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Review Article

Review on Fruit Quality Parameters and Biochemical Basis of Anthracnose Disease Resistance in Chillies

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ABSTRACT

India is the world's largest producer, consumer, and exporter of chillies, which is a spice and vegetable crop. The quality and yield of chilli fruits are significantly impacted by anthracnose disease, caused by various *Colletotrichum sps*, notably *C. gloeosporioides* and *C. acutatum*. This disease results in substantial economic losses for farmers, reducing marketable yield by approximately 13%. Resistance to anthracnose in chillies involves a complex interplay of morphological and biochemical factors. Key biochemical mechanisms underlying resistance include the biosynthesis and accumulation of defense-related compounds, induction of defense proteins, and activation of antioxidant systems. Phenolic compounds, synthesized via the phenylpropanoid pathway, play a crucial role in maintaining cell wall integrity and providing antimicrobial properties. Increased activity of antioxidative enzymes is essential for scavenging reactive oxygen species (ROS) produced during infestation, including catalase (CAT), superoxide dismutase (SOD), and peroxidases (POX). Studies have shown that resistant chilli varieties exhibit higher activities of peroxidase and polyphenol oxidase, which contribute to defense responses through lignin deposition and phenolic compound synthesis. Additionally, resistant varieties demonstrate higher levels of ascorbic acid, capsaicin, and phenols compared to susceptible ones. Understanding these biochemical pathways associated with resistance can aid in developing effective breeding strategies for resistant chilli genotypes. This review highlights the importance of biochemical basis and quality parameters in elucidating the mechanisms of anthracnose disease resistance, providing insights for enhancing chilli crop resilience and productivity.

KEYWORDS

Chilli (*Capsicum annuum*), Anthracnose Disease, Fruit Quality, Biochemicals Basis of Resistance

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INTRODUCTION

India is the world's leading producer, consumer, and exporter of chillies, which are cultivated there as a spice and vegetable crop [1]. Colletotrichum ranks as the eighth most significant group of plant pathogenic fungi globally based on its scientific and commercial value. Chilli anthracnose disease, induced by *Colletotrichum species*, greatly diminishes the quality and yield of chilli fruits, causing farmers to experience low returns. This generally leads to an approximate 13% decrease in marketable yield. Typical symptoms of anthracnose on chilli fruits include sunken necrotic tissues with concentric rings of acervuli and fused lesions [2]. Severe conditions may produce conidial masses. Several Colletotrichum species are associated with anthracnose diseases in chillies, including *C. acutatum*, *C. coccodes*, *C. dematium*, and *C. gloeosporioides*. Different species infect chilli plants at various growth stages: *C. coccodes* and *C. dematium* damage leaves and stems, while *C. acutatum* and *C. gloeosporioides* infect chilli fruits. Colletotrichum capsici commonly affects red chilli fruits, whereas *C. acutatum* and *C. gloeosporioides* cause infections in both young and mature chilli fruits. Among these species, *C. gloeosporioides* and *C. acutatum* are the most destructive and widespread [3].

Multiple modes of action, such as antibiosis, synthesis of essential secondary metabolites, cell wall-degrading enzymes, and the deposition of callose and lignin in the cell wall, contribute to reducing disease severity and inducing systemic resistance in the plant. This involves signaling from the root to the shoot system, providing long-lasting protection against invading pathogens compared to chemically treated plants. The biochemical defense response is indicated by increased activities of antioxidative enzymes such as Catalayse (CAT), Super Oxide Dismutase (SOD), GPx, and APx, which are involved in scavenging reactive oxygen species (ROS) like H_2O_2 and O_2^- during a pathogen attack. Moreover, the increase in biochemical defense enzymes like Proline dehydrogenase, polyphenol oxidase and Phenylalanine ammonia (POX, PPO, and PAL) and antioxidative enzymes Super oxide Dismutase, Catalase, Ascorbate peroxidase and Glutathione Peroxidase (SOD, Cat, APx, and GPx) activities, phenol, and the accumulation of Reactive Oxygen Species (ROS) highlight the key role of these molecules in host–pathogen interactions [4]. Several quality traits are associated with anthracnose disease resistance in chillies, including ascorbic acid content, sugar content, and capsaicin content of the fruits.

