ЕФЕКТ НА ПОЧВЕНОТО ЗАСУШАВАНЕ ВЪРХУ ЛИСТНИЯ ГАЗООБМЕН И ВОДООБМЕНА НА МЛАДИ РАСТЕНИЯ ОТ ФАСУЛ (*PHASEOLUS VULGARIS* L.)
EFFECT OF SOIL DROUGHT ON LEAF GAS EXCHANGE AND WATER RELATIONS IN YOUNG BEAN PLANTS (*PHASEOLUS VULGARIS* L.)

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Резюме

Проучено е влиянието на почвеното засушаване върху параметрите на листния газообмен и водообмена в млади растения от фасул (*Phaseolus vulgaris* L.) от два сорта – *Абритус* и *Добруджански 7*. Засушаването е приложено върху двуседмични растения чрез прекратяване на поливането за 10 дни. Установено е, че приложеният воден дефицит предизвиква значително понижение в скоростта на нето фотосинтезата и интензивността на транспирацията при растенията от двата сорта. Засушените растения от сорта *Абритус* запазват ефективността на използване на водата (WUE), а при тези от сорта *Добруджански 7* WUE е значително повишена. Установени са и съществени промени в показателите на водообмена, които са сходни при проучваните сортове фасул. Съществени различия са установени само по отношение на транспирацията на единица маса (T), която е понижена повече от два пъти в растенията от сорта *Добруджански 7*. Въз основа на получените експериментални резултати е установено, че сортовата реакция към приложеното засушаване е идентична, но се установяват и някои различия. В растенията от сорта *Добруджански 7* E и gs са понижени в по-голяма степен от A и това води до повишена WUE. В растенията от сорта *Абритус* A е понижена в по-голяма степен от E и gs, поради което WUE е незначително понижена. От показателите на водообмена в най-голяма степен се понижава водният потенциал (Ψw) – повече от 4 пъти.

Abstract

The effect of soil drought on the leaf gas exchange parameters and water relations in young bean plants (*Phaseolus vulgaris* L.) – cv. *Abritus* and cv. *Dobrudjanski 7* were studied. Drought conditions were imposed on 2-week old plants by withholding water for 10 days. It was found that drought stress significantly decreased the net photosynthetic rate and transpiration. *WUE* in stressed plants of cv. *Abritus* remained unchanged, while in cv. *Dobrudjanski 7 WUE* was significantly increased. The water relation parameters were also affected. The changes were similar in the studied cultivars. In cv. *Dobrudjanski 7 T* was decreased more than twice, while in cv. *Abritus T* was decreased by 40 %. On the basis of the experimental outcomes, it was established that the cultivar reaction to drought was identical, but some differences were observed as well. In cv. *Dobrudjanski 7 E* and gs were decreased to a greater extent than *A*, and *WUE* was significantly higher. In cv. *Abritus A* was decreased to a greater extent than *E* and gs, and *WUE* was slightly reduced. The leaf water potential (Ψw) is a parameter of water relations, which was reduced more than fourfold.

Ключови думи: фасул, засушаване, водообмен, листен газообмен.
Key words: common bean, drought, leaf gas exchange, water relations.

INTRODUCTION

Drought is one of the most important environmental stresses affecting agricultural productivity around the world and may result in considerable yield reduction (Ludlow and Muchow, 1990). Approximately 60% of bean production regions suffer serious drought conditions (Wang et al., 2003). The plant response to drought at the whole plant and crop levels is complex because it reflects the integration of stress effects and responses at all underlying level of organization over space and time (Blum, 1996). Drought stress leads to morphological, physiological, biochemical and molecular changes that negatively affect plant growth. The dehydration process during drought is characterized by fundamental changes in water relations, photosynthetic carbon assimilation, uptake and assimilation of mineral nutrients, membrane structure and ultrastructure of subcellular organelles (Yordanov et al., 2000; Zlatev and Yordanov, 2004).

At the whole plant level, the effect of drought is usually perceived as a decrease of photosynthesis and growth (Mwanamwenge et al., 1999; Yordanov et al., 2001). The rate of CO_2 assimilation in the leaves was reduced at moderate water deficit (Yordanov et al., 1997; Zlatev and Yordanov, 2004) or even before leaf water status was changed in response to a drop in air humidity or soil water potential (Socias et all., 1997).

The reduction in photosynthesis as a result of water stress can be attributed to both stomatal and non-stomatal limitations (Graan and Boyer, 1990; Shangguan et al., 1999). Non-stomatal reduction in photosynthesis is attributed to reduction in RuBP carboxylation efficiency, reduction in RuBP regeneration, or reduction in the amount of ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBPCO) (Kanechi et al., 1995; Tezara and Lawlor, 1995). Generally, water stress damages oxygen-evolving complex of photosystem 2 (PS2) and PS2 reaction centres (Havaux, 1992; He et al., 1995).

