease: A Review". *Asian Journal of Advances in Agricultural Research* 24 (10):34-43. <https://doi.org/10.9734/ajaar/2024/v24i10554>.

extracts, essential oils), and disease-resistant varieties, etc. These alternative and eco-friendly methods not only give long-term sustainability in agricultural production but also reduce the environmental hazards associated with the overuse of fungicides. So this review sheds light on the importance of an integrated disease management approach that can be employed in diverse agroclimatic conditions, aiming to reduce the impact of *Alternaria spp.* on crop productivity, improving global ecosystem health and a greener environment.

Keywords: *Alternaria*; bioagent; plant extract; ecofriendly; fungicides.

1. INTRODUCTION

With the increasing population and degradation of available land, plant disease control is becoming increasingly important for Indian agriculture. Pesticides and fertilizers are two examples of the increased inputs needed to meet the growing demand for a sustainable food supply. However, frequent chemical use pollutes the environment and might cause pathological conditions. It can also cause the target organism to become resistant to the chemicals. Since the nation is currently supporting organic and natural farming, it is crucial to treat plant diseases using environmentally friendly methods in order to preserve ecosystem health and human nutrition through a balanced food chain in agro-ecosystems. For many sensitive regions of the world, the occurrence and severity of plant disease outbreaks are increasing, posing serious and expanding concerns to primary productivity, global food security, and biodiversity loss. Both yield and ecological losses result from these disease outbreaks. This has a direct effect on food security, local economies, and other related socio-economic factors. Therefore, to create agricultural and natural ecosystems that are resilient to climate change, a better understanding of how climate change affects the molecular, epidemiological, and ecological interactions between diseases, plants, and the microbial communities that are associated with them is required.

Alternaria black spot of cruciferous vegetables, caused by different species of *Alternaria*, remains an increasing threat to *Brassicaceae* crops throughout the world [1]. Under the Ascomycota division, *Alternaria* species are potentially global fungi that are found in soil, plants, food, feed, and indoor air [2]. The opportunistic pathogen affects a wide range of hosts, accounting for at least 20% of agricultural spoilage, with the most severe losses potentially amounting to 80% of the crop [3]. *Alternaria* blight the most common disease caused by the genus *Alternaria* is responsible for about 32-57%

loss in yield [4]. These pathogens are responsible for significant seed yield loss in oleraceous brassicas, the most significant part of economic importance [5].

Although the use of resistant cultivars is an ideal solution to the disease, crucifer cultivars resistant to black leaf spot are currently scarce. The use of fungicides is still the most popular method for control of black leaf spot of crucifers. Dithiocarbamate based fungicides are being used to control this disease. Mancozeb belonging to ethylene bis-dithiocarbamate (EBDC) group of fungicides can effectively control this disease [6]. Ethylene thiourea (ETU) the decomposed product of EBDC is reported to be carcinogenic [7]. Excess use of sprays and higher volumes of fungicides leads to development of residues in the consumable part of the vegetables and also develops resistance [8]. This necessitates the need to look for safer, eco friendly and effective management strategies of the disease. Biocontrol agent, phytoextracts different cultural practices are safe and cheaper that are equally effective as compared to fungicides.

Sustainable techniques, such as the use of biocontrol agents and various plant products to reduce plant disease, provide a potent substitute for synthetic chemicals that have comparable goals. A seemingly limitless resource is available for this purpose due to the abundance of medicinal plants and the enormous diversity of the microbial population. Numerous foliar diseases in plant species, such as leaf spots, leaf blights, and leaf blotches, are caused by fungus pathogens. Among these diseases, this brief study aims to compile knowledge on environmentally friendly *Alternaria* species management techniques for future need.

Biology: Most *Alternaria* species generate asexual spores, or conidia, that are between 160 and 200 μm length, which are produced by their conidiophores. In vitro, sporulation takes place between 8 and 24 $^{\circ}\text{C}$, and mature spores appear

after 14 to 24 hours. The ideal temperature range for sporulation is 16–24 °C, with a 14–hour time frame. For the majority of species, moisture in the form of rain, dew, or high humidity is necessary for infection and must be present for at least 9–18 hours [9]. Infection is guaranteed when there is constant wetness present for 24 hours or more [10,11]. Large numbers of ripe spores will be produced in less than 24 hours with a relative humidity of 91.5% (at 20 °C) or above [9].

Symptomatology: Aneja and Agnihotri reported in brassica crop that the symptoms of *Alternaria* initially starts as tiny brown to black dots on the lower leaves, which quickly multiply and enlarge to form noticeable round spots. These spots are associated with concentric rings that vary in size, color, shape, and intensity depending on the host plant and causal species under various environmental conditions. The disease eventually causes the entire leaf to become infected and defoliate. The infection then appears as tiny spots on the middle and top leaves. During the advanced phases of plant development, the dots typically manifest as black stripes on the stem and siliquae, which eventually merge to turn the siliquae black [12]. In tomato that the disease causes oval to angular lesions that are 1-2 mm in diameter and form concentric rings surrounded by a yellow chlorotic halo. The symptoms are brown necrotic lesions that are visible on older leaves and advance upwards as the plants age. The severe phase of the disease results in premature defoliation and drying of the plant [13].



