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Research Article

Effect of Elevated Temperature and CO_2 Concentration on Disease Incidence, Severity and Yield of Wheat, Cabbage, and Tomato

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Abstract

This study investigated the effects of elevated temperature and carbon dioxide (CO_2) on disease incidence, severity, and yield impacts in wheat (*Triticum aestivum*), cabbage (*Brassica oleracea*), and tomato (*Solanum lycopersicum*) under open-field and nethouse conditions. The pathogens evaluated included *Rhizoctonia solani*, *Sclerotium rolfsii*, *Bipolaris sorokiniana*, *Alternaria brassicae*, and *Fusarium oxysporum* f. sp. *lycopersici*. During the experimental period, maximum and minimum temperatures reached 39.3°C and 11°C in nethouse conditions compared with 37.5°C and 9°C in the open field, while CO_2 concentration was 388–395 ppm in the nethouse and 385 ppm in ambient air. Elevated CO_2 and temperature consistently increased disease incidence and severity. In wheat, sclerotium wilt showed the highest incidence (55.6%); in cabbage, both sclerotium wilt and *Alternaria* blight reached 100%; and in tomato, sclerotium wilt also caused 100% incidence. These infections were associated with significant yield reductions across all crops. To our knowledge, this is the first report from Bangladesh quantifying crop disease yield interactions under elevated temperature and CO_2, underscoring the vulnerability of key crops to climate change and the urgent need for adaptive management strategies.

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1. Introduction

Crop production in a sustainable manner is significantly affected by climate change. The climate has changed in the past ten years, resulting in fluctuations in average temperature, precipitation, and atmospheric circulation. These changes have led to an increased occurrence and intensity of extreme weather events (Rosenzweig and Parry, 1994; Stack et al., 2013; Duan et al., 2019; Holden et al., 2018; Hoque et al., 2019). Since agriculture is weather-dependent, a slight deviation in its existing condition such as rise in temperature and CO_2 concentration of the atmosphere affects agricultural yield potential as well as food security worldwide. However, Bangladesh is an agrarian country. Around 14% of the national gross domestic product (GDP) is contributed by agricultural products. Additionally, almost 43% of the population's employment and income are generated by agriculture (BBS, 2019; Clarke et al., 2015; Kashem et al., 2013; Paparrizos et al., 2020).

Among the elements of climate, temperature and CO_2 concentration of the atmosphere are very crucial for the growth and development of maximum crops. The alarming increasing rate of temperature and CO_2 concentration in the atmosphere not only hampers crop physiology and decreases the production rate but also influences plant-pathogen interactions, pathogen reproduction, dispersal, and survival. Higher CO_2 concentration and temperature in the atmosphere can enhance disease symptoms or end in the generation of new diseases of plants or make a plant host of a pathogen that was not a host of that pathogen once. Possible reasons for this occurrence may be due to change in host resistance or change in pathogen aggressiveness and fecundity (Anderson and Garlinge, 2000; Chakraborty et al., 2011; McElrone et al., 2005; Pangga et al., 2013). In the past century, the average temperature of the earth has risen by 0.74 °C, while the concentration of CO_2 in the atmosphere has increased from 280 ppm in 1750 to 368 ppm in 2000 (IPCC, 2001). The alteration of these two factors leads to the occurrence and intensity of biotic diseases caused by microorganisms, including fungus, bacteria, viruses, and insects (Pautasso et al., 2012). The temperature range of 10-40 °C is often conducive to the growth and development of fungal microorganisms, with the most favorable growth occurring within the 25-35 °C range (Magan et al., 2003). Both low and high temperatures significantly impact the metabolic activity and growth of fungus. The concurrent rise in CO_2 levels and temperature frequently enhances the generation of fungal spores and reproductive capacity beneficially (Wolf et al., 2010). The impact of climate change on plant diseases has been studied in various crops, including wheat, barley, rice, soybean, and potato (Luck et al., 2011; Bregaglio et al., 2013; Launay et al., 2014; Mikkelsen et al., 2014). It has also been evaluated in forest trees (Sturrock et al., 2011) and tropical and plantation crops (Ghini et al., 2008). In general, most of the research has been carried out on diseases of broad acre field crops (Luck et al., 2011) much less horticultural crops (Koo et al., 2016). That's why this study was undertaken to reveal the change in the disease incidence and severity of three main diseases of three winter crops, i.e., wheat, tomato and cabbage grown in Bangladesh with the change in elevated temperature and CO_2 concentration.

