COMPARATIVE STUDY OF DROUGHT STRESS RESISTANCE IN TWO WINTER WHEAT VARIETIES RAISED AT AMBIENT AND DOUBLED CO_2 CONCENTRATION

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Abstract: In preparation for the abiotic stress effects likely to be caused by climate change the impact of doubled carbon dioxide concentration and drought stress on two winter wheat varieties, Mv Mambó and Mv Regiment, were studied in growth chambers at the Agricultural Research Institute of HAS. The meteorological parameters (temperature, humidity, radiation) were the same in both PGV-36 chambers but the carbon dioxide concentration was either ambient (380 ppm) or doubled (750 ppm). The effect of elevated CO_2 level and drought stress were examined in various phenological stages (first node appearance, heading and grain filling). The drought stress was continued for 3-7 days, during which period the soil water humidity decreased from 20-25 volumetric water content (VWC%) to 3-5 VWC%. Photosynthesis and antioxidant enzyme activities (catalase, glutathione reductase, glutathione S-transferase, ascorbate peroxidase, guaiacol peroxidase) were measured at various levels of water stress. Phenological and yield parameters were determined at the end of the vegetation period. Significant differences were found between the varieties and treatments in the antioxidant enzyme activity and a number of phenological parameters. Elevated CO_2 concentration improved stress tolerance increasing biomass production and the grain number in both varieties. High CO_2 concentration also reduced the negative effect of drought stress on yield parameters.

Keywords: abiotic stress, climate change, elevated CO_2 level, drought.

Introduction

The global atmospheric carbon dioxide concentration has been increasing continuously during the last two centuries and its value is 35 % higher nowadays than before the industrial revolution. The present average level is 385 ppm, but according to predictions the carbon dioxide concentration will reach 650 to 970 ppm by the end of the 21st century (IPCC 4th report). The increase in temperature, which is more intensive in the Carpathian Basin than global, and the decrease in precipitation in summer (Bartholy, 2008; Mika, 1991) and the declining water reserves aggregate the disposition of the Hungarian climate to drought (Huszár, 1999). One direct consequence of the increasing CO_2 concentration is that the assimilation rate of plants is more intens (Wolf, 1996). Elevated CO_2 level increase both the above-ground and below-ground biomass. The two impacts may interact as higher carbon dioxide levels can decrease the negative effect of drought on quantitative yield parameters (Bencze, 2007). Different varieties have different levels of adaptability which will make it possible to select genotypes which can be grown successfully even under changed conditions (Veisz et al. 2005). High temperature reduces the antioxidant enzyme activities and the intensity of the reactions decrease as the plants age (Balla et al. 2007).

Materials and methods

This study was carried out in two PGV-36 growth chambers at the Agricultural Research Institute of HAS in Martonvásár. Two winter wheat varieties, Mv Mambo and Mv Regiment, were raised at normal (380 ppm)(NC) and elevated (750 ppm)(EC) carbon dioxide concentration and the Spring 2 - Summer 2 climatic programme

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(Tischner et al. 1997) was applied in both chambers. Four seedlings were planted after vernalization for 42 days in pots containing approximately 3000 cm^3 of a soil and sand mixture. The irrigation was constant and nutrient solution was used twice a week till the start of the treatments. Drought effects and yield parameters were examined at both CO_2 concentrations compared to the control. The first period of water withdrawal was after the first node appearance (FNA), the second during heading (H) and the last 10 days after full heading, in the grain filling (GF) period. Drought was continued for 3-7 days during which time the volumetric water content (VWC %) of the soil decreased from 20-25 VWC% to 3-5 VWC% while the plants started to wilt. The water content of the pots was measured using an Em50 data logger and ECH_2O EC-05 sensors (Decagon Inc., USA). Antioxidant samples were collected at various level of water stress and were stored at at -80^oC until the analyses. Antioxidant enzyme activity was recorded using the methodology of Janda et al. (2005). Measurements were made on five enzymes: catalase, glutathione reductase, glutathione S-transferase, ascorbate peroxidase and guaiacol peroxidase. The grain number, grain weight, biomass production per plant, and the thousand-kernel weight (TKW) were determined after harvest. Two-way ANOVA was used to establish the significant level between the treatments (Kuti et al. 2008).

Results and discussion

The grain number per plant did not change significantly in response to drought stress in Mv Mambo (*Table 1.*) while higher atmospheric CO_2 level increased the grain number in the control and in the GF treatment compared to the ambient CO_2 but it had no effect in the other two treatments (*Table 2.*). In response to higher atmospheric CO_2 level there was an increase in grain number in the control and in the GF plants, compared with normal CO_2, while the other two treatments did not respond to enhanced CO_2. The grain number of Mv Regiment declined significantly as the result of drought in the FNA and H treatments at high CO_2 level, but was still higher than that recorded at the ambient concentration under water stress conditions.

In response to a dry period the grain yield of Mv Mambó did not change in the FNA or H treatments at either CO_2 level. Plants treated at the grain filling period, however, exhibited a 30.1% reduction in the grain weight per plant at normal CO_2 level, while this decrease was considerably smaller (17.8%) at the higher concentration. High CO_2 concentration thus had a favourable effect on the grain production. At normal CO_2 a significant difference was only observed in Mv Regiment in the GF treatment, with a value 22.3% lower than the control, while no difference was observed between the treatments at enhanced CO_2. In response to higher CO_2, an increase in grain yield per plant was observed both in the control and in the three treatments. The effect of drought stress at the grain filling period was particularly striking at higher CO_2, where the grain weight was 65.7% higher than that of plants raised under normal CO_2.