Fig. 1. Typical leaf spot caused by *A. brassicicola* in cauliflower

Epidemiology: Humpherson-Jones and Phelps reported that the pathogens are greatly influenced by weather with the highest disease incidence reported in wet seasons and in areas

with relatively high rainfall. Humidities equal to or higher than 91.5% and 87% were required for the sporulation in *A. brassicae* and *A. brassicicola* on naturally-infected leaf discs of oilseed rape and cabbage respectively. The optimum temperatures for sporulation were 20–30°C for *A. brassicicola* and 18–24°C for *A. brassicae*. At this temperatures both fungi produced spores in 12–14 h. Sporulation in *A. brassicae* was inhibited above 24°C [9]. Biswas, M. K. conducted an experiment to study how different weather parameters effect the development of *Alternaria* leaf spot of mustard under the agro-ecological conditions of red and lateritic belt of West Bengal. He found that a maximum temperature of 23.83 to 29.63°C was most favoured for the disease development. Also Maximum relative humidity (80.33 to 90.55 %), minimum relative humidity (52 to 58 %) and average sunshine of 7 to 8 hours per day favoured the disease development. He further concluded that different meteorological factors viz., maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and daily sunshine hours were collectively contributed to 53.7 - 96.9 % for the development of the lesion size caused by *Alternaria brassicae* in mustard field [14]. Manjhi et al., examined the weather parameter of *Alternaria* blight of mustard and observed that rainfall and relative humidity were more correlated with disease intensity than maximum temperature. A relative humidity of $\geq 70\%$ coupled with warm weather ($\geq 28^\circ\text{C}$) and intermittent rains favoured the disease development [15].

Conidial characters: As reported by Devi et al., among 8 isolates of *Alternaria brassicae*, maximum conidial length was 21.7µm and minimum 15.6µm. The average conidial length were varied from 15.6µm to 21.7µm with a range of conidial length from 14µm to 26µm. They found that maximum conidial breadth was 2.7µm and minimum conidial breadth was 1.5µm. The average conidial width varied from 1.8µm to 2.7µm with a range from 1.5µm to 3µm. Horizontal and vertical septation in conidia also showed variation in different isolates. The average number of horizontal septa was maximum in Ab6 (13.8) with a range of 8-14 and minimum in Ab7 (6.8) with a range of 5-8 were observed. The average number of vertical septa was highest in Ab8 (4.2) with a range from 1-5 and lowest in Ab5 (1.5) with a range from 1-2. The average number of beak length was highest in Ab4 (9.8µm) with a range from 5-10µm and lowest in Ab8 (6.5µm) with a range from 5-9µm.

Finally it was revealed that smallest size of conidia in isolates Ab8 and longest size of conidia in isolates Ab4 were observed [16]. Mehra *et al.*, reported significant morphological variability in respect of conidial length, conidial width, conidial beak length, number of septa and number of cells of 20 different isolates of *Alternaria brassicae* [17].

2. CULTURE MEDIA FOR GROWTH OF ALTERNARIA SPP.

According to Abeer *et al.*, potato dextrose agar was the most effective medium for *A. alternata* of Avicennia marina's radial growth and sporulation [18]. Hubballi *et al.*, found that host leaf extract medium was the best medium for *A. alternata* causing leaf blight on *Morinda citrifolia* followed by potato dextrose agar (PDA) media [19]. Mishra & Mishra discovered that PDA medium exhibited the highest growth of the cotton pathogen *A. alternata*, with Richards agar, Czapek's agar, Coon's agar, and leaf decoction agar following that [20]. In non synthetic media such as oat meal agar and PDA, *A. alternata*, the pathogen that causes gerbera leaf blight, exhibited outstanding mycelial growth and conidial production [21]. Richard's agar medium and potato dextrose agar were the next best media for *A. lini* growth and sporulation [22]. Munde *et al.*, found that maximum growth of *A. solani* was obtained on yeast extract glucose agar medium followed by soil extract agar medium, oat meal agar and Sabour's agar medium [23]. Aneja & Agnihotri reported in Alternaria Blight of Brassica that the shape of colonies has been seen to vary; the diameter ranges from 32 to 68 mm, the surface texture is velvety to wooly, and the color is olive green to dark green, with sporulation ranging from minimal to intense [12]. Kiran *et al.*, reported that cultural characters of the seven isolates were differ in average growth rate, growth pattern and colony colour. The colony colour of those isolates were initially white but later turns to brown to light brown and to grey brown. Colony characters of *A. brassicicola* were described as olive to grey brown in colour and showed velvety growth [24]. The mycelium was septate, branched and produced conidiophores [25]. Rahimloo & Ghosta stated that the colony colour of 38 isolates of *A. brassicicola* were grey to brown and average growth rate was 0.78 cm /day [26].