The objectives of this study were to assess and describe the effects of elevated CO_2 and temperature on the disease incidence and severity and plant damage by Rhizoctonia root rot (*R. solani*), Sclerotium wilt (*S. rolfsii*) and leaf blight (*B. sorokiniana*) of wheat; Alternaria leaf blight (*A. brassicae*), rhizoctonia root rot (*R. solani*), sclerotium wilt (*S. rolfsii*) of cabbage and rhizoctonia root rot (*R. solani*), sclerotium wilt (*S. rolfsii*), fusarium wilt (*F. oxysporum* f. sp. *lycopersici*) of tomato, and evaluate the effect of elevated temperature and CO_2 on the yield of wheat, tomato and cabbage grown in open air and nethouse condition. Currently, no research exists on the effects of CO_2 and temperature on the disease incidence and severity of wheat, tomato and cabbage in Bangladesh. Among the diseases of wheat, tomato and cabbage the selected three diseases of the respective crops are the most serious and prevalent; hence, we focused and reported on the effects of elevated CO_2 and temperature on the infection of these diseases in the field and nethouse condition. In this study, we mainly compared the data of disease incidence-severity as well as yield of the respective crops under ambient and elevated temperature and CO_2 environments. Since global CO_2 concentration has been steadily increasing, we need to predict the effect of CO_2 concentration and temperature elevated on plant disease development as well as on their yield in advance.

2. Materials and Methods

2.1 Collection, isolation, and preservation of the pathogens

The pathogens, including *R. solani, S. rolfsii, B. sorokiniana, A. brassicae* and *F. oxysporum* f. sp. *lycopersici* were collected, isolated, and preserved using standard methods (Mian, 1995; Briste et al., 2019; Rahman et al., 2020; Rahman et al., 2021).

2.2 Cultural characterization of the test pathogens

Following isolation, the fungi's morphological properties were examined. After seven days of incubation on potato dextrose agar (PDA) at 25°C with a 12-hour photo period under near-black light, observations on color and mycelial growth were recorded. Additionally, culture factors such as colony color, colony type, and sclerotia production were observed after seven days of incubation.

2.3 Inoculum preparation of the tested pathogen

Inoculum for the test pathogens was prepared according to standard methods outlined by Rubayet and Bhuiyan (2016), Rubayet et al. (2017), Arefin et al. (2019) and Liton et al. (2019).

2.4 Pathogenicity test

For the pathogenicity test, one-month-old seedlings of tomato, cabbage, and wheat were employed, following the procedure described by Briste et al. (2022). The pathogenicity test was replicated three times.

2.5 Design of experiments

The trial site was in the Madhupur tract at 24°09' N latitude and 90°26' E longitude with an elevation of 8.2 m above sea level, featured a shallow red-brown terrace soil type from the Madhupur tract's Salna series (Shaheed, 1984). The field experiment was structured using a Randomized Complete Block Design (RCBD) and a Completely Randomized Design (CRD) for the nethouse, with four treatments and three replications (Figure 1). Each unit plot measured 1 m × 1 m, adhering to standard row-to-row and plant-to-plant distances for individual crops.

Figure 1. Experiments under Open field and nethouse (pot) environmental conditions

2.6 Treatment of the experiments

1. Experiment of Wheat: T_1=Soil inoculated with *R. solani*, T_2= Soil inoculated with *S. rolfsii*, T_3=Seedling inoculated with *B. sorokiniana*, and T_4= Control.
2. Experiment of Cabbage: T_1=Soil inoculated with *R. solani*, T_2= Soil inoculated with *S. rolfsii*, T_3=Seedling inoculated with *A. brassicae*, and T_4= Control.
3. Experiment of Tomato: T_1=Soil inoculated with *R. solani*, T_2= Soil inoculated with *S. rolfsii*, T_3=Soil inoculated with *F. oxysporum* f. sp. *lycopersici*, and T_4= Control.

