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Influence of rising temperature and atmospheric CO_2 on blast disease development in pearl millet

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Abstract
Temperature and CO_2 level of the atmosphere are rising hence a study was carried out at college of agriculture, RVSKVV, Gwalior (M.P.) during 2023 to access the impact of elevated level of CO_2 and temperature on the severity of pearl millet blast. Results revealed a significant increase in Percent disease index (PDI) of pearl millet blast with hike CO_2 and temperature levels. The highest PDI at 30 DAS (30.6%) was observed in 550 ppm CO_2, followed by 25.7% and 21.5% in 500 and 450 ppm respectively. Similarly, temperature elevation led to increased disease severity, with PDI values of 22.2%, 27.0%, and 28.9% under ambient + 1 °C, + 1.5 °C, and + 2 °C, respectively, compared to 20.2% under ambient and 15.2% under open field conditions. The findings suggest that both elevated CO_2 and higher temperatures significantly enhance the severity of Pearl millet blast, indicating a potential threat to pearl millet production under future climatic change scenarios. These results emphasize the need for climate-resilient crop hybrids/varieties and adaptive disease management strategies to safeguard food security.

Keywords: Blast, PDI, temperature, elevated CO_2

Introduction
Pearl millet (*Pennisetum glaucum* [L.] R. Br.), is the sixth most important cereal crop globally, following rice, wheat, maize, barley, and sorghum. (Satyavathi *et al.*, 2021) [10]. It is commonly cultivated during the *kharif* season and adapted to the arid and semi-arid agro-climatic zones of Asia, Africa, and the Americas. Pearl millet is recognized as a nutri-cereal due to its high nutritional value and multi-functional utility, cultivated for grain and fodder also serves as a staple food in many low-input farming systems (Anuradha *et al.*, 2017) [2]. The crop exhibits exceptional climate resilience, thriving under high temperatures, drought conditions, and poor soil fertility. Major Pearl millet producers include India, Pakistan, China, and countries in Southeast Asia. Notably, India and Africa together account for approximately 90% of the global area under pearl millet cultivation (Yadav *et al.*, 2012) [11]. India holds the distinction of being the world's leading producer of pearl millet, achieving an average productivity of 1,510 kg/ha (Anonymous, 2023) [1]. The cultivation of this crop is concentrated in six major states—Rajasthan, Haryana, Gujarat, Maharashtra, Uttar Pradesh, and Madhya Pradesh—which collectively account for approximately 90% of the country's total pearl millet output (Satyavathi *et al.*, 2021) [10]. Among these, Madhya Pradesh emerges as an important contributor, exhibiting a substantially higher mean yield of 2,599 kg/ha, indicative of favourable agro-climatic conditions and improved agronomic practices in certain regions (Anonymous, 2023) [1]. In Madhya Pradesh, pearl millet cultivation is spatially concentrated in the northern agro-ecological zones, where the crop is an integral component of the rainfed farming systems. The districts of Morena, Bhind, Gwalior, Sheopur, Shivpuri, Alirajpur, and Datia represent the principal production hubs, contributing to the state's overall pearl millet acreage and yield performance.

The productivity of pearl millet is influenced by a variety of biotic and abiotic factors, which prevent farmers from realizing the crop's full yield potential. Among the biotic stresses, blast disease—caused by *Pyricularia grisea* (Cooke) Sacc. is of growing concern. First reported in India from Kanpur in 1953 (Mehta *et al.*, 1953) [6], the disease remained relatively minor throughout the 20th century.

However, over the past decade, it has emerged as a serious threat and now ranks among the most damaging diseases of pearl millet in the north-central regions of India, particularly in Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Punjab, and Delhi (Meena *et al.*, 2019; Patro *et al.*, 2020) [8, 9]. In the northern region of Madhya Pradesh, blast disease has become one of the most important biotic constraints, affecting the crop at all stages of growth—from seedling to maturity. The pathogen has been observed to cause disease severity ranging between 25% and 55%, depending on the agroclimatic conditions. Climate change has further intensified the problem, as the pathogen continues to evolve and develop new races in response to environmental pressures. With global increases in temperature and CO_2 levels, it becomes essential to study how these factors influence the occurrence and spread of the disease. The increasing inability of the host plant to resist infection in the field can be attributed to this evolving pathogen pressure. Therefore, considering the rising importance and impact of blast disease on pearl millet production, the present investigation has been undertaken.

