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RESISTANCE TO HIGH TEMPERATURE STRESS OF VARIOUS BEAN (*PHASEOLUS VULGARIS* L.) CULTIVARS AND LINES

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Summary. The high temperature stress-induced changes in chlorophyll *a* fluorescence parameters were used to study heat tolerance in nine accessions of common bean (*Phaseolus vulgaris* L.) received from the germplasm collection of “Maritsa” Vegetable Crops Research Institute and the Invstitute for Introduction and Plant Genetic Resources. The bean plants were treated for 2h at two temperatures, 23°C and 45°C in controlled conditions. We found that most of the studied cultivars and lines did not show a significant decrease in the maximal PS2 quantum yield (F_v/F_m) below values reflecting reduced structural stability of PS2, except for lines *83201007* and *RRR46*. Simultaneously, a statistically significant increase in the initial fluorescence (F_0) was measured in these lines. A decrease in the maximum fluorescence (F_m) after heat treatment was observed in most of the cultivars and lines studied, except for line *RRR46*. Despite the significant decrease in the F_v/F_m ratio, both lines *83201007* and *RRR46* should not be considered as heat sensitive because of their plastic response to high temperature treatment. Similarly to other lines and cultivars, the lines *83201007* and *RRR46* showed a well-expressed recovery 4h after treatment. Thus, such a flexible response of bean parental lines to high temperature can be used in future breeding programs when seeking a better response to conditions like a sudden jump to higher temperatures.

Key words**:** high temperature stress, photosynthesis, *Phaseolus vulgaris*, chlorophyll *a* fluorescence, photosystem 2.

Abbreviations: PS2 – Photosystem 2, F_0 – initial fluorescence, F_m – maximum fluorescence, F_v – variable fluorescence, PEA – plant efficiency analyzer, LED – light-emitting diode, LHC2 – light harvesting complex, PFD – photon flux density.

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INTRODUCTION

The growth and development of common bean plants (*Phaseolus vulgaris* L.) often coincides with the unfavorable high temperatures which induce heat stress and as a consequence, a significant decrease of productivity. The existing heat tolerant lines usually have both low productivity and quality. New heat-tolerant varieties with higher productivity and good quality were recently investigated (Petkova et al., 2007).

Photosynthesis has long been recognized as one of the most heat-sensitive processes in plants (Berry and Björkman, 1980; Zhang and Sharkey, 2009). There are at least three major stress-sensitive sites in the photosynthetic machinery, the Photosystem 2 (PS2), the ATPase, and the carbon assimilation processes (for review see Allakhverdiev et al., 2008).

Our earlier paper presented a breeding program aimed to find promising lines for heat-tolerance selection (Petkova et al., 2007). As breeding markers a limited number of chlorophyll fluorescence parameters were used that are known to exhibit changes under heat stress, namely F_0, F_m and the F_v/F_m ratio (Briantais et al., 1996).

In field conditions high temperature is usually associated with high light intensity and drought which exacerbate the damages in PS2 (Srivastava and Strasser, 1996; Lichtenthaler, 1996). In the present investigation, the bean plants were estimated for heat tolerance after treatment with high temperature as well as during recovery from the heat stress after the plants were transferred to optimal temperature. Heat treatment was performed in controlled conditions, thus eliminating interference of additional stress effects such as drought, light etc. Thus, searching for distinctive traits necessary for successful breeding was achieved.

MATERIAL AND METHODS

Plant material, cultivation and treatment

Nine common bean (*Phaseolus vulgaris* L.) accessions (3 varieties and 6 lines) from the germplasm collections of the Maritsa Vegetable Crops Research Institute, Plovdiv, and the Institute of Plant Genetic Resources, Sadovo were used for this screening including var. *Starozagorski cher, Ranit, Secuntsa*, and lines *83201007, RH13, RH26D, BBSR17, BBSR28*, and *RRR46*. Fifteen plants from each accession were grown in 5L pots on a mixture of soil and peat under controlled greenhouse conditions until blossoming stage. Plants were treated with HT (45^{o}C) for 2h and returned for another 4 h to recover at a control temperature of 23^{o}C.

Fluorescence measurements

Chlorophyll fluorescence parameters were measured using a Plant Efficiency Analyzer (PEA), Hansatech Instruments Ltd., UK The details of measurements are described elsewhere (Petkova et al., 2007).

The data were statistically processed by the common MS Excel software and only differences with $P < 0.05$ were discussed.

