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Effect of Elevated Carbon Dioxide and Temperature on Tolerance Potential of Maize Genotypes for Maydis Leaf Blight Disease

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Abstract—*An experiment was conducted with two maize (Zea mays L.) genotypes (PEHM 5 and CM119) in open top chambers (OTCs) to determine the effects of elevated atmospheric carbon dioxide (CO_2) and temperature on maydis leaf blight (MLB) disease tolerance. Both genotypes were grown with two levels of carbon dioxide i.e., ambient (400 ppm) and elevated (550 ± 20 ppm) and three levels of temperature i.e., ambient, ambient +1.5℃ and ambient +3.0℃ during kharif (July–November) seasons of 2014 in New Delhi, India. Both genotypes were artificially inoculated with MLB pathogen at 25 days after sowing (DAS). Different physiological and biochemical parameters was recorded, as well as disease development was observed at three growth stages. It was found that total phenol content was significantly increased at all the three growth stages followed by ascorbic acid content at ambient CO_2 with ambient +3.0℃ temperature and relative leaf water content (RLWC) was found to decrease significantly at ambient CO_2 with ambient +1.5℃ temperature and ambient CO_2 with ambient +3.0℃ temperature in PEHM 5; and for CM 119, Melonialdehyde (MDA) content was increased at ambient CO_2 with ambient +3.0℃ temperature followed by at ambient CO_2 with ambient +1.5℃ temperature followed by RLWC and total dry mass. The results indicate that PEHM 5 was resistant towards MLB disease even under changing environmental conditions and CM 119 was susceptible. Elevated CO_2 had negative effects whereas elevated temperature had positive effects on MLB disease development for both genotypes. With elevation of both CO_2 and temperature, elevated CO_2 reduced the severity of MLB disease.*

1. INTRODUCTION

Maize (*Zea mays* L.), as one of the major staple food crop contributes to food and economic security in most of the developed and developing countries [1]. Together with rice and wheat, maize provides 30% of the food calories to more than 4.5 billion people in 94 developing countries [2]. 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 has been projected to reach 560 ppmv by 2050 [3]. Many studies have reported the effect of elevated temperature [4,5] and CO_2 [6,7] on various physiological and biochemical characters of maize, but effect of elevated temperature and CO_2 in combination on disease tolerance potential of maize needs a systematic study. In tropical and temperate regions, 61 diseases in maize have been reported [8]. Of these diseases, maydis leaf blight (MLB), also known as southern corn leaf blight, caused by the fungus *Bipolaris maydis* (Nisikada and Miyake) Shoemaker is a major disease of maize. It has potential to reduce the grain yield up to the extent of 70% in susceptible cultivars. In India, although studies related to impact of elevated temperature and CO_2 on growth and yield of maize has been done, however impact of elevated temperature and CO_2 on response of maize crop to diseases has to be undertaken. Keeping this view in mind, the present study was conducted to assess the effect of elevated temperature and CO_2 on tolerance potential of maize to maydis leaf blight disease.

2. STUDY AREA, MATERIALS AND METHODS

The experiment was conducted during 2014 *kharif* season using open-top chambers (OTCs) in the farm of Indian Agricultural Research Institute (IARI), New Delhi, which is situated at 28°40’N and 77°12’E, at an altitude of 228 m above mean sea level. The location lies in the subtropical belt, has continental monsoon climate exhibiting a masked seasonal rhythm, hot summer, cool winter, un-reliable rainfall, great variation in temperature and mean maximum and minimum temperatures from June to November are 38°C and 19°C. The soil at the experimental site belongs to the major group of Indo-Gangetic alluvium. The soil is non-calcareous and slightly alkaline in reaction. Surface and subsoil texture ranges from sandy loam to loam, with medium to weak angular blocky structure. The physical and physico-chemical properties of the soil (0–30 cm) are: sand, silt and clay: 63.8, 24.7 and 11.5%, respectively, bulk density 1.59 Mg m^{-3}, hydraulic conductivity (saturated) 1.12 cm h^{-1}, pH (1:2.5 soil: water suspension) 7.4, EC 0.46 dS m^{-1}, organic C 3.9 g kg^{-1}, total N 0.031%, available P (10.2 kg ha^{-1}) and K (279.9 kg ha^{-1}).