Quality Parameters of Chilli

Chilli fruits are highly valued for their pungency and quality characteristics. Biotic stresses induced by pathogens are known to alter the chemical constituents of the fruit. Infection and tissue rotting by various pathogens cause distinct metabolic changes compared to healthy tissues. Changes in Ascorbic acid content, Capsaicin content and sugar Content of fruits are known to show resistance to anthracnose disease [5].

In Guwahati, the ascorbic acid percentage was highest (1.74 mg per g) in resistant varieties and lowest (1.35 mg per g) in susceptible chilli varieties during infection with *Colletotrichum capsici* (Azad, 1991). A reduction in ascorbic acid content due to pathogen infection has also been reported by Sujathabai [6] and Jeyalakshmi et al. [7].

Similarly in Guwahati the proportion of capsaicin in resistant chilli cultivars was 1.60 percent, whereas in susceptible types it was 1.20 percent (Azad, 1991). Anon [8] found a negative correlation between the occurrence of anthracnose and the fruits' capsaicin concentration. All 56 genotypes of small-fruited cultivars with high capsaicin content (Cili Padi) were resistant to anthracnose, according to a breeding study conducted at AVRDC in Taiwan. Every cultivar that proved resistant had large, pungent fruits, with the exception of the small, dry Tampar Skincau variety [9]. Capsaicin, the substance that gives chilli a spicy kick, was found in 50% less resistant chilli fruits (67.40 mg/100g) [7].

Madhukar and Reddy [10] and Subbaraja [11] both noted lower sugar levels in infected chilli fruits. On the other hand, Azad (1991) noted elevated sugar levels in three distinct types of *Colletotrichum capsici* infection. Low sugar levels were observed in infected fruits by Jeyalakshmi et al. [7], who reported changes in biochemical contents after infection. Rajavel [12] also reported lower overall sugar content in infected chillies, with a range of 9.78% to 45.66%; the K2 variety had the greatest overall sugar decrease (88%). Both reducing and non-reducing sugar content showed similar outcomes.

Phenolics and Biochemical Resistance

The biochemical mechanisms underlying resistance to anthracnose disease in chillies involve a complex interplay of various molecular and cellular processes. These include the biosynthesis and accumulation of defense-related compounds, induction of defense-related proteins, and activation of antioxidant systems [13]. The phenylpropanoid pathway regulates the biosynthesis of phenolic compounds in plants, involving enzymes such as phenylalanine ammonia-lyase (PAL), chalcone synthase (CHS), and flavonoid biosynthetic enzymes. Upon pathogen attack or elicitor treatment, the expression of these enzymes is upregulated, leading to increased production and accumulation of phenolic compounds in resistant chilli genotypes.

The most prevalent class of secondary metabolites in plants are phenolics, which are produced by the phenylpropanoid pathway from the aromatic amino acids tyrosine and phenylalanine. Under biotic and abiotic stress situations, they support plants' defence response [13]. The disturbance of the electron transport system is the reason behind their hazardous character, according to researchers. These substances are essential for preserving the integrity of the cell wall and fending off pathogen invasion. Diseased plant tissues have higher concentrations of phenols and their precursors, which accumulate more in incompatible host-pathogen complexes than in compatible ones. Polyphenols have been found to positively correlate with the level of disease resistance against Fusarium, according to Chhabra et al. [14].