RESULTS AND DISCUSSION

The effects of high temperature (45°C) on bean plants were estimated by changes in the maximal PSII quantum yield, i.e. the F_v/F_m ratio (Fig. 1). Thus, the level of structural stability of the PSII complex was used as a maker for estimation of the best heat resistance among the studied lines and cultivars. The capacity for recovery from the heat-induced decrease in the F_v/F_m ratio was studied 4h after heat treatment and was also used for assessment of heat resistance. We found that most of the studied cultivars and lines did not show a significant decrease in the maximal PS2 quantum yield (F_v/F_m) below values that reflect reduced structural stability of PS2, except for lines *83201007* and *RRR46* (Fig. 1). It is considered that heat-induced damages in PS2 occur when the F_v/F_m ratio was lower than 0.76. Such a decrease was observed in lines *83201007* and *RRR46* (0.73 and 0.66, respectively) (Fig. 1). Despite the significant decrease in the F_v/F_m ratio both lines *83201007* and *RRR46* should not be considered as heat sensitive because of their plastic response to high temperature treatment. Similarly to most other lines and cultivars, lines *83201007* and *RRR46* showed a well-expressed recovery in the F_v/F_m ratio 1h after heat treatment (Fig. 1).

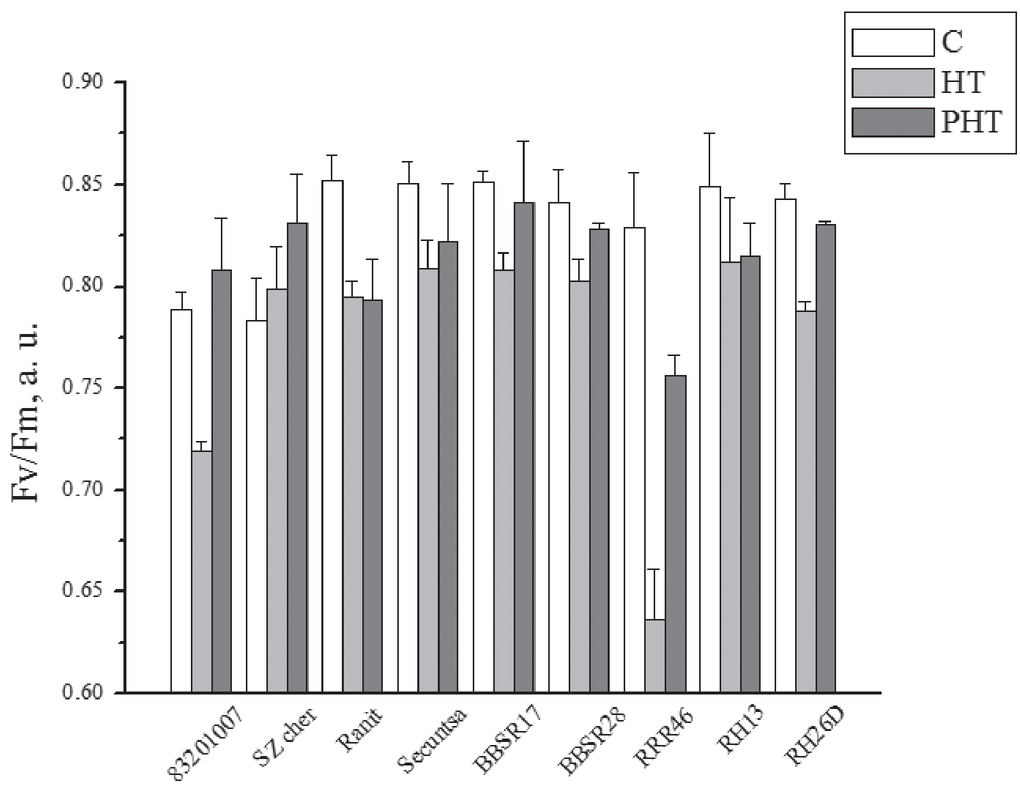

Fig. 1. Temperature-induced changes in the maximum quantum yield of primary photochemical reactions in PS2 revealed as the F_v/F_m ratio in 9 accessions of common bean (*P. vulgaris* L.). Plants were treated with 45°C for 2h and then returned for recovery to control temperature conditions. C – control plants at 23°C; HT – high temperature treated plants at 45°C for 2h; PHT – HT treated plants returned for recovery for 4h at 23°C.