Pathogenicity: Pathogenicity of *Alternaria alternata* was confirmed by Sarkar *et al.*, in which initial symptoms of Alternaria leaf spot was

recorded 7-9 days after inoculation on leaves with a small, circular necrotic spot with development of concentric rings [27]. Pathogenicity test of seven isolates of *A. brassicicola* was confirmed that was obtained during the survey by artificial inoculation on healthy plants [24]. Aboomer *et al.*, confirmed the pathogenicity of *Alternaria brassicicola* in cabbage by injecting spore suspension in healthy plants. Infection was appeared in healthy plants within approximately 10-15 days [28]. Thambi *et al.*, confirmed the pathogenicity of *Alternaria* spp. collected from the diseased leaves of broccoli by detached leaf method inoculated with 10^4 spores/ml . Results showed the appearance of brown spots on the tested healthy broccoli leaves within 72 h of incubation at 25 ± 2 °C [29]. Deep *et al.*, conducted pathogenicity test for 32 isolates of *Alternaria brassicicola* in susceptible variety of cauliflower. They found all the isolates pathogenic in nature. Out of which nine were highly pathogenic (spot size more than 1cm), eight isolates were moderately pathogenic (spot size were 0.6-1cm) and rest fifteen isolates were lowest pathogenic (spot size were 0.2- 0.5cm) [30].

Management of Alternaria spp.: Since a number of *Alternaria* species infect crops of economic importance, there is a strong need for effective control of this pathogen. Several research works focusing different management practices are going on. Some of them are discussed below with special reference to environmental friendly nature. The extensive use of chemical fungicides has to be curbed immediately because of the possible harm they could do to the environment and public health.

3. CULTURAL MANAGEMENT

The planting of susceptible varieties in field should be avoided with infected residues from a previous crop retained on the surface. Apart from this, balanced crop nutrition especially of potassium should be provided [31]. Various cultural practices *viz.* covering the cauliflower nursery with nylon net, growing nursery under poly cover, use of hessian cloth (shelter belt) in the field and removal of diseased foliage is an effective mean of eco friendly management of Alternaria Blight and Black rot of Cauliflower [32].

4. NANO PARTICLE BASED MANAGEMENT

Using nanoparticles as a management strategy for Alternaria leaf blight is a possible substitute for conventional fungicides. Nanoparticles

provide a number of benefits for managing diseases, including a high surface area to volume ratio that improves their interaction with fungal pathogens and a small size that facilitates effective penetration of plant tissues. Furthermore, compositions based on nanoparticles can offer long-lasting defense against *Alternaria*, negating the need for repeated applications. This novel method presents a safer and more effective substitute for traditional fungicides, with considerable promise for long-term disease control in agriculture. Taha et al., studied nano-selenium (nano-Se) and nano-silica (nano-SiO₂) against the leaf spot disease caused by *Alternaria alternata* in common bean (*Phaseolus vulgaris* L.). The in vitro study showed that 100 ppm nano-Se had an efficacy rate of 85.1% on *A. alternata* mycelial growth, followed by the combined applications (Se + SiO₂ at half doses) with an efficacy rate of 77.8%. The field study showed that nano-Se and the combined application of nano-Se and nano-SiO₂ significantly decreased the disease severity of *A. alternata* [33]. Significant antifungal potential of Mycogenic copper oxide nanoparticles (M-CuO NPs) was recorded by Gaba et al., as it inhibited the growth of *A. brassicae* up to 92.9% and 80.3% in supplemented media with C-CuO NPs at 200 ppm dose [34].

5. ESSENTIAL OIL AND BIOPOLYMERS

Bio-fungicides derived from essential oils and biopolymers are being utilized as eco-friendly solutions for combating plant-infecting fungi [35]. Essential oils stand out as a promising option for controlling diseases spread by these fungi, provided it should have efficiency, biodegradability, and non-toxic to human health and environment [36]. Recently, numerous research findings have shown the effectiveness of essential oils. For instance, Feng et al., found that essential oils from thyme (*Thymus vulgaris*), eucalyptus (*Eucalyptus globulus* Labill), cassia (*Cassia didymobotrya*), sage (*Salvia officinalis*), and nutmeg (*Myristica Fragans* Houtt) had a suppressive impact on *A. alternata*, responsible for forming necrotic lesions [37]. Zaker et al., showed that eucalyptus (*Eucalyptus globulus*), peppermint (*Mentha piperita*), lavender (*Lavandula angustifolia*), and alcoholic solutions of datura were effective against *Alternaria alternata* [38].