Polyphenol oxidase (PPO) is widely recognized for its role in defense responses against biotic stresses. Murria et al. [15] studied metabolic changes in grapevine leaves during anthracnose infection and observed higher PPO activity in infected tissues of resistant varieties compared to susceptible ones. Increased phenol synthesis and polyphenol activity were linked to resistance against various host-parasite interactions. PPO catalyzes the oxidation of phenols into reactive quinones, which may enhance disease resistance by cross-linking quinones with other phenolics, causing direct toxicity of quinones, and generating Reactive Oxygen Species (ROS). Prasath and Ponnuswami [16] found the highest phenolic content in resistant chilli genotypes (Acc. 16 PCB 81), whereas susceptible genotypes like Hybrid 6 showed lower phenol content.

Hodzic et al. [17] reported elevated total phenols in healthy tissues of resistant and moderately resistant green gram genotypes compared to susceptible ones. Ghai et al. [18], analyzing *Capsicum annuum L.* germplasm against Colletotrichum annuum, observed high total phenolic content in resistant genotypes. The increase in total phenols upon infection in resistant genotypes, compared to susceptible ones, underscores the crucial role of these compounds in plant disease resistance. Phenolic compounds represent a diverse group of secondary metabolites with antimicrobial and antioxidant properties, effectively inhibiting the growth and development of fungal pathogens, including Colletotrichum spp. Flavonoids, phenolic acids, and capsaicinoids are among the key phenolic compounds associated with resistance to anthracnose in chillies [19]. Antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and peroxidases (POX) play crucial roles in scavenging reactive oxygen species (ROS) generated during plant-pathogen interactions [20]. ROS can cause oxidative damage to cellular components, and their accumulation is often associated with disease susceptibility. An efficient antioxidant system helps mitigate oxidative stress, contributing to enhanced resistance to anthracnose disease in chillies.

Host Enzymes Against Anthracnose Disease

Through boosting the activity of defense-related enzymes including peroxidase (POX) and polyphenol oxidase (PPO), jasmonic acid-mediated signalling plays a critical role in strengthening host resistance during pathogen challenges. These enzymes mainly produce free radicals and aid in the deposition of lignin. Phenylalanine Ammonia-lyase (PAL), which controls the synthesis of phenolic compounds, is activated more when Bacillus amylolique faciens is added to chilli seeds. This results in the buildup of phytoalexins and the lignification of xylem cell walls, which effectively stops soil-borne and foliar pathogens from invading and multiplying [21].

Plants are resistant to several infections due to the actions of pathogenesis-related (PR) proteins, such as chitinase (PR-3) and β-1-3 glucanase (PR-2), which break down cell walls, induce cytoplasmic leakage, and eventually lead to cell death. Antioxidative enzymes that detoxify reactive oxygen species (ROS) during pathogen infections, such as glutathione peroxidase (GPx), catalase (CAT), superoxide dismutase (SOD), and ascorbate peroxidase (APx), are more active during the biochemical defence response [16].

In addition to phenol buildup and ROS production, the increased activity of antioxidative enzymes (SOD, CAT, APx, GPx) and biochemical defence enzymes (POX, PPO, PAL) emphasises their crucial role in host-pathogen interactions. Because they aid in the creation and degradation of quinones and phenolics, respectively, host enzymes such as peroxidase and polyphenol oxidase are critical for disease resistance. Quinones have strong fungitoxic and bactericidal effects, which probably play a major role in the development of disease resistance [22].

Research has shown that higher polyphenol oxidase activity is associated with disease resistance in various crops. For instance, in rot-resistant potato variety Kufri Dewa, the activity of polyphenol oxidase was higher compared to the susceptible variety C-1769. Higher peroxidase activity is also correlated with disease resistance in crop plants. Research on *Capsicum annuum* has shown that resistant cultivars' leaves have higher levels of polyphenol oxidase activity. This enhanced activity resulted in the production of more quinones and other oxidation products, which in turn reduced pathogen proliferation and rendered the pathogen inactive [23]. Similarly, okra varieties resistant to yellow vein mosaic displayed increased activity levels of polyphenol oxidase and peroxidase compared to susceptible varieties [24]. Phenylalanine ammonia-lyase (PAL), the first gateway enzyme in the biosynthesis of phenolic compounds, is crucial for controlling the flux along the phenylpropanoid pathway and the rate at which phenolic compounds are generated. An increase in PAL activity upon inoculation is a common plant response to the powdery mildew fungus and is often linked to different forms of resistance. In tobacco and Arabidopsis plants, PAL plays a major role in the synthesis of salicylates, which shows resistance.

