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DIFFERENTIAL SUSCEPTIBILITY OF PHOTOSYNTHESIS AND PRODUCTIVITY OF WHEAT CULTIVARS TO ELEVATED TEMPERATURE

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SUMMARY

Wheat (*Triticum aestivum* L.) cvs. HD 2285 and HD 2329 were grown in control(C) and heated (H) open top chambers (OTCs) for entire period of growth and development till maturity. In one set of OTCs, high temperature treatment was given only after anthesis stage. The mean maximum temperature of the entire period was around 3^0C higher in H-compared to C-OTCs. Moderately high temperature differentially affected photosynthesis (Pn) in wheat cultivars. At anthesis, Pn of HD 2285 was more sensitive to elevated temperature than HD 2329, whereas, at post anthesis stage HD 2329 was more sensitive. The heat susceptibility index (S) for grain yield showed that HD 2285 is more susceptible than HD 2329 when moderate high temperature stress was given during entire period of growth and development. However, under moderate high temperature exposure after anthesis, the heat susceptibility index showed HD 2285 as stress tolerant and HD 2329 as a susceptible type. The greater susceptibility of HD 2285 than HD 2329 to moderately high temperature exposure during entire period of growth and development was due to greater reduction in tillers, consequently, ear number per plant in HD 2285. The study revealed that cv. HD 2285 tolerant to terminal high temperature would become susceptible when high temperature spells come during pre-anthesis period. There is a need, therefore, to develop wheat varieties which are tolerant not only to terminal high temperature stress, but to a warmer climatic condition.

***Key words*: Elevated temperature, grain growth, heat susceptibility index, open top chamber, photosynthesis, yield**

INTRODUCTION

High temperature is one of the most important constraints for wheat productivity. Substantial yield losses as a result of heat stress have been reported for wheat crop (Chinoy 1947, Asana and Williams 1965, Prakash *et al.* 2003, 2004, Sharma-Natu *et al.* 2006). This has become all the more relevant in the light of projected global warming as a result of greenhouse effect (Bowes 1996, Ghildiyal and Sharma-Natu 2000, Ravi *et al.* 2001, IPCC 2007). In wheat, major emphasis has been directed towards improving terminal high temperature tolerance. However, temperature may become warmer even earlier and would adversely affect photosynthesis and phenological events, consequently, productivity (Sharma-Natu and Ghildiyal 2005, Sharma-Natu *et al.* 2006, Pushpalatha *et al.* 2007, 2008). Since, moderate heat stress occurs more frequently, the present investigation was undertaken to analyse the effect of moderate heat stress on photosynthesis and productivity of wheat. Wheat cultivars known to differ in temperature tolerance were examined for their susceptibility to elevated temperature exposure during entire period of growth and development and also only during post anthesis exposure.

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MATERIALS AND METHODS

Wheat (*Triticum aestivum* L.) cvs. HD 2285 and HD 2329 were grown in the field inside control (C) and heated (H) open top chambers (OTCs) for entire period of growth and development till maturity. The construction of OTCs (300 x 200 cm) was based on the design of Leadley and Drake (1993). In heated OTCs warm air was supplied by hot air blower, blown by an axial fan. The warm air entered the chamber through double walled plenum around the base perforated towards inside. To eliminate chamber environment effect, chambers in which only air is blown served as control. The maximum and minimum temperatures of C and H-OTCs were recorded daily to assess the temperature difference. The H-OTCs maintained mean maximum temperature of around 3^0C higher than C-OTCs. The mean maximum temperature of entire period from sowing to maturity in C- and H-OTCs was 38.3 and 41.2^0C, respectively. In one set of OTCs, high temperature treatment was given only after anthesis stage. Standard cultural practices were followed (Singh 1983). Date of anthesis in the main shoot (MS) was recorded on the tags placed on each plant.

Photosynthesis rate (Pn) in the flag leaf of MS of C- and H-plants were determined at anthesis and 20 days after anthesis (DAA) using portable photosynthetic system (CIRAS-2 PP Systems, UK). Pn was measured between 10:00 and 11:00 h at respective growth temperatures in C- and H-OTCs. The incident photon flux density during gas exchange measurement was saturating (>1500 µmol m^{-2} s^{-1} upon the leaf surface). Yield components were determined at maturity. Yield components of plants exposed to elevated temperature exclusively during post anthesis period were also determined. Heat susceptibility index (S) was calculated for grain yield and thousand grain weight in wheat cultivars exposed to elevated temperature during entire period of growth and development and also only during post anthesis exposure as described by Fischer and Maurer (1978): $S=(1 - Y/Yp) / (1 - X/Xp)$, where, Y = mean grain mass of a genotype grown at high temperature, Yp = mean grain mass of a genotype grown at control conditions, X = mean of Y of all genotypes, Xp = mean Yp of all genotypes ($S \leq 1.0$ means stress tolerant and $S > 1.0$ susceptible genotype).

