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Short Communication

Effect of timing of heat stress during grain filling in two wheat varieties under moderate and very high temperature

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Abstract

In order to examine the effect of short periods heat stress on grain growth, two cultivars (Longmai26 and Longmai30) were grown in pots at two different diurnal temperatures (32/22°C; 25/15°C) in climate-controlled growth cabinets and exposed to a 5-day heat stress (38/22°C) at 5-day intervals throughout grain filling after anthesis. The results indicated that long periods of moderate high temperature (>30°C) have higher effect than short periods of heat stress (5 days with maximum 38°C for 6h each day). However, plants grown at the moderate temperature (25/15°C) showed a greater response to a short period of heat stress than plants grown at the high temperature (32/22°C). At elevated temperatures, the change in the rate of grain filling is smaller than duration of grain filling. The high grain-filling rate and high potential grain weight should be used as a criterion in selecting for high temperature tolerance in wheat.

Key words: Wheat; post-anthesis heat stress; grain weight; rate of grain filling; duration of grain filling

High temperature stress is a common abiotic stress factor during the post-anthesis period in most of the wheat-growing areas of the world (Wardlaw et al. 1989). Long periods of moderately high temperature (25-32°C) as well as short periods of very high temperature (>35°C) following anthesis can significantly reduce grain weight in wheat (Stone and Nicolas, 1995; Jagdish and Santha, 1004; Tahir et al. 2006). For wheat, air temperature of about 15°C has been considered optimum for grain growth [5]. Under both controlled environments and field conditions during grain filling, wheat grain weight declines by approximately 3-4% for each 1°C increase in average temperature above the optimum (Wardlaw et al. 1989; Wardlaw and Wrigley 1994; Choudhary and Wardhaw 1978). There was about 23% decline in grain weight when wheat was exposed to as little as 4 days of heat stress (>35°C) at the most sensitive grain-filling stages (Stone and Nicolas, 1994). However, these effects are dependent on the wheat genotype and the grain development stages at which the heat stress occurs (Wardlaw et al. 1989; Stone and Nicolas 1995).

The reproductive stages have been considered the most temperature-sensitive period in wheat (Viswanathan and Khanna Chopra 2001; Yang et al. 2002; Wollenweber et al. 2003; Prasad et al. 2008). When plants were exposed to high temperature, changes in the duration and rate of grain filling were the major cause of reductions of grain weight at maturity. The major purposes of this study were to examine more precisely the effect of high temperature stress following anthesis on grain growth, by varying the timing of heat stress under moderate and high temperature conditions.

This research was conducted in the spring of 2012 at Crop Breeding Institute, Heilongjiang Academy

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of Agricultural Sciences, China. Two spring wheat cultivars used in this study were Longmai26 (heat sensitive) and Longmai30 (heat tolerant). After anthesis, plants were moved into climate-controlled growth cabinets at a day/night temperature of either 25/15°C (10/14h) or 32/22°C (10/14h) and a 16h photoperiod. Heat-treated plants were exposed to a day/night temperature of 38/22°C (6/18h) in a naturally lit glasshouse. The heat stress was imposed for a duration of 5 days at 5-day intervals throughout grain filling for the two growth temperatures.

For each treatment, grains were harvested at 5-day intervals following the heat stress treatment and continued until 40 days after anthesis (DAA). The grain samples from the three replications of each treatment were oven-dried for 48h and their dry mass was recorded. The duration and rate of grain filling were determined by the ordinary logistic model described by Zahedi and Jenner (2003).