Conversely, biopolymers derived from carbohydrates like alginate and chitosan are

highly appealing for shielding plants from fungal infections because of their antifungal characteristics and their ability to degrade naturally [39]. Applying chitosan, which is a modified form of chitin discovered in the exoskeleton of crustaceans like shrimp, crab, lobster, and shellfish, as a protective layer for crops against fungal diseases is extensively researched [40]. Biocontrol agents (*Pseudomonas*, *Trichoderma*) and effective chitosans (D4 10 and chitosan 134) alone or in combination can be effectively used that gives significant reduction in the disease severity of early blight of tomato. This is an effective alternative control measure that can reduce the reliance on chemical fungicides [41].

Resistant variety: The introduction of different crop varieties resistant to diseases has boosted their inherent resistance, making them more cost-effective for farmers and ensuring their effectiveness over time. For instance, the Cucumis melo line MR-1 is immune to *A. cucumerina* [42], while Mathur & Shekhawat discovered that watermelon varieties Sel-1 and Sugarbaby possess resistance, and Meetha, Durgapura, AY, WHY & WHY-4 are highly vulnerable to *Alternaria* leaf spot [43]. Similarly, RW-177-3, RW-1, RW-187-2, and Milan are moderately resistant to the same disease. Katiyar et al., identified three bottle gourd varieties, Azad Harit, 7002, and 7003, as resistant to *A. cucumerina* [44]. Additionally, two highly resistant chili varieties, CA 87-4 and CA 748, were found to be effective against fruit rot caused by *Alternaria* [45], and tomato varieties such as Arka Alok, Arka Abha, Arka Meghali, Arka Saurabh, IHR-305, IHR-308, IHR2266, IHR-2285, and IHR-2288 were shown to be resistant to early blight [46].

Arka Kalyan was found to be a resistant variety of onion against foliar blight caused by different species of *Alternaria* [47]. Different wild species of brassica was screened for resistance against *alternaria* leaf spot and complete resistance was found in Capsella while resistance in Lepidium, Camelina and Biscutella was observed [48]. Recent developments in the fight against *Alternaria* blight in India have highlighted the potential of Australian genotypes, particularly 'JM06014' and 'JM018'. These varieties have demonstrated significant field resistance to *Alternaria* blight, making them promising candidates for cultivation in regions affected by this fungal disease [49]. Likewise, researchers worldwide are focusing on the manipulation of

genes that encode for essential proteins for inducing resistance in various crops are going on.

Bioagents: Given the antagonistic characteristics of different bacteria and actinomycetes, there is a push for the use of bio-control agents. Their growing use is also largely due to the fact that they are environmentally beneficial. Zaker & Mosallanejad conducted in vitro evaluation of two fungal bio-agents viz., *Trichoderma viride*, *Trichoderma harzianum*, and two bacterial bio-agents *Pseudomonas fluorescens* and *Bacillus subtilis* against *A. alternata* for the antagonistic activity by dual culture technique. They found that all the antagonistic fungi and bacteria inhibited the growth of *A. alternata* ranging from 51.21 to 83.73 per cent. *T. harzianum* was found to be superior over all treatments with 83.73 per cent growth inhibition followed by *T. viride* (78.45%) and *P. fluorescens* (63.00%), while *B. subtilis* (51.21%) was found to be least effective [38]. Sarkar et al., found *T. harzianum* to be the most effective antagonist in suppressing mycelia growth of *Alternaria alternata* (76.23%) [27]. Aboomer et al., found similar results where mycelia growth of *Alternaria brassicicola* was inhibited by *T. harzianum* upto 40% [28]. Mamgain et al., conducted in vitro evaluation of four biocontrol agents viz., *Trichoderma viridae*, *Trichoderma harzianum*, *Trichoderma virens* and *Aspergillus niger* against *Alternaria brassicae*. Their findings showed that the antagonists either by demonstrating inhibitory zones or by overgrowing, greatly restrict the growth of *Alternaria brassicae*. *T. viridae* was shown to be the most successful biocontrol agent against *Alternaria brassicae*, showing an 80.68% inhibition rate compared to the other treatments. This was followed by *T. harzianum*, *T. virens* and finally *Aspergillus niger* with 78.4 percent, 75 percent and 55.68 percent inhibition respectively [31]. Singh & Abhimanyu studied the efficacy of *Trichoderma viride*, *T. harzianum*, *T. hamatum*, *T. koningii* and *Pseudomonas fluorescens* in controlling *A. brassicae* causing Indian mustard blight under laboratory conditions. All the fungal antagonists found to inhibited the growth of *A. brassicae*, with *T. viride* recording the highest growth inhibition of the pathogen (67.9%) [50].

