DOI: 10.1007/s11099-018-0829-1 PHOTOSYNTHETICA 56 (4): 1287-1296, 2018

Chlorophyll fluorescence, yield and yield components of bread wheat affected by phosphate bio-fertilizer, zinc and boron under late-season heat stress

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Abstract

We examined effects of late-season heat stress (L-SHS) on chlorophyll (Chl) fluorescence parameters and yield of bread wheat as well as roles of phosphate bio-fertilizer (PB-F) and Zn and B to compensate for the likely effects of heat stress. Factors were planting date (21 November and 5 January to coincide with grain filling to L-SHS) as the main factor, no inoculation (control) and inoculation of the seeds with PB-F as the sub-factor, and foliar application of water (control), Zn, B, and Zn + B as 3 L ha^{-1} as sub-sub factor. Results revealed that L-SHS reduced maximal quantum yield of PSII photochemistry, effective quantum yield of PSII photochemistry, efficiency of PSII in the light-adapted state, and the grain yield. Moreover, L-SHS increased the nonphotochemical quenching. The PB-F mitigated the effects of L-SHS on Chl fluorescence, yield, and yield components. Among nutrients, the combined Zn + B was more effective in reducing the effects of L-SHS than that of Zn and B alone. Nevertheless, there was an interaction between foliar nutrients application and PB-F, suggesting that Zn application alone had a profound influence on improving Chl fluorescence parameters and increased yield in combination with PB-F.

Additional key words: photosynthesis; plant nutrition; *Triticum aestivum* L.

Introduction

Wheat (*Triticum aestivum* L.), as a major source of human food, is grown in a vast area of cultivated lands mostly located at altitudes from a few meters to more than 3,000 m a. s. l. (Ahmed and Farooq 2013). High temperature and drought are two major environmental factors limiting the growth and productivity of wheat (Prasad *et al.* 2011). Heat stress affects many cellular processes in plants, resulting in physiological, morphological, and biochemical changes (Zhang *et al.* 2016). Terminal or late heat stress during the last phases of wheat development, especially in booting, heading, anthesis and grain filling stages of the spring, is considered one of the major environmental constraints that drastically reduces grain yield and yield components of wheat in Khouzestan province and other warm and dry regions of Iran (Modhej *et al.* 2008). For optimum growth and yield, wheat plants need phosphorus (P) as a macronutrient and its role irreplaceable (Mohammadi 2012). Phosphate biofertilizers (PB-F), bacteria, such as *Bacillus* and *Pseudomonas*, increase soil soluble P by secreting organic acids and phosphatase enzyme (Ehteshami *et al.* 2007). The supply of P promotes the development of roots, flowers, and fruits formation, the rate of plant maturation, the efficiency and quality of crops, and the resistance to both biotic and abiotic environmental factors (Mohammadi 2012). Most of the Iranian soils, have a high pH and calcareous nature (Abdoli *et al.* 2014) and micronutrients solubility in these soils is low (Mousavi *et al.* 2007). It is believed that micronutrients foliar application is more effective in controlling deficiency problem than soil application (Torun *et al.* 2001). Micronutrients significantly affect dry matter, grain yield, and straw yield in wheat (Asad and Rafique 2000). Zinc is a ubiquitous micronutrient. It is required as a structural and functional component of many enzymes and proteins, and increases the yield and yield components of wheat (Jafari Moghadam *et al.* 2012). Boron is essential for pollen viability, flowering, fruiting, and seed production. As a micronutrient, it plays

Received 11 May 2017, *accepted* 7 February 2018, *published as online-first* 21 June 2018.

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Abbreviations: Chl – chlorophyll; FA – foliar application of Zn and B; F_v/F_m – maximal quantum yield of PSII photochemistry; F_v'/F_m' – efficiency of PSII in the light-adapted state; LPD – late planting date; L-SHS – late-season heat stress; N-HS – no heat stress; NPQ – nonphotochemical quenching; OPD – optimum planting date; PB-F – phosphate bio-fertilizer; ROS – reactive oxygen species; Φ_{PSII} – effective quantum yield of PSII photochemistry.