Materials and Methods

The present study was conducted in the department of plant pathology and the department of soil and environmental science, college of agriculture, Gwalior, Madhya Pradesh, India during kharif season in 2023. The materials required for the experiment were controlled open top chambers, pots, sterilized soil and seed material (ICMB 95444), inoculum of pathogen for infection, spray bottle. The experiment was conducted using CRD design with four replications. The study of role of temperature and elevated levels of CO_2 on the severity of blast disease was studied under artificial controlled condition. The whole experiment was set in open top chamber. Three different levels of CO_2 and three different levels of temperature i.e., 450 ppm, 500 ppm, 550 ppm and + 1, + 1.5, + 2 °C temperature from ambient was set in the open top chambers. Ambient and open field was kept as control. The average maximum temperature of open field was 34 °C and in ambient treatment it was 36 °C and the average CO_2 level in the environment was 418 ppm whereas in ambient treatment it was 420 ppm. All the pots were filled with sterilized soil and ICMB 95444 susceptible variety was sown in the pots.10 plants of pearl millet in each pot were maintained. On the 7th day of germination, the inoculum of pathogen was sprayed to induce the infection and increase the disease pressure to test the variety. The observation was recorded on the five plants, in each plant 3 leaves was assessed as per 0 to 9 disease scale rating at 30 DAS.

Results

It is evident from the table 1 and presented in figure 1 that blast severity increase with the increase in CO_2 level and temperature. Under 550 ppm (T3), 500 ppm (T2), and 450 ppm (T1) CO_2 level the blast PDI was 30.6, 25.7 and 21.5 percent respectively. Whereas under the ambient treatment (T7) and under open field condition (T8) it was 20.2 and 15.2 percent respectively. The PDI under ambient + 1 °C (T4), ambient + 1.5 °C (T5) and in ambient + 2 °C (T6) was 22.2, 27 and 28.9 percent respectively. The maximum PDI (30.6) was recorded under 550 ppm CO_2 level while minimum PDI (15.2) was recorded under open field condition. The blast PDI was significantly increased with the increase in CO_2 level from open field to ambient, ambient to 450 ppm, 450 ppm to 500 ppm and 500 ppm to 550 ppm. The blast PDI was also significantly increased with the increase in the level of the temperature. In respect of levels of temperature, the significantly higher blast PDI was recorded in T6 (ambient + 2 °C) than the T4 (Ambient + 1 °C) and T7 (Ambient) while it was statistically at par with T5 (Ambient + 1.5 °C). The blast PDI under open field condition was significantly low over all the treatments.

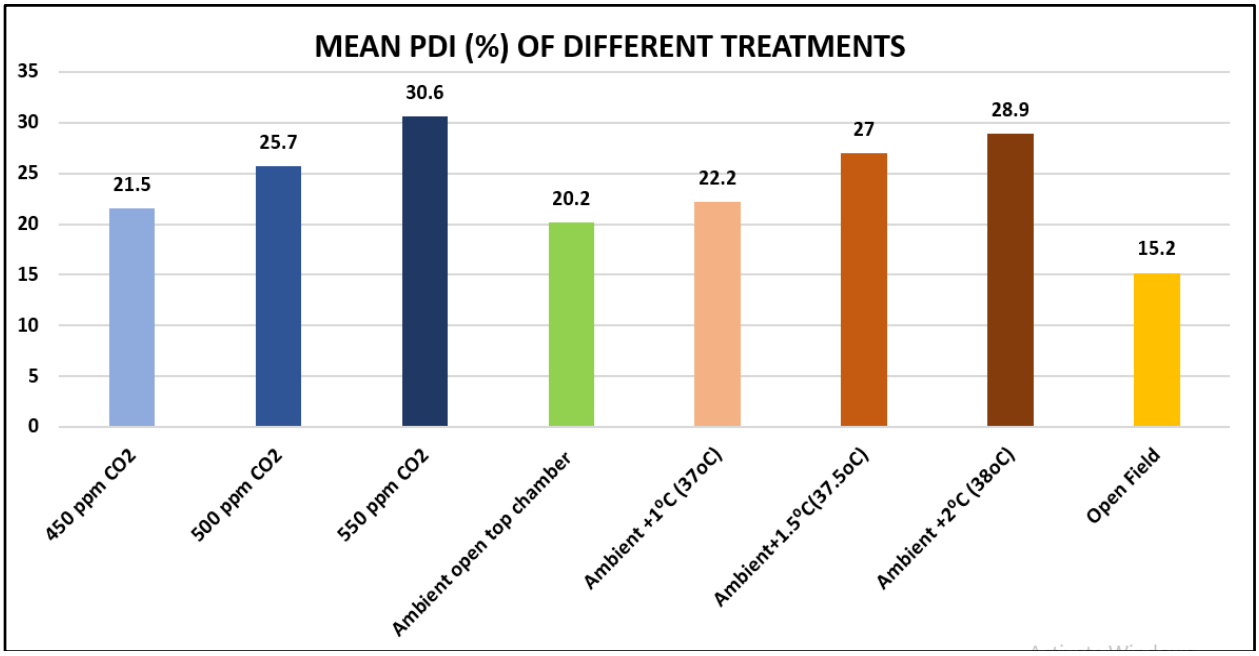

Fig 1: Graphical representation of mean PDI of different treatment.