Plant extract: Out of six different plant extract tested against *Alternaria alternata* Neem leaf extract was found to be most effective inhibiting 55% of the pathogen, followed by garlic cloves (41.25%), Tulsi leaf extract (36.25%), nilgiri leaf

extract (32.5%), mixture of onion and garlic leaf extract (30%) and parthenium(28.75%) [27]. Similar results were found by Aboomer et al., where Neem leaf extract and Garlic showed better results in inhibition of mycelia growth of *Alternaria brassicicola* in vitro. [28]. Similar results were also reported by Habib et al., where Neem and Garlic showed better result in reduction of severity of the disease [51]. Guleria and Kumar showed that plants treated with neem leaf extract showed a considerable reduction in *Alternaria* leaf spot disease. The control group showed the highest level of disease severity (65%), while the plants treated with a 1:2 dilution of neem leaf extract only showed 10% of severity [52]. Crude extract from dried leaf tissues of *Agave americana* possessed excellent antifungal activity against *A. brassicae*, the casual agent of *Alternaria* blight of Indian mustard [53].

Integrated disease management: Numerous methodologies are currently employed for the management of *Alternaria* blight in Brassicas, specifically encompassing chemical, cultural, nutrient modification, and biological strategies. In light of heightened awareness regarding the potential hazards associated with fungicide application, considerable emphasis is being directed towards an integrated approach to pathogen management. The incineration of crop residues from the preceding year, adherence to timely sowing schedules, utilization of healthy certified seeds, regular weeding practices, application of balanced nutrient doses, maintenance of optimal plant population density, and the avoidance of irrigation during the crop's susceptible stages (45 and 75 days after sowing) may contribute to the reduction of disease incidence. The application of potash(K) at a rate of 40 kg/ha along with the soil application of minerals such as sulfur, borax, potash, and zinc, has been demonstrated to be effective in the management of *Alternaria* blight in mustard [54,55,56]. These minerals have been shown to enhance plant resistance. Kumar and Kumar discovered that plants were least affected by the disease at 45 cm between rows compared to when seeds were sown by broadcast, and that crops sown early and regularly weeded had lower disease incidence [57]. Vermicompost @ 50g/m² along with Biomix @ 50g/m² and *Lantana camara* @100g/m² significantly reduced the disease intensity (%) of purple blotch of onion which also increase the plant height, number of leaves, fresh weight of bulbs and ultimately yield [58]. Neem oil in combination with microalgae

has also found to be effective in controlling leaf spot of cowpea and can be used as an alternative to chemical control measure [59].

Molecular based control method: Carrascal-Hernández et al. highlighted the application of 'omics' and gene editing through the CRISPR/Cas9 system and RNAi technologies focusing their effectiveness as emerging greener alternatives for controlling this phytopathogenic fungi. This work explores the transformative potential of CRISPR/Cas9 gene-editing technology in enhancing plant resistance against *Alternaria*, a significant fungal pathogen [60]. This innovative approach offers a promising alternative to traditional disease management practices, which often rely on chemical fungicides.

Host resistance: Source of resistance in different brassicaceous vegetables have been identified, which can be incorporated through conventional and biotechnological techniques under suitable agronomically sound yield and quality bases to be effective against *Alternaria* spp.. However, exploitation of this information to manage *Alternaria* disease under field conditions need much more emphasis [61].

Future work strategy: Future opportunities for the environmentally friendly control of *Alternaria* blight appear bright and varied. First, more research into innovative biological control agents, such as microbial consortia and beneficial microorganisms, has the potential to improve disease suppression and advance soil health and biodiversity. Furthermore, potential for the production of genetically modified crops with improved resistance to *Alternaria* infections are presented by advances in molecular biology and biotechnology. By facilitating early diagnosis and focused application of control measures, the integration of precision agriculture tools, such as remote sensing and data analytics, can further optimize disease management tactics. Furthermore, resilient agro-ecosystems that are less prone to *Alternaria* blight and other diseases can be created with the adoption of sustainable farming methods such as crop rotation, intercropping, and organic farming. In order to ensure the long-term sustainability of agricultural production systems, cooperative research projects and knowledge sharing platforms will be crucial for hastening the adoption of eco-friendly management techniques among farmers globally.

6. CONCLUSION

In conclusion, it can be noted that *Alternaria* leaf spot is a widespread disease causing significant economic losses. Management of the disease mostly included fungicides which have an adverse effect on environment and human health. Considerable progress has been achieved in lowering the dependency on chemical fungicides with managing the disease through alternative tactics such as biological control agents, plant extracts, resistant variety, nano particle-based formulations, etc. In addition to being effective in managing *Alternaria* blight, these environmentally friendly methods also have the advantage of having less adverse effect on the environment, prevents development of resistance in pathogen and enhances the general health of the agro-ecosystem. To make these techniques more cost-effective and scalable, as well as to optimize them for a variety of crops and environmental circumstances, more research is necessary. Through sustained innovation and the incorporation of environmentally conscious management techniques into agricultural systems, we may work towards a future where crop protection is more resilient and sustainable. As our environment is already polluted and damaged with lots of chemicals, it's time to choose a greener pathway to tackle the diseases.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nowicki M, Nowakowska M, Niezgodna A, Kozik E. *Alternaria* black spot of crucifers: symptoms, importance of disease, and perspectives of resistance breeding. *Journal of Fruit and Ornamental Plant Research*. 2012;76(1):5-19.
2. Nayyar BG, Akhund S, Akram A. A review: Management of *Alternaria* and its mycotoxins in crops. *International Journal*