2.7 Treatments application methods

There were two types of pathogens such as soil-borne and air-borne. The prepared inocula of the soil-borne pathogens (*R. solani*, *S. rolfsii*, *F. oxysporum* f. sp. *lycopersici*) were applied 90 g/m^2 soil (Yuen et al., 1994; Rubayet and Bhuiyan, 2016). On the other hand, *B. sorokiniana* and *A. brassicae* were applied through the spraying 5×10^5 spores per ml for seedling inoculations (Zhang and Yuen, 1999; Arefin et al., 2019).

2.8 Data recording

The ambience temperature, carbon dioxide concentration, soil temperature, p^H were recorded by using digital devices (Figure 2). The disease infestation was confirmed by symptom study according to the standard procedure. After that, 12 seedlings from each wheat plot and three plants each from the cabbage, and tomato plots were uprooted randomly for assessment of rhizoctonia root rot (*R. solani*), sclerotium wilt (*S. rolfsii*), leaf blight (*B. sorokiniana*), alternaria leaf blight (*A. brassicae*), and fusarium wilt (*F. oxysporum* f. sp. *lycopersici*) disease incidence and severity. The rhizoctonia root rot (*R. solani*), sclerotium wilt (*S. rolfsii*), fusarium wilt (*F. oxysporum* f. sp. *lycopersici*), alternaria leaf blight (*A. brassicae*), and leaf blight (*B. sorokiniana*) disease were graded 0-4 scale (Chandran et al., 2021), 1-6 scale (Le et al., 2012), 1-6 scale (Bayoumi & El-Bramawy, 2007), 0-5 scale (Madhu Kiran & Thara, 2018), and 0-9 scale (Mujeeb-Kazi et al., 1996), respectively (Table 1).

Table 1. Disease scale of Rhizoctonia root rot, Sclerotium wilt, Fusarium wilt, Alternaria leaf blight and leaf blight diseases of wheat, cabbage and tomato

Disease scale	Rhizoctonia root rot 0-4 scale	Sclerotium wilt 1-6 scale	Fusarium wilt (% wilting) 1-6 scale	Alternaria leaf blight (% infestation) 0-5 scale	Leaf blight (% infestation) 0-9 scale
0	No infection on roots		-	No infection on leaves	0
1	Very few small lesions on roots	No symptoms	0	<5	10
2	Lesions on roots	Water-soaked gray color lesions present on stem at collar region of stem	1-10	5-10	20
3	More lesion on roots	White color fungal mycelia or sclerotia at the collar region of stem	11-20	10-25	30
4	Roots infected and completely discolored	Wilting partially	21-30	25-50	40
5	-	Wilting completely	31-50	>50	50
6	-	Pre-emergence mortality and seed rot	>50	-	60
7	-	-	-	-	70
8	-	-	-	-	80
9	-	-	-	-	90

Finally, disease incidence (DI), percent disease index (PDI), and yield were computed, drawing upon the methods outlined by Rahman et al. (2013) and Razaq et al. (2015).

A B

Figure 2. Digital measuring devices: (A) Carbon dioxide and temperature (B) Soil pH

3. Results

3.1 Isolation and characterization of the test pathogens

The isolates of *R. solani, S. rolfsii, F. oxysporum* f. sp. *lycopersici, B. sorokiniana,* and *A. brassicae* were systematically collected from diverse crop fields located in Gazipur district, Bangladesh. A rigorous sampling approach was employed to ensure representation from different agricultural settings in the region. To authenticate the identity of these test pathogens, a comprehensive analysis was conducted based on morphological and microscopic observations, adhering to the established protocol detailed by Barnett and Hunter in 1972. This methodological approach ensures the accurate identification and confirmation of the collected isolates, forming a crucial foundation for subsequent analyses and experimentation in the study of these pathogens (Table 2 and Figure 3).