RESULTS AND DISCUSSION

In the present study, the heated OTC grown wheat cultivars were exposed to a moderately high temperature, i.e. a mean maximum temperature of around 3^0C higher than that of control OTC grown plants. Photosynthesis rate measured at respective growth temperatures in C and H-OTC showed 52.4% and 21.1% decrease in Pn in H-grown plants compared to C-grown plants at anthesis stage in HD 2285 and HD 2329 respectivley. At post-anthesis stage no significant effect on Pn was observed in HD 2285, whereas, H-grown plants of HD 2329 had 23.1% lower Pn compared to control plants (Fig. 1). Under moderately high temperature exposure during entire period of growth and development, HD 2285

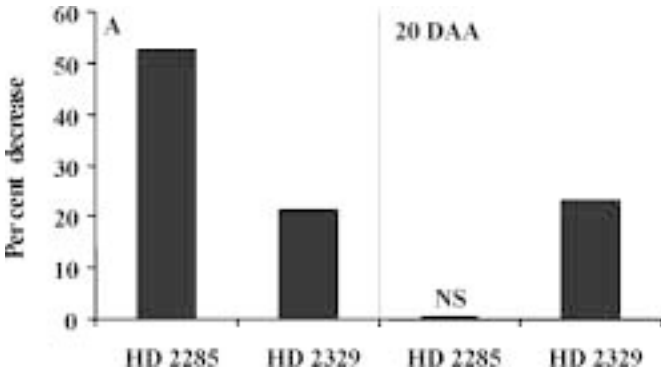

Fig. 1. Decrease (%) in photosynthesis rate of flag leaf of wheat cultivars in heated OTCs as compared to control OTCs, measured at respective growth temperature at anthesis (A) and twenty days after anthesis (20 DAA) (NS = decrease not significant at 5% P)

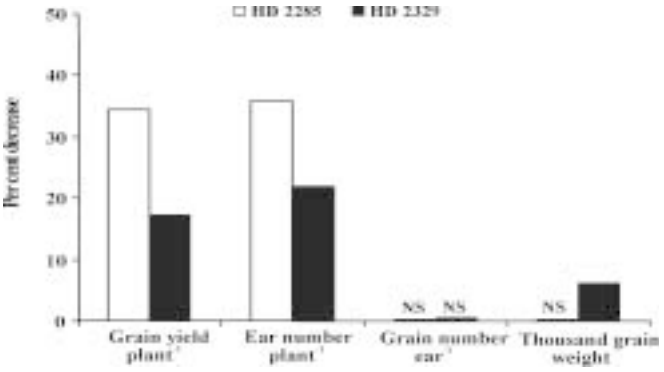

Fig. 2. Decrease (%) in yield components of wheat cultivars (grown throughout the growth and development till maturity) in heated OTCs compared to control OTCs (NS = decrease not significant at 5% P)

showed a greater reduction of 34.5% in grain yield compared to only 17.3% reduction observed in HD 2329. This effect was mainly brought out by greater reduction (35.9%) in ear number per plant in HD 2285 compared to only 21.9% reduction observed in HD 2329 by elevated temperature (Fig. 2). Moderately high temperature did not significantly affect grain number per ear in both the cultivars and thousand grain weight in HD 2285. In HD 2329, 6% reduction in thousand grain weight was observed in E compared to C plants (Fig. 2).

Heat susceptibility index (S) for grain yield of wheat cultivars grown in C and H-OTCs throughout growth and development till maturity showed HD 2285 as susceptible and HD 2329 as tolerant type, whereas S in term of thousand grain weight showed HD 2285 as a tolerant type (Table 1). However, when moderately high temperature stress was given only after anthesis stage, the heat susceptibility index for grain growth and grain yield showed that HD 2285 is stress tolerant and HD 2329 as a susceptible type (Table 2).

Table 1. Heat susceptibility index (S) for grain growth and yield of wheat cultivars grown in control and heated OTCs throughout the growth and development till maturity

Cultivar	S for grain yield (g plant^{-1})	S for grain growth (1000 grain weight)
HD 2285	1.292**	0.888*
HD 2329	0.648*	2.944**

* stress tolerant, ** susceptible

Table 2. Heat susceptibility index (S) for grain growth and yield of wheat cultivars grown in control and heated OTCs, when high temperature exposure was given only after anthesis

Cultivar	S for grain yield (g plant^{-1})	S for grain growth (1000 grain weight)
HD 2285	0.117*	0.326*
HD 2329	1.798**	1.717**

* stress tolerant, ** susceptible

Of the two cultivars used in the present study, HD 2285 is considered as relatively tolerant to terminal high temperature exposure (i.e. during grain development) as compared to HD 2329 (Prakash *et al.* 2003, 2004). However, under moderately high temperature exposure during entire period of growth and development in the present study, HD 2285 was found to be more susceptible than HD 2329 (Table 1). Data showed that this sensitivity was mainly due to greater reduction in tillering, consequently, ear number per plant under elevated temperature in HD 2285 compared to HD 2329 (Fig. 2). In wheat, pre-anthesis phenological phases which determine potential yield components are quite sensitive to high temperature (Slafer *et al.* 1996, Abrol and Ingram 2005, Sharma-Natu *et al.* 2006). Pre-anthesis phenology of HD 2285 seemed to be more susceptible than HD 2329 to elevated temperature resulting in greater overall susceptibility. This was also found true for greater susceptibility of pre-anthesis photosynthesis in this cultivar under moderately high temperature (Fig.1). In terms of grain growth (1000 grain weight), HD 2285 was however, found to be tolerant to elevated temperature compared to HD 2329 as revealed from heat susceptibility index (Table 1). When moderately high temperature stress was given after anthesis, the S for grain growth and yield showed that HD 2285 is tolerant and HD 2329 as a susceptible type (Table 2). This is in line with the observations reported earlier showing that high temperature tolerance for grain growth in HD 2285 is due to its ability to sustain higher activity and catalytic efficiency (V_{max}/K_m) of soluble starch synthase (SSS) in the developing grains at elevated temperature and higher content of heat shock protein (HSP 100) than susceptible type (Prakash *et al.* 2003, Sumesh *et al.* 2008).

The present study, revealed that cv. HD 2285 tolerant to terminal high temperature would become susceptible when high temperature spells come during pre-anthesis period. There is a need, therefore, to develop wheat varieties which are tolerant not only to terminal high temperature but to warmer climatic conditions.

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