To test the functionality of the light harvesting complex 2, LHC2, fluorescence measurements were done on the initial F_0 level (Fig. 2). The rise in the F_0 values suggested damages in PS2 antenna or reversible movement of part of LHC2 to either photosystem 2 or 1. In both *83201007* and *RRR46* lines a statistically significant increase in the initial fluorescence (F_o) was observed in parallel with the decrease in the maximum PS2 quantum yield, thus suggesting the development of damages in LCH2. A well observable decrease in F_0 after recovery was also found (Fig. 2). Such a recovery of F_0 values could mean that a heat-induced transition of the mobile part of LHC2 to PS1 rather than heat-induced damages could be expected. The movement of LHC2 regulates excitation between both photosystems.

Consequently, the *83201007* and *RRR46* lines showed a well-expressed recovery 4h after treatment similarly to other studied bean plants. Thus, such a flexible response of bean parental lines to high temperature can be used in future breeding programs when seeking a better response to conditions including sudden

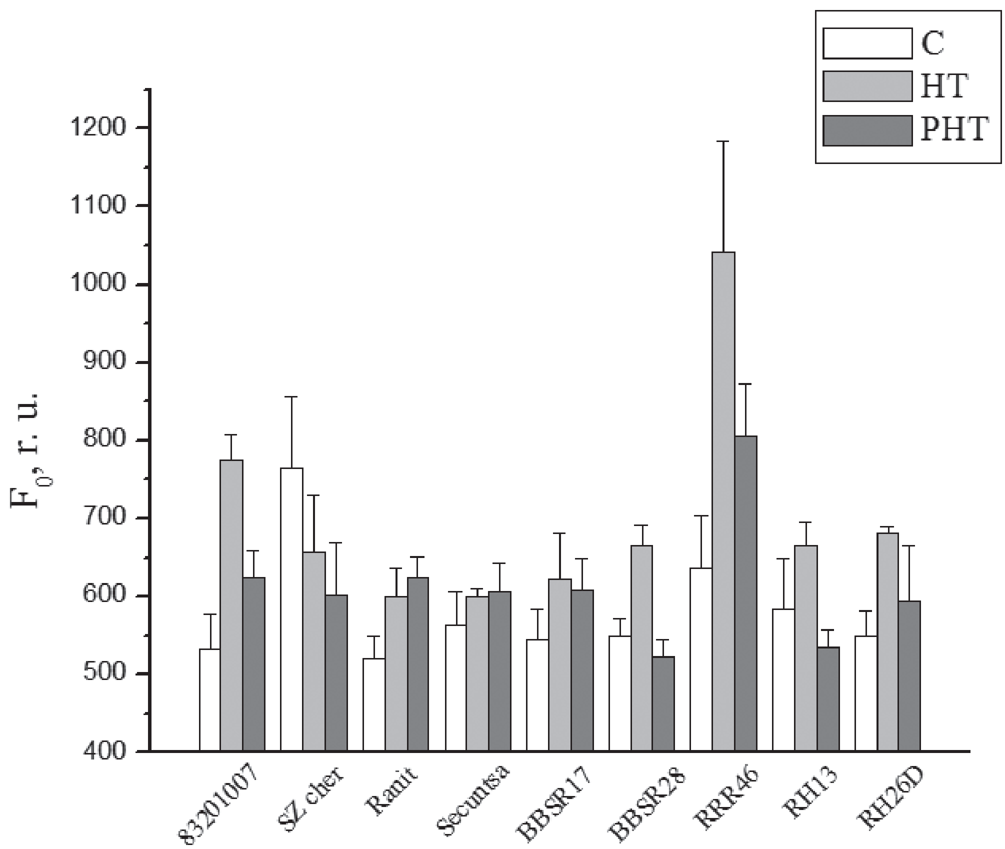

Fig. 2. Temperature-induced variations in the initial chlorophyll fluorescence (F_0) in 9 accessions of common bean (*P. vulgaris* L.) measured in controlled conditions with a portable PEA system. Plants were treated with 45°C for 2h and then returned for recovery to control temperature conditions. C – control plants at 23°C; HT – high temperature treated plants at 45°C for 2h; PHT – HT treated plants returned for recovery for 4h at 23°C.

jump to higher temperatures.

The obtained results confirmed that *in vivo* chlorophyll *a* fluorescence could be successfully applied in a breeding program. The present experiments with heat treatment of bean plants under controlled conditions for assessment of heat tolerance revealed some differences when compared with our earlier field investigations (Petkova et al., 2007). Consequently, precise observations of the effects of higher temperatures alone or in combination with other stress factors should be taken into account during development of breeding programs.

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