Studies on chilli varieties have reported significant increases in peroxidase and polyphenol oxidase activities in resistant varieties upon infection, indicating their role in disease resistance [25]. Acid phosphatases, associated with phosphate metabolism, have also been linked to disease resistance. Increased acid phosphatase activity has been observed in plants in response to pathogen attack. For example, in barley, acid phosphatase transcript accumulation is associated with systemic resistance. In tobacco, acid phosphatase activity increases following inoculation with bacteria that induce a hypersensitive response [26].

In chillies, higher acid phosphatase activity was recorded in susceptible varieties after infection by *Colletotrichum capsici*, highlighting its potential role in the plant's defense mechanism. Overall, these enzymes and their associated pathways play critical roles in enhancing the plant's defense system, contributing to resistance against anthracnose disease[27-35].

CONCLUSION

The study on anthracnose disease resistance in chillies is influenced by various biochemical, morphological, and enzymatic factors. Chilli varieties resistant to anthracnose exhibit higher levels of ascorbic acid, capsaicin, and phenolic compounds, which enhance their defense mechanisms. Antioxidant enzymes are essential for scavenging reactive oxygen species (ROS) during pathogen infections and enhancing resistance. Examples of these enzymes are peroxidases (POX), catalase (CAT), and superoxide dismutase (SOD). Enzymes in the phenylpropanoid pathway, particularly phenylalanine ammonia-lyase (PAL) and polyphenol oxidase (PPO), are crucial for the biosynthesis of defense-related phenolic compounds. This approach ensures sustainable chilli production, mitigates economic losses for farmers, and enhances crop resilience. Future research should continue to unravel the intricate host-pathogen interactions and leverage advanced molecular techniques to refine breeding strategies for disease-resistant crops[36-42].

REFERENCES

1. Malathi G (2004) Genotype and seasonal interaction of F1 hybrids and their parents in chilli (Capsicum annuum L.) for anthracnose resistance and high yield Ph.D Thesis, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-3, Tamil Nadu, India.
2. Yadav M, Dubey MK, Upadhyay RS (2021) Systemic resistance in chilli pepper against anthracnose (caused by Colletotrichum truncatum) induced by Trichoderma harzianum, Trichoderma asperellum and Paenibacillus dendritiformis. Journal of Fungi 7(4): 307.
3. Oo MM, Oh SK (2016) Chilli anthracnose (Colletotrichum spp.) disease and its management approach. Korean Journal of Agricultural Science 43(2): 153-162.

4. Gunaeni N, Korlina E, Hamdayanty H, Gaswanto R (2021) Resistance validation of several chili peppers to anthracnose (*Colletrothicum acutatum*) isolate Sukabumi. In IOP Conference Series: Earth and Environmental Science 807(2): 022111.

5. Malathi G, Veeraragavathatham D (2005) Per se performance and heterosis of two hybrids of chillies (Capsicum annuum L.) for qualitative traits in three different seasons. SOUTH INDIAN HORTICULTURE 53(1/6): 78.

6. Sujathabai N (1992) Reduction in ascorbic acid content due to pathogen infection in chillies (Capsicum annum L.) M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore, India.

7. Jeyalakshmi et al. (1999) Changes in biochemical constituents during infection in chilli fruits. Capsicum and Egg plant Newsl 18: 80-82.

8. Anon (1992) Capsaicin content of the fruits and its correlation with anthracnose resistance in chilli fruits. J Amer Soc Hort Sci 125(1): 66-70.