2.1. Planting material and experimental design

Two genotypes of maize (PEHM 5 and CM 119) were grown under two levels of atmospheric CO_2 (ambient and 550 ± 20 ppm) and three levels of temperature (ambient, ambient + 1.5°C and ambient + 3°C) during *kharif* (July–November) season of 2014 in OTCs (chamber area of 7.07 m^2) and ambient field conditions (Table 1). The experiment was conducted in a 3 factorial completely randomized design with 5 replications each of PEHM 5 and CM 119. Both genotypes were grown in same OTC with 20 cm spacing between plants and 60 cm between rows. Seeds were sown on July 11 in 2014. In the elevated CO_2 treatment, concentration of CO_2 was maintained at 550 ± 20 ppm inside the OTCs by releasing compressed CO_2 gas from cylinders. The gas was supplied using a 30 kg capacity CO_2 cylinder at the perimeter of the circular ring through tubes at 35 cm height from the soil surface. Air circulation was done to the chamber via air blowers located near the base of the chamber and CO_2 was added to the incoming air. The actual concentration of CO_2 within the OTCs was measured by a CO_2 analyser and controlled by computer-aided regulation of inlet valves. The fluctuations of CO_2 concentration both within fully and partially open OTCs was about ± 20 ppm. The OTCs were made up of transparent polyvinyl chloride sheets with about 90% transparency. This ensured that the light intensity was not a limiting factor for the growth of the crops. The temperatures of ambient +1.5°C and ambient +3.0°C in the OTCs were maintained by keeping the upper portion of the OTCs fully open and partially covered, respectively. Continuous monitoring of daily maximum temperatures for all the treatments (ambient, fully open OTCs and partially covered OTCs) was done using digital thermometer. It was observed that the fully open OTCs had about 1.5°C and the partially covered OTCs had about 3.0°C above the ambient temperature. For the ambient temperature with elevated CO_2 treatment (T3), temperature inside the OTCs was maintained by making several perforations on the side walls and keeping the gate of the OTCs open. The crops were fertilized with 120, 26 and 50 kg ha^{-1} N, P and K, respectively. All the P and K and 50% of N were applied at the time of sowing. The remaining N was applied in two equal splits at knee high stage at 25 days after sowing (DAS) and tasseling (45 DAS) stage of maize.

Table 1: Description of treatment combinations

Treatment	Description
T0	Ambient temperature and ambient CO2
T1	Ambient temperature + 1.5ºC and ambient CO2
T2	Ambient temperature + 3.0ºC and ambient CO2
T3	Ambient temperature and elevated CO2 (550 ± 20 ppm)
T4	Ambient temperature + 1.5 ºC and elevated CO2 (550 ± 20 ppm)
T5	Ambient temperature + 3.0 ºC and elevated CO2 (550 ± 20 ppm)

2.2. Inoculation of maize plants with Bipolaris maydis

For inoculation two pinch of the inoculum (approx. 3–4 g) of MLB pathogen in powder form was taken in between fingers and placed it into the central whorl of 35 days old maize plants [9] exposed to different treatments.

2.3. Assessment of disease development

Maydis leaf blight disease development was observed on artificially inoculated maize genotypes PEHM 5 and CM119 exposed to elevated CO_2 and temperature under field and lab conditions. In the field condition disease severity was recorded using 1-5 rating scale (Table 2) developed by Payak and Sharma (1983) at vegetative, tasseling and dent stages. For determination of leaf area infected images of leaves of maize genotypes were captured to assess disease development under field and lab experiment were analysed using the ImageJ software. Detached leaf technique [10] developed by Tedford *et al.,* (1990) was followed for the assessment of disease development under controlled lab conditions.

Table 2: Maydis leaf blight disease rating scale (Payak and Sharma, 1983)

Rating scale	Disease severity (%)	Disease reaction
1.0	Very slight to slight infection, one or two to few scattered lesions on lower leaves	Resistant (Score: ≤ 2.0) (PDI: ≤ 40.0)
2.0	Light infection, moderate number of lesions on lower leaves only	
3.0	Moderate infection, abundant lesions on lower leaves, few on middle leaves	Moderately resistant (Score: 2.1 – 3.0) (PDI: 40.1 – 60.0)
4.0	Heavy infections abundant on lower and middle leaves, extending to upper leaves	Moderately susceptible (Score: 3.1 – 4.0) (PDI: 60.1 – 80.0)
5.0	Very heavy infection, lesions abundant on almost all leaves, plants prematurely dry or killed by the disease.	Susceptible (Score: ≥4.1) (PDI: ≥ 80.0)

2.4. Crop parameters

Different physiological and biochemical parameters such as total biomass, relative leaf water content, total chlorophyll, leaf extract pH, ascorbic acid content, MDA content, total phenol content, photosynthetic rate, stomatal conductance and transpiration rate was analysed to estimate the tolerance potential and the results of different parameters were subjected to principal component analysis (PCA) to find out the most influencing parameters which were having significant contribution towards MLB disease tolerance and contribution of different parameters towards crop health.