Table 1: Effect of elevated levels of CO_2 and temperature on pearl millet blast.

Treatment Names	Percent Disease Index (PDI %)					
	R1	R2	R3	R4	MEAN	S.E.
T1:450 ppm CO_2	22.2 (28.1)	19.3 (26)	20.7 (27.1)	23.7 (29.1)	21.5 (27.6)	0.662
T2:500 ppm CO_2	25.2 (30.1)	28.1 (32)	24.4 (29.6)	25.2 (30.1)	25.7 (30.5)	0.529
T3:550 ppm CO_2	30.4 (33.4)	32.6 (34.8)	27.4 (31.6)	31.9 (34.4)	30.6 (33.5)	0.722
T4:Ambient + 1 °C (37ºC)	21.5 (27.6)	20.7 (27.1)	23.7 (29.1)	23 (28.6)	22.2 (28.1)	0.472
T5:Ambient + 1.5 °C (37.5ºC)	25.9 (30.6)	28.1 (32)	27.4 (31.6)	26.7 (31.1)	27 (31.3)	0.304
T6:Ambient + 2 °C (38ºC)	27.4 (31.6)	30.4 (33.4)	28.1 (32)	29.6 (33)	28.9 (32.5)	0.433
T7: Ambient open top chamber (36 °C/420 ppm)	20.7 (27.1)	19.3 (26)	21.5 (27.6)	19.3 (26)	20.2 (26.7)	0.388
T8: Open Field (34 °C/418 ppm)	15.6 (23.2)	14.8 (22.6)	14.1 (22)	16.3 (23.8)	15.2 (22.9)	0.381
SE(m) 0.505						
SE(d) 0.714						
C.D. 1.482						
C.V. 3.464						

*The figure given in parenthesis are angular transformed.

Discussion

It is clear from the result of present study that the pearl millet blast significantly increases with the increase in CO_2 level. From 450ppm to 550ppm. The disease also increases with the increase in temperature from ambient to ambient + 1 °C and ambient + 1 °C to ambient + 1.5 °C and ambient + 1.5 °C to ambient + 2 °C. The increase in blast severity under higher level of CO_2 and temperature may be due to the morphological changes in host leaf and silicon content which may facilitate the entry of the pathogen. These findings are consistent with the results of Kobayashi *et al.*, (2006) [4], who conducted a three-year free-air CO_2 enrichment (FACE) experiment in northern Japan. Their study revealed that elevated CO_2 significantly increased the severity of rice blast as indicated by a higher number of lesions on leaf surfaces. Increased atmospheric CO_2 may also influence plant-pathogen interactions. Lake and Wade (2009) [5] reported that elevated CO_2 not only enhanced the aggressiveness of pathogen but also induced morphological changes in host plants, such as increased stomatal density, longer guard cells, and greater trichome numbers—traits that facilitate pathogen invasion. Supporting these observations, Goria *et al.*, (2013) [3] found that disease severity in rice increased under CO_2 enrichment, reinforcing the conclusion that future atmospheric conditions may intensify the impact of blast. Given the projected rise in global CO_2 levels, these findings highlight the urgent need to reassess disease management strategies and to incorporate climate resilience into crop breeding programs. Matic *et al.*, (2021) [7], who explored the combined effects of elevated CO_2 and temperature on bakanae disease under phytotron conditions. Rice plants infected with *Fusarium fujikuroi* were grown under six regimes combining three temperature levels (low: 18/22 °C, medium: 22/26 °C, high: 26/30 °C) and two CO_2 concentrations (ambient: 450 ppm, elevated: 850 ppm). The disease index (DI) varied significantly with both CO_2 and temperature. Notably, DI values ranged from 67.5% to 95.8% under medium and high temperatures, markedly higher than those recorded under low temperatures (45.8%-47.5%), regardless of CO_2 concentration. Overall, these findings underscore the complex and synergistic effects of elevated CO_2 and rising temperatures on disease dynamics. The compounded impact of these climatic factors is likely to enhance pathogen virulence, disrupt plant defences, and escalate disease severity. This highlights the need for integrated research approaches aimed at understanding the molecular, physiological, and ecological dimensions of host-pathogen interactions under future climate scenarios. Developing resilient pearl millet cultivars and adaptive management practices will be critical to safeguarding global pearl millet production in the face of climate change.

Conclusion

This study highlights the significant influence of elevated atmospheric CO_2 and rising temperatures on the severity and progression of pearl millet diseases, particularly blast. The results confirm that increasing CO_2 concentrations exacerbate disease severity, a trend further intensified under higher temperature regimes. It is an alarm for future. The findings underscore the urgent need for proactive strategies, including the development of climate-resilient pearl millet varieties and adaptive disease management practices, to mitigate the potential threats posed by climate change on global pearl millet production and food security.

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