9. Anon (1993) Breeding study for resistance to anthracnose at AVRDC in Taiwan. AVRDC 1992 Progress Report. pp.122-123.

10. Madhukar TS, Reddy K (1991) Reduced sugar levels in infected chilli fruits. Indian J Mycol Pl Pathol 21: 179-182.

11. Subbaraja, et al. (1981) Changes in biochemical constituents during infection in chilli fruits. Ph.D. Thesis Tamil Nadu Agric. Univ., Coimbatore, India.

12. Rajavel, et al. (2000) Reduced total sugar content in infected chillies. M.sc. (Agri. Thesis, Tamil Nadu Agricu. Univ., Coimbatore) India.

13. Naveen J, Navya HM, Hithamani G, Hariprasad P, Niranjana SR (2021) Pathological, biochemical and molecular variability of Colletotrichum truncatum incitant of anthracnose disease in chilli (Capsicum annuum L.). Microb Pathog 152: 104611.

14. Chhabra R, Kaur N, Bala A (2019) Physiological and biochemical alterations imposed by Fusarium fujikuroi infection in aromatic and non-aromatic rice cultivars. Plant Physiology Reports 24(4): 563-575.

15. Murria S, Kaur N, Arora N, Mahal, A K (2018) Field reaction and metabolic alterations in grape (Vitis vinifera L.) varieties infested with anthracnose. Scientia horticulturae 235: 286-293.

16. Prasath D, Ponnuswami V (2008) Screening of chilli (Capsicum annuum L.) genotypes against Colletotrichum capsici and analysis of biochemical and enzymatic activities in inducing resistance. Indian Journal of Genetics and Plant Breeding 68(03): 344-346.

17. Hodzic Z, Pasalic H, Memisevic A, Srabovic M, Saletovic M, Poljakovic M (2009) The influence of total phenols content on antioxidant capacity in the whole grain extracts. European Journal of Scientific Research 28(3): 471-477.

18. Ghai N, Kaur J, Jindal SK, Dhaliwal MS, Pahwa K (2016) Physiological and biochemical response to higher temperature stress in hot pepper (Capsicum annuum L.). Journal of Applied and Natural Science 8(3): 1133-1137.

19. Katediya M A, Jaiman RK, Acharya SK (2019) Management of chilli anthracnose caused by *Colletotrichum capasici*. Journal of Pharmacognosy and Phytochemistry 8(3): 2697-2701.

20. Saxena A, Raghuwanshi R, Gupta VK, Singh HB (2016) Chilli anthracnose: the epidemiology and management. Frontiers in microbiology 7: 215999.

21. Kiran R, Akhtar J, Kumar P, Shekhar M (2020) Anthracnose of chilli: Status, diagnosis, and management. In Capsicum. IntechOpen. London.

22. Chhabra R, Kaur S, Vij L, Gaur K (2020) Exploring physiological and biochemical factors governing plant pathogen interaction: A review. Int J Curr Microbiol App Sci 9(11): 1650-1666.

23. Susheela K (2012) Evaluation of screening methods for anthracnose disease in chilli. Pest Management in Horticultural Ecosystems 18(2): 188-193.

24. Rajapakse, RGAS, Ranasinghe JADAR (2002) Development of variety screening method for anthracnose disease of chilli (Capsicum annum L.) under field conditions. Tropical Agricultural Research and Extension 5(1 & 2).

25. Malathi G, R Jegathambal, Vijayan R, P Kalai Selvi, G Anand (2023) Assessing the Performance of Chilli (Capsicum annuum L.) Hybrids TNAU Chilli Hybrid CO 1 and Arka Saanvi in Salem District of Tamil Nadu. International Journal Of Engineering Technology and Management Sciences 7(1): 70-73.

26. Abhayashree MS, Murali M, Thriveni MC, Sindhu GM, Amruthesh KN (2017) Crude oligosaccharides mediated resistance and histo-chemical changes in Capsicum annuum against anthracnose disease caused by Colletotrichum capsici. Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology 151(2): 221-233.