A significant reduction in the aboveground biomass of plants exposed to water stress in various phenophases was only observed in the GF treatment at normal CO_2 (15.2% for Mv Mambó and 14.5% for Mv Regiment). In the case of Mv Mambó the biomass production in the control and GF treatments was 16.9% and 32.15% higher, respectively, at high CO_2 than at the normal concentration, while in Mv Regiment a

considerable increase in biomass was observed in all the plants in response to enhanced CO_2.

Table 1. Impacts of drought stress at various phenophases compared to values at the corresponding CO_2 concentration and normal water supply level

Treatments		Mv Mambó				Mv Regiment			
		Grain Number %	Grain. weight %	Biomass %	TKW %	Grain weight %	Grain mass %	Biomass %	TKW %
First node apparen-ce	NC	107.5	104.4	106.7	102.4	100.8	95.5	95.6	96.3
	EC	89.2	94	96.3	106.2	**87.7**	**89.0**	97.3	101.7
Heading	NC	112.5	118.9	**118.4**	105.9	90.7	94.6	93.2	104.8
	EC	90.3	98.0	102.7	107.4	**84.3**	92.1	96.5	109.8
Grain filling	NC	106.7	**69.9**	**84.8**	**77.5**	88.9	**78.8**	**85.5**	90.3
	EC	103.5	**78.2**	95.8	**71.1**	104.6	102.7	101.6	99.9

100%= the normal water supply and either the ambient or the elevated CO_2 level, respectively.

In Mv Mambó drought treatment had no significant effect on TKW except the GF treatment, where the size of the grains decreased by 22.5% at normal CO_2 and 29% at the elevated CO_2 level compared to the controllower at the higher level. The thousand-kernel weight of plants grown at enhanced CO_2 and exposed to drought during grain filling was significantly (12.5%) lower than at normal CO_2, indicating that higher atmospheric CO_2 concentration aggravated the unfavourable effects of drought. In Mv Regiment the TKW of water stressed plants did not differ from the control at either CO_2 level, but the grai weight was significantly higher at the enhanced CO_2 level than at normal CO_2 in all the treatments.

Table 2. Effect of enhanced CO_2 concentration on the biomass and yield components, compared with plants grown at normal CO_2 concentration at same water supply level

Treatments	Mv Mambó				Mv Regiment			
	Grain number %	Grain weight %	Biomass %	TKW %	Grain number %	Grain weight %	Biomass %	TKW %
Control	**19.34**	**11.95**	**16.93**	-4.50	**14.20**	**27.06**	**23.52**	**11.12**
First node a.	-0.95	0.80	5.53	-0.91	-0.63	**18.48**	**25.73**	**17.32**
Heading	-4.18	-7.77	1.39	-3.16	**6.13**	**23.66**	**27.93**	**16.39**
Grain fill.	**30.96**	**25.31**	**32.15**	**-12.50**	**34.41**	**65.70**	**46.64**	**22.85**

Significant values in bold

Investigations on the effect of drought stress and enhanced CO_2 on the antioxidant enzyme system revealed that the activity of the ascorbate peroxidase enzyme was modified to the greatest extent in both varieties, particularly during the ripening period (*Fig. 1*). In both varieties glutathione reductase exhibited greater activity at higher CO_2 level, especially in the grain filling period and in the case of low soil moisture. High catalase activity was characteristic of both varieties at high CO_2 in the GF treatment, particularly at soil moisture levels below 6 VWC%. No significant changes were observed in the activity of glutathione reductase or glutathione-S-transferase.

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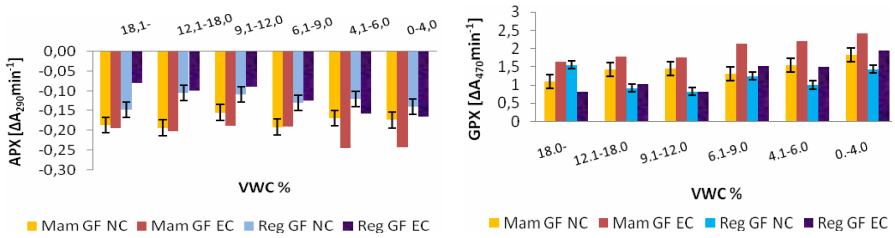

Figure 1. Activity of ascorbate peroxidase and guaiacol peroxidase at normal and enhanced CO_2 level after drought stress at grain filling period

Conclusions

The two varieties tested exhibited considerable differences in their responses to drought and to enhanced atmospheric CO_2 concentration. Mv Mambó made better use of low soil moisture contents, with only slight changes in yields, but the effect of a higher level of available CO_2 was not reflected in the yield, despite the fact that positive changes were recorded in the spike number and productivity. Mv Regiment proved to be more sensitive to water withholding, but it exploited surplus CO_2 more efficiently and was thus able to compensate for the negative effects of drought, resulting in a higher yield level than that of Mv Mambó at enhanced atmospheric carbon dioxide concentration.

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