Table 2. Cultural characteristics of the test pathogens

Source Crops	Locations	Isolates	Colony colors and types
Wheat	BSMRAU	*R. solani*	Brownish and compact
	BSMRAU	*S. rolfsii*	Whitish, radiate and fluffy
	BSMRAU	*B. sorokiniana*	Blackish fluffy growth
Cabbage	BSMRAU	*R. solani*	Brownish and compact
	BSMRAU	*S. rolfsii*	Whitish, radiate and fluffy
	BSMRAU	*F. oxysporum* f. sp. *lycopersici*	Whitish fluffy growth
Tomato	BSMRAU	*R. solani*	Brownish and compact
	BSMRAU	*S. rolfsii*	Whitish, radiate and fluffy
	BSMRAU	*A. brassicae*	Olivaceous black and smooth

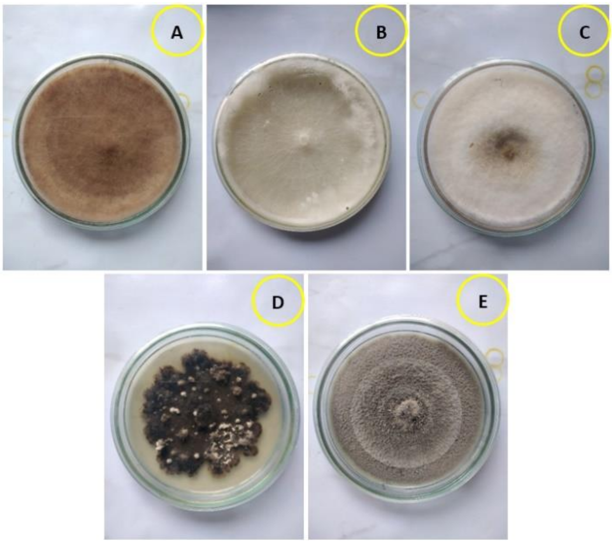

Figure 3. Cultural characteristics of R. solani (A), S. rolfsii (B), F. oxysporum f. sp. lycopersici (C) B. sorokiniana (D), and A. brassicae (E) in PDA medium.

3.2 Pathogenicity test

The pathogenicity test of the individual pathogen against their crop was conducted and confirmed by re-isolation. Every pathogen was shown their maximum severity regarding their crops. After confirmation through the pathogenicity, these pathogens were used for field and nethouse experiments.

3.3 Weather conditions during experimental period

The environmental condition was different in nethouse and open field during the experimentation. Generally, the carbon dioxide concentration and temperature were higher in nethouse than the open atmosphere. The highest temperature in open air was 37.5°C and lowest 9°C but carbon dioxide concentration was almost constant (385 ppm). On the contrary, in nethouse carbon dioxide concentration was 388-395 ppm and maximum and minimum temperature were 39.3°C and 11 °C, respectively. The pH of the soil was almost neutral in both cases.

3.4 Effect of temperature and carbon dioxide on wheat diseases

The rhizoctonia root rot, and sclerotium wilt of wheat diseases were severely affected by temperature and carbon dioxide in the nethouse as compared to open field conditions. However, elevated temperature and CO_2 had no effect on the symptom production by *Bipolaris sorokiniana* as there was no symptom produced by the fungus in both open air and nethouse conditions. The rhizoctonia root rot, and sclerotium wilt disease incidence were 44.44% and 42.22%, and 55.56% and 46.67%, respectively under nethouse and open field conditions. Similarly, 56.67% and 47.78%, and 73.33% and 53.89% diseases severity were recorded from the same conditions of this crop (Table 3). Among these wheat diseases under the opted environment, sclerotium wilt/southern blight severity was the highest (Figure 4 and Figure 8).

Table 3. Effect of temperature and CO_2 concentration on wheat disease incidence and severity

Conditions	% Disease Incidence (DI)				Percent Disease Index (PDI)			
	RRR	SW	LB	C	RRR	SW	LB	C
Open field	42.22	46.67	0.00	0.00	47.78	53.89	0.00	0.00
Nethouse	44.44	55.56	0.00	0.00	56.67	73.33	0.00	0.00

RRR= Rhizoctonia Root Rot, SW= Sclerotium Wilt, LB= Leaf Blight, C= Control.

Figure 4. Pre-emergence damping-off of wheat in nethouse due to presence of R. solani (A), S. rolfsii (B)

3.5 Natural disease incidence and severity

In the open field of wheat experiment, the total number of plots were infected just before ripening stage with yellow/stripe leaf rust disease. It is caused by *Puccinia striiformis* f. sp. *tritici*. The disease incidence and severity were 100%, respectively (Figure 5).

