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Interactive Effect of Elevated CO_2 and Temperature on the Incidence of Brown Spot and Sheath Blight of Rice (*Oryza sativa* L.)

S.K. Dwivedi, S. Kumar, Rahul Kumar*, Ved Prakash, K.K. Rao, S.K. Samal, Shikha Yadav, Kundan Kumar Jaiswal, Shiv Shankar Kumar, Basant Kumar Sharma and J.S. Mishra

ICAR-Research Complex for Eastern Region Patna- (Bihar)-800014, India
**Corresponding author*

A B S T R A C T

Simultaneous increase of (CO_2) and temperature causing significant changes in rice crop growth and productivity, but limited studies has been done in past to examine the interactive effect of these two key variables on the incidence of brown spot and sheath blight of rice. Thus, an experiment was conducted at ICAR Research Complex for Eastern Region, Patna, by growing rice genotypes (Rajendra bhagwati, IR83376-B-B-24-2, IR 64 and IR84895-B-127-CRA-5-1-1) inside open top chambers (OTCs) and open field condition with two levels of carbon dioxide (ambient and elevated; 500±25 ppm) and temperature (ambient and ambient+2°C) during *kharif* season of 2016 in order to determine their simultaneous effect on incidence of brown spot and sheath blight. One hour averages of CO_2 in the elevated CO_2 OTC ranged between 455 and 510 ppm with a mean of 482 ppm and a standard deviation (S.D.) of 12.7ppm. LAI of the elevated CO_2 treatment was significantly ($p<0.05$) greater than the control OTC and open field at all times in both *kharif* seasons. Brown spot (*Helminthosporium oryzae*) and Sheath blight (*Rhizoctonia solani*) the disease incidence was observed at physiological maturity stage in *kharif* season during 2016. The effects of disease on yield contributing characters were also observed. The incidence of brown spot ranged from 24.91 to 51.25 % and highly susceptible variety was observed IR-64. The disease incidence of sheath blight of paddy ranged from 34.33 to 47.08 % and highly susceptible variety was observed Rajendra bhagwati. It was observed that disease incidence was gradually increased from flowering stage to maturity stage with the age of the plant and minimum incidence gave the maximum yield.

Keywords

Rice, kharif, OTC, Rice variety and disease.

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Introduction

Rice (*Oryza sativa* L.) is cultivated under diverse ecologies, ranging from irrigated to rain-fed and upland to lowland and deep water system (Kumar *et al.*, 2014). Globally, more than 3 billion people have rice as staple food, and it accounts for 50 to 80 per cent of their daily calorie intake (Delseny *et al.*, 2001). Rice is successfully grown from sea level to about 2000 m altitude and from humid areas in eastern India to dry but irrigated areas of Punjab, Haryana, western Utter Pradesh and northern Rajasthan.

CO_2 and temperature are most important environmental variables that regulate physiological and phenological phases in plants and changes in ambient CO_2 and temperature are likely to occur concomitantly, it is of particular interest to quantify the effect of interactions of these two climate variables on crop (Prakash *et al.,* 2017; Dwivedi *et al.*, 2015 and 2016; Morison and Lawlor, 1999). Plant diseases are one of the important factors which have a direct impact on global agricultural productivity and climate change will further aggravate the situation (IPCC, 2007).

Disease risk analyses based on host–pathogen interactions should be performed, and research on host response and adaptation should be conducted to understand how an imminent change in the climate could affect plant diseases. In Asia, 14.2 per cent of the potential production costing about US$ 43.8 billion is lost due to diseases (Oerke, 1994). Climate models predict a gradual rise in CO_2 concentration and temperature all over the world, but are not precise in predicting future changes in local weather conditions.

Generally rice crop is suffered by more than 17 diseases and certain diseases are more common on rice varieties than on conventional varieties. Among the different diseases brown spot, sheath blight, blast, stem rot and bacterial leaf blight are considered important disease at various parts of rice growing areas of the world. Sheath blight is an important soil borne disease caused by *Rhizoctonia solani* that can cause up to 25 per cent yield loss (Kumar *et al.*, 2009). Brown spot of rice caused by *Helminthosporium oryzae* can reduce crop yield by up to 40 per cent. Brown spot disease of rice is also known as poor disease.

Therefore, present study was undertaken to determine the interactive effect of elevated temperature and carbon dioxide on rice brown spot and sheath blight disease tolerance attributes in four rice genotypes.

