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Effect of elevated temperature and carbon dioxide levels on maydis leaf blight disease tolerance attributes in maize

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ABSTRACT

In the present study, effect of elevated temperature and CO_2 levels was assessed on maydis leaf blight (MLB) disease tolerance attributes of two maize genotypes PEHM 5 (moderately resistant) and CM 119 (highly susceptible). The maize genotypes were exposed to two CO_2 levels: ambient (400 ppm) and elevated (550 ± 20 ppm) and three temperature levels: ambient, 1.5 °C higher than ambient and 3 °C higher than ambient temperature throughout crop growth periods. Disease severity in CM 119 was higher than PEHM 5 in all treatments. The disease severity increased when temperature was increased 3 °C higher than ambient temperature, but effect of temperature was subsided when CO_2 concentration was increased from ambient to 550 ppm level. Maximum (76.5% and 95.4%) and minimum (61.7% and 78.7%) disease severity in PEHM 5 and CM 119 was observed in 3 °C elevated temperature and ambient CO_2 level; and ambient temperature and elevated CO_2 level, respectively. Six disease stress tolerance attributes were calculated based on yield under diseased (Ys) and without disease condition (Yp). Both Ys and Yp were positively correlated with disease stress tolerance index (DSTI), mean productivity (MP) and geometric mean productivity (GMP) and negatively correlated with disease tolerance (TOL) and disease stress susceptibility index (DSSI). Results showed that with the increase in ambient temperature, severity of MLB disease is likely to increase in future.

1. Introduction

Global food production has to increase by 50% to meet the projected demand of the world's population by 2050 (Chakraborty and Newton, 2011), but due to effect of climate change the production is going to be affected severely (Sakschewski et al., 2014). Recent studies have shown that global atmospheric carbon dioxide (CO_2) concentration has increased by 40% and caused the global average surface temperature to increase by 0.89 °C ± 0.2 °C during 1901–2012 period; and it has been also projected that as a result of climate change, the global surface temperature increase by the end of the 21st century is likely to exceed 1.5 °C relative to 1850 and CO_2 concentration to reach 560 ppmv by 2050 (IPCC, 2014). Since both CO_2 and temperature are among the most important environmental variables that regulate physiological and phenological processes 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 (Morison and Lawlor, 1999). In literature, it has been reported that elevated temperature adversely affects growth and yield of maize (Morison, 1996; Mendelsohn and Dinar, 2009). Elevated CO_2 has been reported to have variable effects ranging from little positive effect (Leakey et al., 2004), no effect (Kim et al., 2007) and increased yield up to 50% (Vanaja et al., 2015). When both CO_2 and temperature are increased simultaneously, elevated CO_2 reduces the negative effect of elevated temperature on growth and yield (Abebe et al., 2016).

Although studies related to impact of elevated temperature and CO_2 on growth and yield of maize has been done, yet impact of elevated temperature and CO_2 interaction on the response of maize crop to diseases has to be undertaken. In tropical and temperate regions, 61 diseases in maize including rust, stalk rot, leaf spot, downy mildew, turcicum leaf blight, maydis leaf blight etc. have been reported (Payak and Sharma, 1981). Of these diseases, maydis leaf blight (MLB), also known as southern corn leaf blight, caused by necrotrophic fungus *Bipolaris maydis* (Nisik.) Shoemaker (Syn. *Helminthosporium maydis* Nisik. and Miyake) is a major foliar disease reported from most maize growing regions of the world and in India. It has potential to reduce the grain yield up to the extent of 70% in susceptible cultivars (Nasir et al., 2012). The

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occurrence of diseases in crop is a key constraint with global average yield losses and production costs. Changes in the occurrence of disease incidence due to climate change are of ecological and economical importance. MLB disease is one of the important factors which has a direct impact on maize productivity and climate change may or may not further aggravate the situation. Therefore, present study was undertaken to determine the interactive effect of elevated temperature and carbon dioxide on maydis leaf blight disease tolerance attributes in two maize genotypes.

2. Materials and methods

2.1. Site description

The experiment was conducted during 2014 *kharif* season (July–Mid November) using open-top chambers (3 m diameter and 2.5 m height) in the farm of Indian Agricultural Research Institute (IARI), New Delhi (28°40′N and 77°12′E) at an altitude of 228.6 m above mean sea level. The location lies in the subtropical belt and has continental monsoon climate with an average annual rainfall of 750 mm, more than 60% of which is received during July to September and variation in maximum and minimum temperatures from July to November were 35.7 °C and 15.3 °C (Table 1). The soil of the experimental site was sandy clay loam in texture with pH 8.43 (1:2 soil:water), electrical conductivity (1:2 soil:water) 0.16 dS m^{-1}, organic carbon 0.45%, alkaline $KMnO_4$ extractable N 185.1 kg ha^{-1}, Olsen P 25.1 kg ha^{-1} and NH_4OAc-extractable K 247.9 kg ha^{-1}.