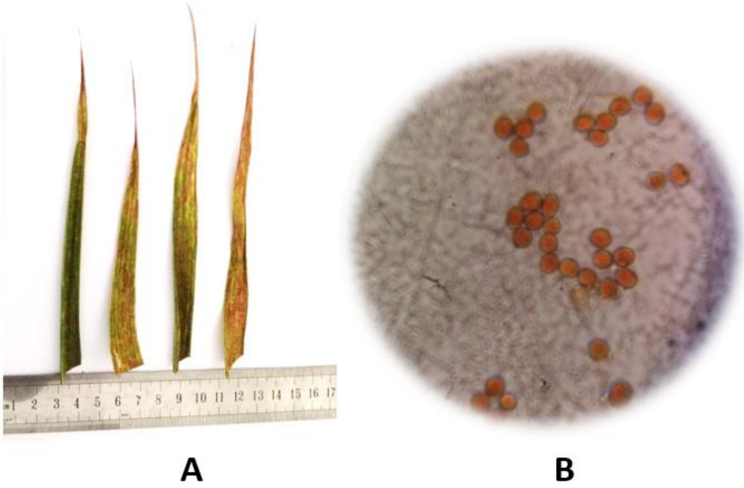

Figure 5. (A) Yellow rust disease severity on wheat leaf (B) Uredospore of P. striiformis f. sp. tritici under microscope

3.6 Effect of temperature and carbon dioxide on cabbage diseases

Temperature and carbon dioxide in the nethouse had a significant impact on cabbage diseases such as rhizoctonia root rot, sclerotium wilt, and alternaria leaf blight when compared to open field conditions. The rhizoctonia root rot, sclerotium wilt, and alternaria leaf blight disease incidence was 88.89% and 83.33%, 100.00%, and 91.67%, and 100.00% and 100.00%, respectively under nethouse and open field. Under the same conditions of this crop 93.33% and 89.89%, 96.67% and 93.89%, and 98.33% and 96.67% diseases severities were documented (Table 4). Among these cabbage diseases under the selected environment, alternaria leaf blight severity was the highest followed by sclerotium wilt in nethouse (Figure 6 and Figure 8).

Table 4. Effect of temperature and CO_2 concentration on cabbage disease incidence and severity

Conditions	% Disease Incidence (DI)				Percent Disease Index (PDI)			
	RRR	SW	ALB	C	RRR	SW	ALB	C
Open field	83.33	91.67	100.00	41.67	88.89	93.89	96.67	13.33
Nethouse	88.89	100.00	100.00	0.00	93.33	96.67	98.33	0.00

RRR= Rhizoctonia Root Rot, SW= Sclerotium Wilt, ALB= Alternaria Leaf Blight, C= Control.

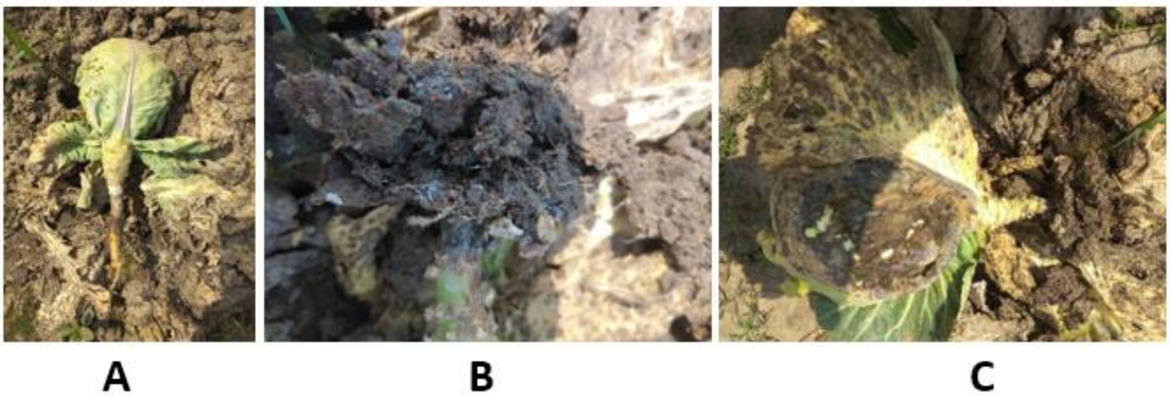

Figure 6. Rhizoctonia root rot (A), Sclerotium wilt (B), Alternaria leaf blight (C) diseases of cabbage in open field before harvesting period.