Materials and Methods

Field experiment

This study was conducted in the experimental farm of ICAR Research Complex for Eastern Region, Patna located at 25°35’37" N latitude and85°05’ E longitude and at an altitude of 51.8 m above mean sea level during 2016-17. The land area of open-top chambers (OTCs) had a fairly level topography.

The climate of the experimental site is semi-arid with dry hot summer and mild winters. The soil at the experimental site belongs to the major group of Indo-Gangetic alluvium (Table 1).

Planting material

Seeds of four genotypes of rice namely Rajendra bhagwati, IR-64, IR83376-B-B-24-2 and IR84895-B-127-CRA-5-1-1 were grown inside open top chambers. The field soil inside the OTCs was dry ploughed and levelled but not puddled during land preparation. Twenty one days old seedlings from wet bed nursery were transplanted at the rate of one seedling per hill at a spacing of 20 cm x 15 cm in plots. In each plot a uniform plant stand was maintained and standard agronomic practices were followed for raising and maintenance of plants. Plots were fertilized at the rate of 100:60:40 kg N:P:K ha^{-1}. Nitrogen was applied on three occasions (1/3each at transplanting as basal, at active tillering and panicle initiation), while the P_2O_5 and K_2O were applied as basal application. The experimental plots were kept weed free by hand weeding.

CO_2 and temperature treatments

Rice genotypes were exposed to different levels of temperature and CO_2 in different combinations in open top chambers (OTCs) starting from sowing up to harvesting stage. The OTCs used in the study were of cylindrical shape, fabricated with galvanized iron (GI) pipe and fixed in the field. The fabricated sides of structures were covered with polyvinyl chloride (PVC) sheet having more than 90% light transmittance to ensure that light intensity could not be a limiting factor for the growth of rice crop.

All the OTCs were equipped with humidity, temperature and (CO_2) sensors. Pure (CO_2) (99.7%, v/v (CO_2) and less than 10 ppm CO) was released from a commercial grade cylinder fitted with a regulator. The carbon dioxide concentration of the air within the elevated (CO_2) chambers was maintained around the target concentration by a PC-based real-time data acquisition and control (DAC) system designed based on the principles described in Collins *et al*., (1995). The air sample from the middle of the chamber was drawn periodically into a (CO_2) sensor (*NDIR*, *make Topak*, USA) to monitor the (CO_2) concentration.

The set level of (CO_2) was maintained with the help of solenoid valves which were controlled by Program Logic Control (PLC) and Supervisory Control and Data Acquisition (SCADA) system running win log software (SELCO, Italy). A data logger recorded the mean (CO_2) within all chambers at 15-min intervals. The (CO_2) supply was switched on and temperature was maintained only during the daylight hours (i.e. from 09:00 to 17:00-h). In the OTCs with elevated temperature, reference temperature was obtained from the control OTC and air temperature was increased 2^oC above ambient chamber by infra red (IR) heating tubes, and controlled by the SCADA system. The chambers were washed regularly with a gentle stream of water to remove the dust and to maintain transparency.

Assessment of the disease incidence

Each plot was visited on regular basis for recording the incidence. The disease incidence was recorded in the maturity stages of the plant. Data were recorded visually by observing the symptoms.

Ten plants were randomly selected from each unit plot and the following parameters were considered for data collection-

Number of tillers / plants
Number diseased tillers / plants
Percent leaf area diseased (LAD)
Disease incidence was calculated by the following formula (Rajput and Bartaria, 1995):

Disease incidence = Number of diseased tillers/
Total number of inspected tillers x 100

Isolation and identification of causal organism

The symptomatic leaves from the diseased plants were collected from the field and cut into small pieces along with healthy portion. Cut pieces were sterilized by the surface disinfectants e.g. 0.1% mercuric chloride for 30 seconds. After sterilization the cut pieces were washed three times with sterile water. The cut pieces were then placed on sterile blotter paper to remove excess water. The cut pieces were then placed on the Potato Dextrose Agar plate. The plate were labelled and placed in the incubation chamber for 7 days at $25 + 2^o$ C. After 7 days of incubation, the fungi grown on culture media. A portion of culture was taken on slide and observed under microscope and identified the pathogenic fungi *i.e. Helminthosporium oryzae*, *Rhizoctonia solani*, with the help of relevant literature (Mew and Gonzales, 2002; Barnet and Hunter, 1972). The pathogen, thus purified, was kept in refrigerator for future use. All these operations were done aseptically in the laminar air flow chamber.

Analysis of data

The data on different characters were subjected to estimates of ANOVA (analysis of variance) by using statistical software OPSTAT.