- of Advanced and Applied Sciences. 2014;3(4):432-7.
3. Valvi HT, Saykar AD, Bangar VR. *In vitro* and *In vivo* field efficacy of different fungicides against *Alternaria brassicae* (Berk.) sacc. causing Alternaria leaf spot of cauliflower. Journal of Pharmacognosy and Phytochemistry. 2019;8(2):1333-1337.
 4. Conn KL, Tewari JP. Survey of Alternaria blackspot and Sclerotinia stem rot of canola in central Alberta in 1990. Canadian plant disease survey. 1991;71(1):96.
 5. Hossain MS, Hossain MM. Effect of Alternaria blight on the seed yield of cauliflower (*Brassica oleracea* L.). Bangladesh J. Agril. Res. 2010;35(3):381-5.
 6. Sinha PP, Prasad RK. Chemical management of Alternaria blight of cauliflower seed crop. Indian Journal of Mycology and Plant Pathology. 1989;19(2):204-205.
 7. Graham SL, Hansen KJ, Davis, Perry CH. Effect of one year administration of ethylene thiourea upon the thyroid of the rat. J. Agric. Fd. Chem. 1973;21:324-29.
 8. Kashyap PL, Dhiman JS. Eco-friendly strategies to suppress the development of Alternaria blight and black rot of cauliflower. Academic Journal of Plant Sciences. 2010;3(4):140-146.
 9. Humpherson-Jones FM, Phelps K. Climatic factors influencing spore production in *Alternaria brassicae* and *Alternaria brassicicola*. Annals of Applied Biology. 1989;114(3):449-458.
 10. Rangel JF. Two *Alternaria* diseases of cruciferous plants. Phytopathol. 1945;35:1002-1007.
 11. Chupp Charles, Arden F Sherf. Vegetable diseases and their control. 1960;693.
 12. Aneja JK, Agnihotri A. Alternaria blight of oilseed brassicas: Epidemiology and disease control strategies with special reference to use of biotechnological approaches for attaining host resistance. Journal of Oilseed Brassica. 2016;1(1):1-0.
 13. Farooq S, Jat RR, Majeed M, Nabi SU, Pandit D, Khushboo SS, Jan R, Choudhary P, Yadav MK. Morpho-molecular identification of *Alternaria alternata* associated with early blight of tomato (*Solanum lycopersicum* L.). The Pharma Innovation Journal. 2022; 11(10):1855-1859.
 14. Biswas MK. Influence of environmental factors on the development of Alternaria blight of mustard caused by *Alternaria brassicae*. The Ecoscan. 2013;4:139-144.
 15. MANJHI P, Tomar DS, Srivastav AK, Nayak MK. Alternaria blight of mustard and its association with weather parameters. Annals of Plant and Soil Research. 2018;20(3):250- 253.
 16. Devi G, Awasthi RP, Tiwari AK, Kumar A. Diversity in *Alternaria brassicae* (Berk.) Sacc. isolates and characterization of host response in different oilseed *Brassica* species. International Journal of Agricultural Invention. 2019;4(1):41-48.
 17. Mehra P, Tewari AK, GoharTaj. Studies on cultural, morphological, pathogenic and molecular variability of *Alternaria brassicae*, the causal agent of blight disease of rapeseed-mustard. Journal of Oilseed Brassica. 2017;8(2):1-11.
 18. Abeer H, Abd-Allah EF, Al-Huqail AA, Alqurawi AA. Report and characterization of *Alternaria alternata* (Fr.) Keissler on *Avicennia marina* (Forsk.) Vierh forests of industrial Yanb'a city, Saudi Arabia. Pak. J. Bot. 2014;46(2):725-734.
 19. Hubballi M, Nakkeeran S, Raguchander T, Anand T, Samiyappan R. Effect of environmental conditions on growth of *Alternaria alternata* causing leaf blight of noni. World Journal of Agricultural Sciences. 2010;6(2):171-177.
 20. Mishra PT, Mishra V. Effect of media, temperature and pH on growth of *Alternaria alternata* causing leaf spot of cotton. Annals of Plant Protection Sciences. 2012;20(1):246- 247.
 21. Dipak TN, Gaikwad PA, Sharma L. Morphological and cultural characterization of *Alternaria alternata* (Fr.) Keissler blight of gerbera (*Gerbera jamesonii* H. Bolus ex J.D. Hook). Journal of Applied Natural Science. 2013;5(1):171-178.
 22. Gupta SL, Rizvi G, Pajjwar MS. *Alternaria lini* causes blight disease on linseed: Its growth response on different parameters. Adv. Life Sci. 2013;2(2):64-66.
 23. Munde VG, Diwakar MP, Thombre BB, Utpal Dey UD. Survey and surveillance of early blight of tomato caused by *Alternaria solani* in Konkan region. International Journal of Plant Protection 2013;6(2):476-477.
 24. Kiran GVM, Thara SS, Brinda GB. Survey, pathogenicity, cultural and morphological characterization of *Alternaria* isolates