3.7 Effect of temperature and carbon dioxide on tomato diseases

Temperature and carbon dioxide in the nethouse had a greater influence on tomato diseases such as rhizoctonia root rot, sclerotium wilt, and fusarium wilt than in open field. The rhizoctonia root rot, sclerotium wilt, and fusarium wilt disease incidence were 66.67 and 50.00%, 100.00 and 91.67%, and 33.33 and 25.00%, respectively under nethouse and open field. At the same time the diseases severities were 80.00 and 58.89%, 95.00 and 95.00%, and 46.67 and 32.78%, respectively found from the same conditions of this crop (Table 5). Among these tomato diseases sclerotium wilt/southern blight severity was the highest in nethouse environment (Figure 7 and Figure 8).

Table 5. Effect of temperature and CO_2 concentration on tomato disease incidence and severity

Conditions	% Disease Incidence (DI)				Percent Disease Index (PDI)			
	RRR	SW	FW	C	RRR	SW	FW	C
Open field	50.00	91.67	25.00	8.33	58.89	95.00	32.78	13.33
Nethouse	66.67	100.00	33.33	11.11	80.00	95.00	46.67	16.67

RRR= Rhizoctonia Root Rot, SW= Sclerotium Wilt, FW= Fusarium Wilt, C= Control.

Figure 7. Rhizoctonia root rot (A), Sclerotium wilt (B), Fusarium wilt (C) disease of tomato in open field before harvesting period

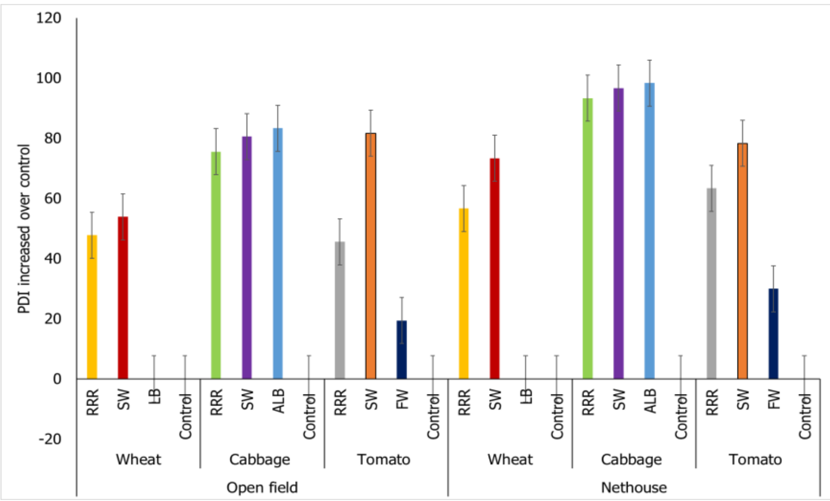

Figure 8. Percent disease increased against the individual control plot of wheat, cabbage, and tomato under open field and nethouse

3.8 Effect of temperature and carbon dioxide on wheat, cabbage, and tomato yield

Environmental variation had a substantial impact on the yield production of wheat, cabbage, and tomato. The yield production was reduced due to disease infestation under congenial environment. Not only declined the yield but quality of the yield component also deteriorated. The highest yield of wheat was 4.33 t/ha in uninoculated fields, whereas 3 t/ha yield was obtained from *S. rolfsii* (Sclerotium wilt) inoculated plot. In cabbage experiment, there was 70 t/ha yield production found in control plot and *S. rolfsii* (sclerotium wilt) and *A. brassicae* (alternaria leaf blight) inoculated plots were reduced by around 30 t/ha than control plot. Yield quantity was statistically the same in *S. rolfsii* (Sclerotium wilt) and *A. brassicae* (Alternaria leaf blight) inoculated plots. However, Sclerotium wilt/southern blight (*S. rolfsii*) was the most devastating disease in tomato field. As a result, yield decreased by 18 t/ha than the control plot. But the fusarium wilt was comparatively less affected yield production of tomato during that time (Table 6 and Figure 9).