Results and Discussion

Daily maximum and minimum temperatures, maximum and minimum relative humidity, daily rainfall were recorded from the meteorological observatory of the ICAR Research Complex, Patna (Fig. 1). Mean daily maximum and minimum temperatures and relative humidity (RH) inside the OTC were recorded.

Disease assessment of brown spot

Maximum disease incidence was observed in rice variety IR-64 51.25 per cent followed by Rajendra bhagwati 37.08 per cent and minimum disease incidence was observed in IR84895-B-127-CRA-5-1-1 24.91 per cent followed by IR83376-B-B-24-2 27.25 per cent. Maximum disease incidence was observed in open top chamber OTC_3 40.08 per cent followed by OTC_4 36.41 per cent and minimum disease incidence was observed in OTC_1 30.91 per cent followed by OTC_2 33.08 per cent.

Disease assessment of sheath blight

Maximum disease incidence was observed in rice variety Rajendra bhagwati 47.08 per cent followed by IR-64 37.25 per cent and minimum disease incidence was observed in IR84895-B-127-CRA-5-1-1 34.33 per cent followed by IR83376-B-B-24-2 35.91 per cent. Maximum disease incidence was observed in open top chamber OTC_3 43.91 per cent followed by OTC_4 42.41 per cent and minimum disease incidence was observed in OTC_1 31.58 per cent followed by OTC_2 36.66 per cent.

Table.1 Soil characteristic of experimental site

Sand (%)	Silt (%)	Clay (%)	Organic carbon (%)	Soil pH	BD (mg m^3)	EC (dSm^{-1})	Nitrogen ($kgha^{-1}$)	Phosphorus ($kgha^{-1}$)	Potassium ($kgha^{-1}$)
29.5	41.5	28.0	0.67	7.3	1.45	0.26	237	27.0	203.2

Table.2 Description of treatment combinations

Treatments	Description
OTC_1	Ambient Condition
OTC_2	25 % higher CO_2 than ambient
OTC_3	25 % higher $CO_{2\ +}$ 2^0 C> ambient temperature
OTC_4	2^0 C> ambient temperature

Table.3 Disease severity scale of brown leaf spot and sheath blight

Name of diseases	Scale
Brown Spot	1 = No incidence
	2 = Less than 1%
	3 = 1-3%
	4 = 4-5%
	5 = 11-15%
	6 = 16-25%
	7 = 26-50%
	8 = 51-75%
	9 = 76-100%
Sheath Blight	0 = No infection observed
	1 = Lesions limited to lower 20% of the plant height
	3 = 20-30%
	5 = 31-45%
	7 = 46-65%
	9 = More than 65%

Table.4 Incidence of brown spot of paddy

Treatment	OTC_1	OTC_2	OTC_3	OTC_4	Mean (V)
Rajendra Bhagwati	32.33	36.33	42.00	37.66	37.08
IR-64	46.66	50.00	55.33	53.00	51.25
IR83376-B-B-24-2	22.66	25.00	32.33	29.00	27.25
IR84895-B-127-CRA-5-1-1	22.00	21.00	30.66	26.00	24.91
Mean (O)	30.91	33.08	40.08	36.41	
Factors	C.D.	SE(d)	SE(m)		
Factor (V)	2.16	1.05	0.74		
Factor (O)	2.16	1.05	0.74		
Factor (V X O)	NS	2.11	1.49		

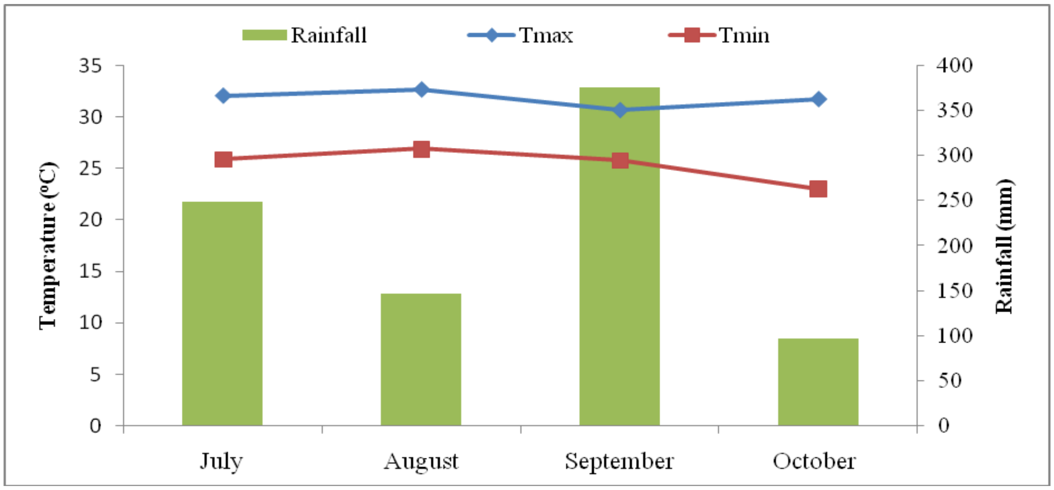
Table.5 Incidence of sheath blight of paddy