- associated with *Alternaria* leaf spot of cabbage. *Journal of Pharmacognosy and Phytochemistry*. 2018;7(5):2281-2286.
25. Pattanamahakul, Strange. Identification and toxicity of *Alternaria brassicicola*, the causal agent of dark leaf spot disease of Brassica species grown in Thailand. *Plant Pathology*. 1999;48(6):749-755.
 26. Rahimloo T, Ghosta Y. The occurrence of *Alternaria* species on cabbage in Iran. *Zemdirbyste. Agric*. 2015;102(3):343-350.
 27. Sarkar D, Barhate BG, Joshi VR. Studies on leaf spot of chilli. *International Journal of Plant Protection*. 2017;369-374.
 28. Aboomer Safder MW, Usman M, Iqbal S, Abbas MH, Anum HH, Firdous H, Sarwar MI. Epidemiological factors increasing the *Alternaria* leaf spot of cabbage and their management strategies. *The International Journal of Biological Research*. 2019;2:01-16.
 29. Thambi NP, Sharma M, Gochar R, Katoch M. *Alternaria* sp., a new pathogen causing leaf spot in broccoli, and its management with *Monarda citriodora* essential oil (MEO) and isoeugenol combination. *Physiological and Molecular Plant Pathology*. 2024;131:102293.
 30. Deep S, Sharma P, Behera N, Chowdappa P. Diversity in Indian Isolates of *Alternaria brassicicola* (Schwein) Wiltshire causing Black Leaf Spot Disease in Cauliflower. *Plant Pathology Journal*. 2014;13(4):232-245.
 31. Mamgain A, Biswas MK, Dey N. In vitro evaluation of bio-control agents against *Alternaria brassicae*. *Research Journal of Agricultural Sciences*. 2018;9:47-49.
 32. Kashyap PL, Dhiman JS. Eco-friendly strategies to suppress the development of *Alternaria* blight and black rot of cauliflower. *Academic Journal of Plant Sciences*. 2010;3(4):140-146.
 33. Taha NA, Hamden S, Bayoumi YA, Elsakhawy T, El-Ramady H, Solberg SØ. Nanofungicides with selenium and silicon can boost the growth and yield of common bean (*Phaseolus vulgaris* L.) and control *Alternaria* leaf spot disease. *Microorganisms*. 2023;11(3):728.
 34. Gaba S, Rai AK, Varma A, Prasad R, Goel A. Biocontrol potential of mycogenic copper oxide nanoparticles against *Alternaria brassicae*. *Frontiers in Chemistry*. 2022;10:966396.
 35. Chrapačienė S, Rasiukevičiūtė N, Valiuškaitė A. Control of seed-borne fungi by selected essential oils. *Horticulturae*. 2022;8(3):220.
 36. Sazvar E, Jahani M, Aminifard MH, Hosseini SA. *In vitro* and *In vivo* control of *Alternaria alternata* in barberry (*Berberis vulgaris*) by some essential oils. *Erwerbs-obstbau*. 2022;64(3):413-423.
 37. Feng W, Zheng X. Essential oils to control *Alternaria alternata* *In vitro* and *In vivo*. *Food control*. 2007;18(9):1126-1130.
 38. Zaker M, Mosallanejad H. Antifungal activity of some plant extracts on *Alternaria alternata*, the causal agent of alternaria leaf spot of potato. *Pakistan journal of biological sciences: PJBS*. 2010; 13(21):1023-1029.
 39. Korbecka-Glinka G, Piekarska K, Wiśniewska-Wrona M. The use of carbohydrate biopolymers in plant protection against pathogenic fungi. *Polymers*. 2022;14(14):2854.
 40. Chakraborty M, Hasanuzzaman M, Rahman M, Khan MAR, Bhowmik P, Mahmud NU, Islam T. Mechanism of plant growth promotion and disease suppression by chitosan biopolymer. *Agriculture*. 2020;10(12):624.
 41. Ramakrishna A, Desai S, Devi GU, Maheswari TU. Management of early blight of tomato caused by *Alternaria solani* by using bio-inoculants and chitosans under greenhouse conditions. *Journal of Experimental Agriculture International*. 2024;46(7):649-654.
 42. Thomas CE, McCreight JD, Jourdain EL. Inheritance of resistance to *Alternaria cucumerina* in Cucumis melo line MR-1. *Plant Dis*. 1990;74:868-870.
 43. Mathur K, Shekhawat KS. Fruit rot of watermelon. *Indian Journal of Mycology and Plant Pathology*. 1992;22(1):80.
 44. Katiyar A, Kant S, Chauhan SS, Alka A. Chemical control of *Alternaria* leaf spot of bottle gourd. *Ann. Plant Protec. Sci*. 2001;9(2):339-341.
 45. Sujatha Bai E, Seetharaman K, Shivaprakasam. *Alternaria* fruit rot disease of chilli-a serious malady in Tamilnadu. *Ind. Phytopathol*. 1993;46:338.
 46. Matharu BK, Sharma JR, Manrao MR. Synthesis and antifungal potential of 2-chlorobenzal derivatives. *Pesticide Research Journal*. 2006;18(2):113-115.
 47. Shahnaz E, Razdan VK, Dar ZA, Lone AA, Habib M, Nisa SU, Iqbal S. Evaluation of