Table 6. Effect of different plant diseases on wheat, cabbage and tomato's yield under open air

Crop	Disease	Yield (t/ha)
Wheat	Rhizoctonia root rot (*R. solani*)	3.23
	Sclerotium wilt (*S. rolfsii*)	3.00
	Leaf blight (*B. sorokiniana*)	3.50
	Control	4.33
Cabbage	Rhizoctonia root rot (*R. solani*)	50.67
	Sclerotium wilt (*S. rolfsii*)	40.00
	Alternaria leaf blight (*A. brassicae*)	40.00
	Control	70.00
Tomato	Rhizoctonia root rot (*R. solani*)	40.00
	Sclerotium wilt (*S. rolfsii*)	32.00
	Fusarium wilt (*F. oxysporum* f. sp. *lycopersici*)	47.33
	Control	50.00

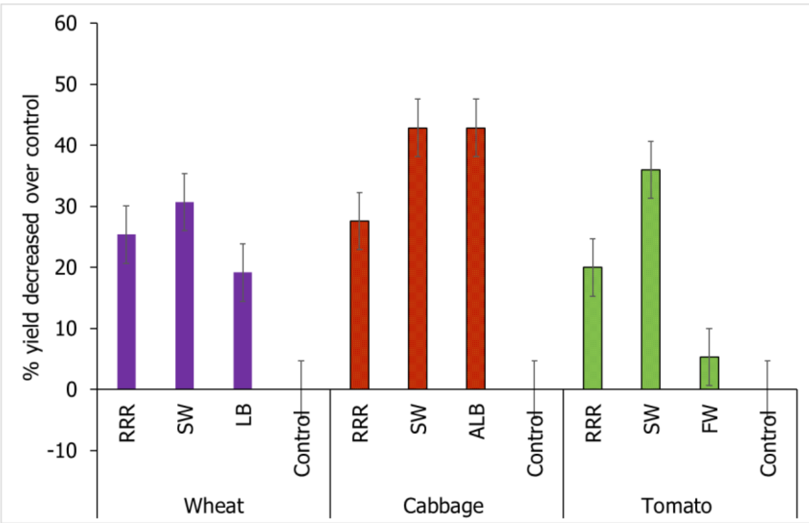

Figure 9. Percent decrease in wheat, cabbage, and tomato yield over control under open air

3.9 Discussion

This study demonstrated the relationship between the enhancement of disease incidence and severity of some crucial diseases of wheat, cabbage and tomato with changing temperature and

CO_2 concentration. Change in temperature and CO_2 concentration of the atmosphere has a negative impact on agriculture. Plant disease incidence and severity may increase, decrease, or remain unchanged with the changing climatic condition (Manning and von Tiedemann, 1995). That's why studies which reveal the changing status of these two elements in the atmosphere and their effect on different pathosystem are needed. Because they can provide us with useful data which can be used to draw better scenario for any disease in the existing situation and will help in developing sustainable management practices for the diseases that get worsen with the changing status of temperature and CO_2 in the atmosphere (Gullino et al., 2018; Juroszek and von Tiedemann, 2011).

Limited research has been conducted to explore the effects of elevated temperature and increased CO_2 concentration on the severity and incidence of crop diseases. Previous studies by Loustau et al. (2007), Ingram et al. (2008), Luck et al. (2011), and Pautasso et al. (2012) have predominantly focused on field crops such as wheat, rice, soybean, and potato. Furthermore, investigations have extended to oil crops and forest trees, utilizing available data to project potential impacts on these crops (Gullino et al., 2018). Very few studies have been carried out in which the effect of increasing temperature was combined with rising CO_2 levels (Gullino et al., 2018). That's why we conducted this research to incorporate data of both temperature and CO_2 concentrations to find out their effect on the disease incidence and severity of some crucial diseases of wheat, cabbage, and tomato. We also wanted to predict what the scenario would be if the temperature and CO_2 concentration rise from its existing condition. To do this, we planted the same crops in open air and in glass house conditions. And compared the data that we generated and pointed on the yield condition of the selected crops under the changing climatic condition.