27. Bashan Y, et al. (1987) Relation between enzymes and resistance against bacterial wilt of tomato. Can J Bot 65: 366-372.

28. Chowdhury M F N, Rafii M Y, Ismail S I, Ramlee S I, Hosen M, et al. (2023) Growth and yield performances, pathogenicity, heat tolerance, antioxidant activity, and pungency level of anthracnose resistant and heat tolerant inbreed lines and their F1 hybrids of chili (Capsicum annuum L.). Scientia Horticulturae 309: 111606.

29. Dwivedi N, Tirkey DS, Katoch S, Prasad L (2021) Evaluation of resistance against anthracnose (Colletotrichum capsici and C. gloeosporioides) in chilli landraces collected from the northeastern region of India. Plant Genetic Resources 19(6): 538-544.

30. Fernandez et al. (1996) Increase in peroxidase enzyme activity in tomato cultivar NCEBR-1 resistant to Alternaria solani. Revista- de-Protection-Vegetal 11: 79- 83.

31. Herath HMSN, Rafii MY, Ismail SI, Jaafar JN, Ramlee SI (2022) Genetic diversity of inbred lines in chilli based on phenotypic and genotypic responses against Colletotrichum truncatum. Archives of Phytopathology and Plant Protection, 55(5): 583-596.

32. Malathi G, PS Kavitha, R Vijayan, M Vijayakumar, Sriram N (2021) Per se performance of hybrid chillies (Capsicum annuum l.) TNAU Chilli Hybrid CO1 and Arka Meghana in Salem district of Tamil Nadu. International Advanced Research Journal in Science, Engineering and Technology 8(8): 488-490.

33. Malathi G, R Vijayan, M Vijayakumar, P Kohila, Sriram N (2021) Assessment of per se performance of chilli (Capsicum annuum L.) hybrids in Salem District of Tamil Nadu. International Advanced Research Journal in Science, Engineering and Technology 8(8): 480-482.

34. Malathi G, Veeraragavathatham D (2005) Per se performance of two hybrids and their parents of chilli for growth and yield characters in three different seasons. SOUTH INDIAN HORTICULTURE 53(1/6): 71.

35. Malathi G, Jegathambal R, Kohila P, Vijayan R (2022) Assessment of per se performance of chilli (Capsicum annuum L.) hybrids TNAU Chilli Hybrid CO 1 and Arka Saanvi in Salem District of Tamil Nadu. Journal of Krishi Vigyan 11(1): 433-435.

36. Malathi G, Veeraragavathatham D (2004) Per se performance and heterosis of two hybrids of chilli (Capsicum annuum L. for qualitative traits in three different seasons. Capsicum and Eggplant Newsletter 25: 65-68.

37. Market CL, Molter H (1959) Isozymes as molecular markers in biological sciences. Proc Nat Acad SCI U.S.A 45: 753-763.

38. Patel SK, Patel DA, Patel NA, Patel R, Vadodariya JM, Patel UN (2022) Assessment of genetic variability based on morphological and biochemical markers in red chilli (Capsicum annuum L.). In Biological Forum–An International Journal 14(4): 1283-1288.

39. Ruth Beulah Rani, et al. (2002) Electrophoretic studies on banding patterns of peroxidase and polyphenol oxidase isozymes.

40. Subash ChandraBose (1999) Screening trial with 24 tomato cultivars against bacterial wilt using peroxidase and polyphenol oxidase isozymes. M.Sc. Thesis, College of Horticulture, Vellaikara, Thrissur, Kerala.

41. Subash ChandraBose, Rajan S (2000) Peroxidase isozyme banding pattern in tomato genotypes. M.Sc. Thesis, College of Horticulture, Vellaikara, Thrissur, Kerala.

42. Tiwari S, Kumar P, Singh GA, Pundir S K, Singh A (2024) Screening of Germplasms for Disease Resistance Against Anthracnose of Chilli Caused by Colletotrichum capsici. International Journal of Plant & Soil Science 36(5): 727-731.