3. RESULTS

Considering the average linear scores the order of importance of key parameters in influencing crop health for PEHM 5 was total phenol content (0.82) > ascorbic acid content (0.75) > relative leaf water content (0.71) > total dry biomass (0.58) > MDA content (0.51), with a corresponding contribution of 24.23%, 22.15%, 21.15%, 17.31% and 15.16%, respectively. Similarly, for CM 119 the order of importance of key parameters in influencing crop health was MDA content (0.83) > relative leaf water content (0.67) > total dry biomass (0.57) > total phenol content (0.52) > ascorbic acid content (0.51), with a corresponding contribution of 36.6%, 21.57%, 18.51%, 11.74% and 11.57%, respectively (Fig. 1). Our study indicated that for MLB disease development under elevated levels of CO_2 and temperature total phenol content, RLWC, Total dry biomass, ascorbic acid content and MDA content were the key parameters for assessing disease development, which were greatly influenced by the combination of biotic and abiotic stress. Among these parameters for PEHM 5 total phenol content and ascorbic acid content were having the highest importance. This was because these chemicals acts as defence compounds under biotic and abiotic stress and PEHM 5 is moderately resistant towards MLB disease. For CM 119, MDA content and RLWC emerged as having high importance in assessing the disease development.

4. ACKNOWLEDGEMENT

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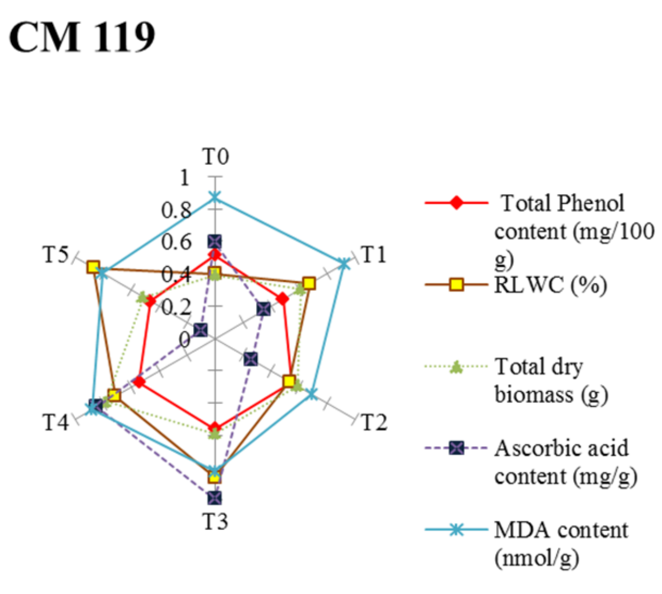

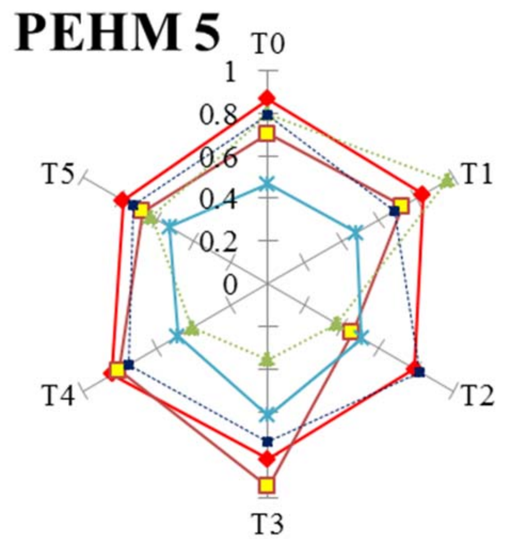

Fig. 1: Radar graphs for PEHM 5 and CM 119 depicting the average linear score of key indicators which are most influenced by disease under different treatments T0, Ambient CO_2 level + Ambient temperature level; T1, Ambient CO_2 level + 1.5°C elevated temperature than ambient level; T2, Ambient CO_2 level + 3°C elevated temperature than ambient level; T3, 550 ppm CO_2 level + Ambient temperature level; T4, 550 ppm CO_2 level + 1.5°C elevated temperature than ambient level; T5, 550 ppm CO_2 level + 1.5°C elevated temperature than ambient level

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