In our study, we found that among the three crucial diseases of wheat; except Bipolaris leaf spot the rest of the two were severely affected by the change in temperature and CO_2 of their surrounding environment. While growing in the net house, where there were increased temperature and CO_2, sclerotium wilt disease showed higher disease incidence and severity compared to rhizoctonia wilt disease and open-air condition. It is found in several studies that global warming would not only enhance the above-ground wheat pathogens but also favor the economically significant soil-borne diseases caused by *Rhizoctonia* sp., *Sclerotium* sp., *Phoma* sp., *Fusarium* sp., *Alternaria* sp. etc. (Delgado-Baquerizo et al., 2020; Pokhrel, 2021). It was speculated by some scientists that elevated CO_2 has positive influence in the development of wheat diseases and increasing the disease incidence and severity of numerous wheat diseases (Oehme et al., 2012; Pokhrel, 2021). The reason was assumed that higher the CO_2 in the environment higher the penetration of light in the wheat canopy affects the structure of the plant canopy and the microclimate environment (Sikma et al., 2020). In return, the altered canopy structure and microclimate will change the morphology and physiology of the host ultimately changes the disease epidemiology (Oehme et al., 2012; Pokhrel, 2021).

In our study we reported that there was crucial link between the elevation of temperature and CO_2 concentration with the enhancement of disease incidence and severity of cabbage diseases. Both in open air and glasshouse condition Alternaria leaf blight showed 100% disease incidence and severity followed by sclerotium wilt. Our findings were like the findings of earlier studies where it was found that Alternaria disease severity was significantly influenced by the environmental conditions particularly with rising temperature and CO_2 (Gullino et al., 2018; Pokhrel, 2021; Pugliese et al., 2012; Siciliano et al., 2017). Tomato plants were vulnerable to all the test fungi in raised temperature and CO_2 concentration in our study. Among the diseases of tomato, sclerotium wilt was mostly affected by the rise in atmospheric temperature and CO_2 concentration. Several lines of evidence suggested that elevated temperature and CO_2 of the atmosphere have serious consequences on the disease incidence and severity of tomato diseases (Jwa and Walling, 2001; Zhang et al., 2015).

In our findings we observed that the yield of the crops, i.e., wheat, cabbage and tomato were reduced in nethouse conditions compared to the open-air condition. The results explain that the raised temperature and CO_2 of the atmosphere not only affect the disease incidence and severity of crops but also reduces their yield drastically. In several studies it was reported that increasing CO_2 concentration may help in the increase of yield of cereal crops, by changing plant metabolism, growth and physiological processes of photosynthesis (Jwa and Walling, 2001; Li et al., 2015). But in addition to increasing temperature with elevated CO_2 helps in reducing the yield and its quality as well. Temperature has serious impact on the yield of wheat, cabbage and tomato. Our results are like the findings of the previous reports. Some authors reported that elevated temperatures have conspicuous effect on photosynthesis, growth, development, number of grains and ultimately yield of wheat; it was also reported that 0.5° C increase in winter temperature would reduce wheat yield by 0.45 ton/ha. (Abou-Hussein, 2012; Aggarwal and Rani, 2009; Castro et al., 2007; Ortiz et al., 2008; Pushpalatha et al., 2008). Numerous studies reported that tomato and cabbage are extremely sensitive to high temperatures during the reproductive phase and if they face heat stress at flowering stage there will be lower dry matter content and ultimately the quality of the yield is deteriorated (Abou-Hussein, 2012; Ebert et al., 2017). In our study similar scenario was observed; where higher temperature not only increased the disease incidence and severity of the respective crops but also the decrease of yield was outrageous. However, further study is needed to ensure an effective yet sustainable management strategy against the diseases of plants growing under the changing climatic condition not only to decrease the disease rate but also to increase the yield of the crops.

4. Conclusion

The findings of this study suggest a positive correlation between carbon dioxide levels and temperature, contributing to increased disease incidence and severity in significant wheat, cabbage, and tomato diseases. This positive relationship ultimately results in decreased crop yields. Notably, Sclerotium for wheat, Alternaria for cabbage, and certain pathogens for tomato emerged as crucial factors significantly influencing disease incidence and severity in their respective crops. To the best of our knowledge, this study represents a pioneering effort in investigating the impact of elevated temperature and CO_2 on the occurrence and severity of key diseases in wheat, cabbage, and tomato.

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