- Genotypes and Varieties against Foliar Blight Disease of Onion (*Allium cepa* L.). Journal of Advances in Biology & Biotechnology. 2024;27(8):505-513.
48. Singh S, Sagar S, Rao M, Saroha S, Garg P, Prasad L. Screening wild Brassica species against *Alternaria brassicicola* (Schw.) Wiltsh for breeding *Alternaria* leaf spot resistance in Brassica vegetables. Genetic Resources and Crop Evolution. 2024;71(6):2509-2525.
 49. Singh R, Singh D, Salisbury P, Barbetti MJ. Field evaluation of indigenous and exotic *Brassica juncea* genotypes against *Alternaria* blight, white rust, downy mildew and powdery mildew diseases in India. Indian Journal of Agricultural Sciences. 2010;80(2):155-9.
 50. Singh SB, Kuwar Singh KS, Abhimanyu A. Evaluation of native bio-agents against *Alternaria brassicae* causing *Alternaria* blight of mustard. Farm Science Journal. 2005;14(2):64.
 51. Habib A, Mansha MZ, Aatif HM, Ikram K, Aslam HMU, Ashraf W, Khalid J. Response of cabbage and cauliflower varieties against *Alternaria* blight disease and its management. Fresenius Environmental Bulletin. 2020;29(11):9782-9788.
 52. Guleria S, Kumar A. Azadirachta indica leaf extract induces resistance in sesame against *Alternaria* leaf spot disease. Journal of Cell and Molecular Biology. 2006;5(2):81-86.
 53. Guleria S, Kumar A. Antifungal activity of Agave americana leaf extract against *Alternaria brassicae*, causal agent of *Alternaria* blight of Indian mustard (*Brassica juncea*). Archives of Phytopathology and Plant Protection. 2009;42(4):370-5.
 54. Sharma SR, Kolte SJ. Effect of soil-applied NPK fertilizers on severity of black spot disease (*Alternaria brassicae*) and yield of oilseed rape. Plant and soil. 1994;167:313-320.
 55. Godika SPAK, Pathak AK, Jain JP. Integrated management of *Alternaria* blight (*Alternaria brassicae*) and white rust (*Albugo candida*) diseases of Indian mustard (*Brassica juncea*). The Indian Journal of Agricultural Sciences. 2001;71(11):733-5.
 56. Meena PD, Chattopadhyay C, Kumar A, Awasthi RP, Singh R, Kaur S, Chand P. Comparative study on the effect of chemicals on *Alternaria* blight in Indian mustard-A multi-location study in India. Journal of Environmental Biology. 2011;32(3):375.
 57. Kumar N, Kumar A. Effect of cultural practices on *Alternaria* blight in *Brassica juncea* and *B. napus*. The Indian Journal of Agricultural Sciences. 2006;76(6):389-390.
 58. Devi TJ, Lal AA. Eco-friendly Management of Purple Blotch (*Alternaria porri*) of Onion (*Allium cepa* L.). International Journal of Environment and Climate Change. 2024;14(8): 519-526.
 59. Kumar GA, Simon S. Assessing the effectiveness of neem oil and microalgae in the Management of Cowpea (*Vigna unguiculata* L.) leaf spot caused by *Alternaria* spp. International Journal of Plant & Soil Science. 2024;36(6):450-459.
 60. Carrascal-Hernández DC, Flórez-López E, Peralta-Ruiz Y, Chaves-López C, Grande Tovar CD. Eco-friendly biocontrol strategies of *Alternaria* phytopathogen fungus: A focus on gene-editing techniques. Agriculture. 2022;12(10):1722.
 61. Chand G, Yadav SP, Yadav GC, Kumar S. Eco-friendly and innovative approaches in management of *Alternaria* blight of broccoli. Ecofriendly Innovative Approaches in Plant Disease management. 2012;419-430.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

© Copyright (2024): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/124912>