Wheat is a crop that is very sensitive to high temperature, particularly when high temperature occurs during grain filling (Yang et al. 2002; Farooq et al. 2013). As was found in this study, the negative effect of high temperature during grain filling on grain weight has been found in many studies (Stone and Nicolas 1995; Tahir et al. 2006; Tewolde et al. 2006). The grain weight and duration of grain filling were significantly reduced in both cultivars at 32/22°C as compared with 25/15°C. The high temperature led to 29% and 24% decrease in mean grain weight and duration of grain filling, respectively. The high temperature led to 8% decrease in maximum rate of grain filling for both cultivars. Some studies indicated that final grain weight at maturity was determined by the rate and duration of grain filling (Santiveri et al. 2002). The decrease in grain weight is mainly due to the change of duration and rate of grain filling (Viswanathan and Khanna Chopra 2001). The results indicated that the decrease in grain weight was mainly due to significantly shortened duration of grain filling in our study. Dias and Lidon (2009) and Yin and Guo (2009) reported that the rate of grain filling was increased whereas the duration of grain filling was shortened by high temperature during grain filling. The increase in grain filling rate under high temperature was not enough to compensate for the decrease in grain filling duration, which caused a considerable decrease in final grain weight (Wardlaw et al. 1980). Our results suggested that the rate of grain filling in both cultivars was reduced at 32/22°C as compared with 25/15°C. These conflicting results may be related to different growth temperature. Due to damaging effect of higher temperature, the rate of starch accumulation declines at temperatures in excess of 30°C, resulting in a significant decrease in the rate of grain filling (Jagadish and Shantha 2004). However, in our experiment when temperatures are elevated (from 25/15°C to 32/22°C) from anthesis to grain maturity the magnitude of changes in the rate of grain filling was smaller than the duration of grain filling. This is an agreement with the results obtained by (Prasad et al. (2008) and Zahedi and Jenner (2003).

Previous workers have generally reported that the grain growth was more severely affected by a short period early heat stress (Stone and Nicolas, 1995) Our results also indicated that short periods of heat stress applied at an early stage of grain development resulted in a greater reduction of grain weight, and duration and rate of grain filling than medium and late stage (Figs. 1, 2 and 3). The extent of the effect was significantly altered by the timing of heat stress for each cultivar at two temperatures. Genotypic variation in response to heat stress was observed between two wheat cultivars for the rate and duration of grain filling at 25/15°C. Longmai30 was less temperature responsive than Longmai26, with regard to both rate and duration of grain growth. But the variation for the rate and duration of grain filling between two wheat cultivars was small at 32/22°C (Figs. 2 and 3). The grain weight, duration and rate of grain filling were greater in Longmai26 as compare Longmai30 (Table 1) at each temperature separately. Although in this study the percentage reduction of grain weight was significantly positively correlated with percentage reduction in duration of grain filling(r = 0.97; P<0.0001

Table 1. The grain weight, duration and maximum rate of grain filling for two spring wheat cultivars grown at 25/15°C and 32°C/22°C (day/night temperature), and as estimated by the ordinary logistic model

Cultivars	Tempe-rature	Grain weight ($mg \cdot grain^{-1}$)	Duration of grain filling (day)	Maximum rate of grain filling ($mg \cdot day^{-1}$)
Longmai 26	25/15°C	32.19	34.82	1.72
	32/22°C	22.68**	25.82	1.58
Longmai 30	25/15°C	26.54	30.26	1.47
	32/22°C	18.89**	23.29	1.35

**: significant 0.01 probability levels

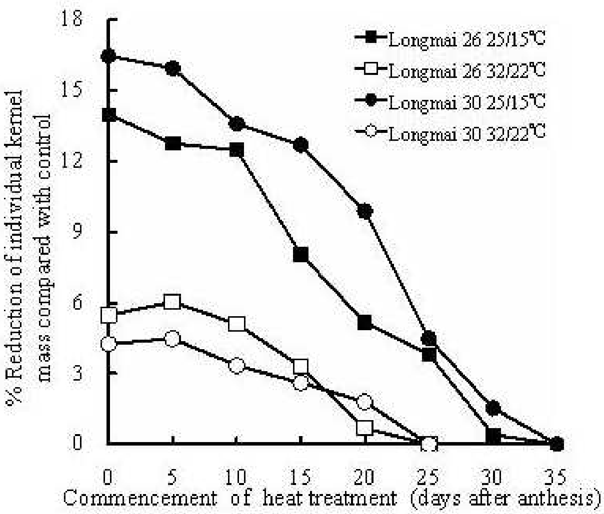

Fig. 1. The effect of short periods of heat stress on percentage reduction of mature grain weight at the two growth temperatures