Treatment	OTC_1	OTC_2	OTC_3	OTC_4	Mean (V)
Rajendra Bhagwati	38.00	42.33	55.33	52.66	47.08
IR-64	31.00	35.33	42.33	40.33	37.25
IR83376-B-B-24-2	29.33	35.33	40.00	39.00	35.91
IR84895-B-127-CRA-5-1-1	28.00	33.66	38.00	37.66	34.33
Mean (O)	31.58	36.66	43.91	42.41	
Factors	C.D.	SE(d)	SE(m)		
Factor (V)	1.97	0.96	0.68		
Factor (O)	1.97	0.96	0.68		
Factor (V X O)	NS	1.92	1.36		

Table.6 Test weight of rice in different treatments under OTC conditions

Treatment	OTC_1	OTC_2	OTC_3	OTC_4	Mean (V) g
Rajendra Bhagwati	26.47	29.77	28.13	24.98	27.34
IR-64	25.63	27.65	22.49	24.04	24.95
IR83376-B-B-24-2	28.54	25.79	26.99	25.36	26.67
IR84895-B-127-CRA-5-1-1	25.91	28.50	27.27	25.73	26.85
Mean (O)	26.63	27.93	26.22	25.03	
Factors	C.D.	SE(d)	SE(m)		
Factor (V)	1.24	0.60	0.42		
Factor (O)	1.24	0.60	0.42		
Factor (V X O)	2.49	1.21	0.85		

Fig.1 Weather conditions during the period of study at experimental site



Test weight of rice

Maximum test weight was observed in rice variety Rajendra bhagwati 27.34 g followed by IR84895-B-127-CRA-5-1-1 26.85 g and minimum test weight was observed in IR-64 24.95 g followed by IR83376-B-B-24-2. Maximum test weight was observed in open top chamber OTC_2 27.93 g followed by OTC_1. 26.63 g and minimum test weight was observed in OTC_4 25.03 g followed by OTC_3 26.22 g.

Research over the past few years suggests that the most likely impact of elevated (CO_2) on plant disease epidemics would be mediated through changes in the host physiology and morphology. Results of the study indicate that exposure to elevated temperature enhanced the progress of disease in both genotypes as compared to elevated CO_2 exposure. Boland *et al.*, (2004) also reported that stress of drier and warmer growing conditions increases the severity of different diseases of maize caused by fungi with necrotrophic mode of nutrition as recorded in case of common smut caused by *Ustilago maydis*, Fusarium ear rot caused by *Fusarium* spp. and Stewart's disease caused by *Erwinia stewartii*. Infection rate of powdery mildew was low in barley plants grown in 700 ppm CO2 concentration as reported by Hibberd *et al.*, (1996). Contrary to these, Kobayashi *et al.,* (2006) found increased incidence of rice sheath blight caused by *Rhizoctonia solani* (necrotrophic) at the CO_2 concentration of 280 ppm higher than ambient CO2 level. Sharma *et al.*, (2007) reported increased severity of necrotrophic fungus *Cochliobolus sativus* causing spot blotch in wheat under high night temperature, especially in March (30–35^{o}C, averaged over 6 years), when evaluated over a 6 year period.

In conclusion all four varieties were noticed as susceptible against brown spot and sheath blight disease. For brown spot, the highest incidence was recorded on IR-64, whereas the lowest incidence was observed on IR84895-B-127-CRA-5-1-1. But in case of sheath blight, the highest incidence was recorded on Rajendra bhagwati whereas the lowest incidence was observed on IR84895-B-127-CRA-5-1-1. There has been only limited research on impact of climate change on plant diseases under field conditions or disease management under climate change. Such kinds of study, will provide a new sight to crop improvement programme for the development of more resilient rice varieties for the geo-graphical region where rice is the major food crop and highly vulnerable to changing climatic conditions.

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