2.2. Planting material

Seeds of two genotypes of maize namely PEHM 5 (moderately resistant) and CM 119 (highly susceptible) were sown in pots (15 l capacity with 30 cm diameter) on July 11, 2014. Prior to seed sowing, soil from experimental site was collected and mixed with FYM for improving soil fertility (14 kg soil and FYM in 3:1 ratio per pot). Plants were maintained in pots throughout experimental crop growth period from seedling to maturity. Plants were irrigated on alternate days on regular basis and fertilizers were applied with 120, 25 and 50 kg ha^{-1} N, P and K, respectively.

2.3. Temperature and CO_2 treatments

Maize 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 maize crop. Two levels of CO_2 (ambient CO_2: 400 ppm (ACO_2) and elevated CO_2: 550 ± 20 ppm (ECO_2)) and three levels of temperature (ambient temperature (AT), ambient temperature + 1.5 °C (1.5T) and ambient temperature + 3 °C (3T)) were used as treatments (Table 2). Top of the OTC was kept opened and side walls were kept partially covered to maintain AT level. Top of the OTC was kept opened and all the side walls were fully covered to maintain 1.5 T level. Top of the OTC was partially covered with PVC shelter and side walls were kept intact to maintain 3 T level.

The elevated CO_2 concentrations were maintained inside the OTCs during 9:30 AM–4:30 PM using high pressurized CO_2 cylinders (of commercial grade 100% CO_2 gas cylinders of 30 kg capacity) with the help of dual stage regulators and gas flow meter. CO_2 was supplied from the cylinders to the OTCs through 6 mm polyurethane tubing and mixed with the ambient air at the outlet of the air blowers and subsequently distributed evenly inside the OTCs. CO_2 gas was released to the chambers through a manifold fitted with copper tubing. Within each chamber, the copper tubing was again fitted with solenoid valve and rotameters to regulate the gas supply. The uniformity of the CO_2 was maintained by pumping CO_2 gas diluted with air by air compressor. CO_2 levels build up inside the chambers were measured by a CO_2 analyzer and controlled by computer-aided regulation of inlet valves. The CO_2 concentration was maintained during day time because photosynthesis occurs during the day time only and plants could response to elevated CO_2.

2.4. Inoculation of maize plants with bipolaris maydis

Pure culture of the pathogen (*Bipolaris maydis*) was freshly multiplied on potato dextrose agar medium at 28 ± 2 °C. For mass multiplication of *B. maydis*, standard method of Ahuja and Payak (1978) was followed. Sorghum seeds were soaked in water for 24 h and excess water was removed and then 40 g of seeds were dispensed in 500 ml conical flask. The flasks containing sorghum seeds were autoclaved twice at 15 lb pressure for 30 min consecutively for two days. Fifteen gram of 8–10 days old fungal culture was placed in the sterilized seeds and incubated at 27 ± 1 °C for 10–15 days. For uniform growth of the fungus, shaking of the seed at 3–4 days interval was done. The mass culture was taken out from the conical flasks, bigger lumps were broken and shade dried for 2–3 days. The shade dried seeds were ground in a mixer-cum-grinder into powder form and stored at 6–9 °C till its use.

For inoculation, two pinch of the inoculum (approx. 3–4 g) in powder form was taken in between fingers and placed it into the central whorl of 35 days old maize plants (Payak and Sharma, 1983)

Table 2
Description of treatment combinations.

Treatment	Description
AT + ACO_2	Ambient temperature and ambient CO_2
1.5T + ACO_2	Ambient temperature + 1.5 °C and ambient CO_2
3T + ACO_2	Ambient temperature + 3.0 °C and ambient CO_2
AT + ECO_2	Ambient temperature and elevated CO_2 (550 ± 20 ppm)
1.5T + ECO_2	Ambient temperature + 1.5 °C and elevated CO_2 (550 ± 20 ppm)
3T + ECO_2	Ambient temperature + 3.0 °C and elevated CO_2 (550 ± 20 ppm)

Table 1
Weather conditions during the experimental period.

Month	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	Sun shine (hours)	Pan Evaporation (mm)
	Maximum	Minimum				
July	34.4	25.8	212.2	81.5	138.6	224.1
August	35.7	25.8	138.6	72.8	153.0	227.3
September	34.1	23.9	124.3	70.3	208.3	164.0
October	33.2	18.8	0.0	61.5	183.5	146.7
November	30.2	15.3	0.0	59.8	161.5	145.3