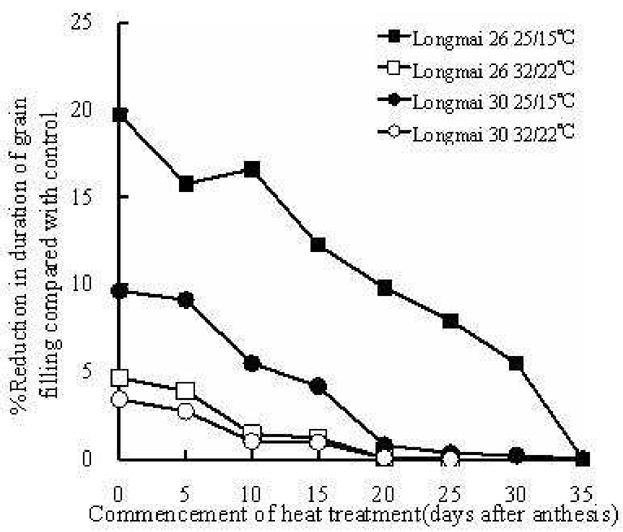

Fig. 2. The effect of short periods of heat stress on percentage reduction in duration of grain filling at the two growth temperatures

and r =0.89; P<0.01 at 25/15°C, r = 0.86; P<0.05 and r =0.87; P<0.05 at 32/22°C, for Longmai26 and Longmai30, respectively). At 25/15°C, for each heat treatment period the effect of a short period of heat stress on the duration of grain filling was greater for Longmai26 than for Longmai30, but the reduction in grain weight was lesser for Longmai26 than for Longmai30. These results probably suggest that the high grain filling rate and high potential grain weight for Longmai26 mitigated the effect of high temperature

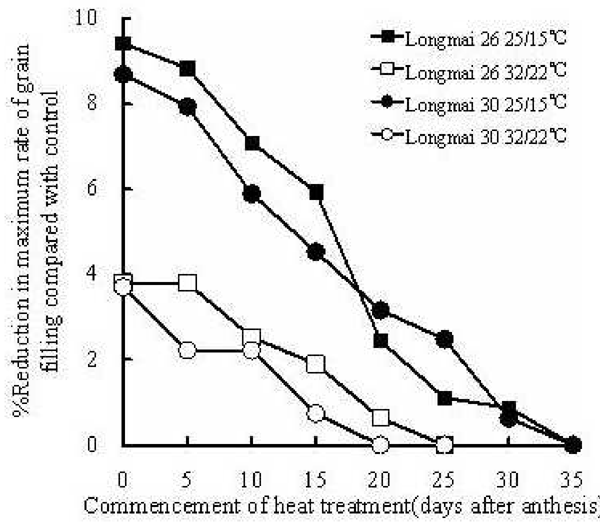

Fig. 3. The effect of short periods of heat stress on percentage reduction in maximum rate of grain filling at the two growth temperatures

stress on grain weight. In contrast, at 32/22°C a brief heat stress also caused the reduction in grain weight, and rate and duration of grain filling for both cultivars, but the magnitude of reduction was smaller than at 25/15°C. The tolerance to a short period of heat stress seems to be improved in higher temperature conditions. Additionally, genotypic variation was small between two cultivars in response of grain filling to heat stress at 32/22°C. The results indicated that genotypic variation in response to a short period heat stress exists when plants were grown at moderately high temperature (<30°C) during grain filling (Zahedi and Jenner 2003). However, when exposed to higher temperature (>30°C) causing damage to plants, there were no significant genotypic variation in response to high temperature including long periods higher temperature and a short period heat stress (Jagdish and Shantha 2004). With the increasing temperature, heat stress is common during grain-filling period in wheat growing areas of the world and will be one of the most important constraints affecting wheat crop productivity. Development of stress tolerant cultivars is one of the promising ways to increase wheat yield under heat stress. High grain weight under heat stress should be the necessary character for selecting heat-tolerant genotype. In our experiment, for all heat treatment, we found that the change in the rate of grain filling is smaller when the heat stress occurs during grain-filling period (Fig. 3). The high grain-filling rate and high potential grain weight should be used as selection criteria in breeding for heat tolerance.

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