However, there are several studies concluding that photosynthetic apparatus (PA) is not affected significantly by water stress (Cornic, 1994). The PA is well protected under water stress (Cornic and Massacci, 1996) by increased non-radiative energy dissipation and by increased photorespiration (Heber et al., 1996).

The main way for reaching high and stable yields is breeding of drought tolerant bean genotypes. Drought tolerant genotypes combine different tolerance mechanisms, and in specific conditions the ones are leading. The determination of these physiological and biochemical leading mechanisms is of importance for breeding process. Breeders have developed tolerant bean genotypes better adapted to specific environmental stress conditions, although the nature of the acquired tolerance remains usually unknown. Ones of the promising methods for assessing drought tolerance of plants are the growth analysis and monitoring of changes in leaf gas exchange and water relation.

The aim of the present study was to establish the effect of soil drought on leaf gas exchange and water relations of two common bean cultivars – *Abritus* and *Dobrudjanski 7*.

MATERIAL AND METHODS

Plants of two bean cultivars – *Abritus* and *Dobrudjanski 7*, were grown into plastic pots with 1.5 kg of sandy soil. 14 days after the emergence plants were divided into two groups – control and droughted. The second group was subjected to a 10-day drought by withholding watering. The conditions of plant growing and the drought treatment have been previously described (Zlatev and Yordanov, 2004).

The leaf gas exchange parameters - net photosynthetic rate (A), transpiration rate (E) and stomatal conductance (gs) were determined at the end of the drought period on the petiole of the central leaflet of the first compound leaf. The analyses were conducted with a portable photosynthetic system LCA-4 (ADC, Hoddesdon, England) under the following conditions – light intensity (PAR) - 750 $\mu mol\ m^{-2}\ s^{-1}$, ambient CO_2 concentration - 350 $\mu mol\ mol^{-1}$ and temperature of 26 °C.

Relative water content of leaves (RWC) was determined according to Morgan (1986). Leaf water potential was determined using a pressure chamber (Turner, 1988). Water use efficiency (WUE) was calculated as the ratio of net photosynthetic rate (A) and transpiration rate (E). Transpiration per unit plant weight (T) was calculated as the ratio of water use on the last day before sampling and plant dry weight. Proline content was determined according to Bates and all. (1973).

Values obtained were expressed as mean ± SE of five replications. The Student's *t-test* was used to evaluate the differences between the control and the stressed plants.

RESULTS AND DISCUSSION

The results in Table 1 show that after 10-day drought period, the leaf gas exchange rate in the plants of both cultivars was significantly reduced. In cv. *Dobrudjanski 7*, E and gs were reduced to a greater extent than A, while in cv. *Abritus*, A was suppressed more than E and gs. The photosynthetic water use efficiency (WUE), expressed as the A/E ratio, increased significantly in cv. *Dobrudjanski 7*, while in cv. *Abritus* it decreased insignificantly. Stomatal closure is a well known plant response to water stress, restricting water losses. Here, the photosynthetic rate is undoubtedly reduced. By the end of the drought period, the plants of cv. *Dobrudjanski 7* restricted their transpiration and stomatal conductance to a greater extent than did the plants of cv. *Abritus*.

Plants differ in the stomatal role in maintaining the functional activity of photosynthetic apparatus during periods of drought (Chaves, 1991). In certain plants, the stomatal control is of dominant importance and these plants are characterised by increased water use efficiency. In others, that keep their stomata relatively open, due to either being able to compensate for water losses or to a loss of stomatal control, the water use efficiency could remain unchanged or insignificantly reduced. Our studies related the young bean plants of cv. *Dobrudjanski 7* to the first group, and those of cv. *Abritus* - to the second.

By the end of the drought period, the changes in the relative water content (RWC) of both cultivars were significant (Table 2). A greater RWC reduction was established in cv. *Abritus*. Ψw decreased significantly at the same extent in both cultivars. The changes in RWC and Ψw were probably due to some structural and functional

Таблица 1. Листен газообмен при два сорта фасул (*Абритус* и *Добруджански 7*) след 10-дневно почвено засушаване. **A** – скорост на нето фотосинтезата [μmol m^{-2} s^{-1}]; **E** – интензивност на транспирацията [mmol m^{-2} s^{-1}]; **gs** – устична проводимост [mmol m^{-2} s^{-1}]; **WUE** – ефективност на използване на водата [μmol $mmol^{-1}$]

Table 1. Leaf gas exchange parameters of two bean cultivars (*Abritus* and *Dobrudjanski 7*) after 10-day of soil drought. **A**–net photosynthetic rate [μmol m^{-2} s^{-1}]; **E**–transpiration rate [mmol m^{-2} s^{-1}]; **gs**–stomatal conductance [mmol m^{-2} s^{-1}]; **WUE**–photosynthetic water use efficiency [μmol $mmol^{-1}$]

Variant	**A**	**E**	**gs**	**WUE**
	Abritus			
control	13,51±0,98	3,76±0,24	374±21	3,59±0,42
drought	3,81± 0,23 *** (28)	1,17±0,09 *** (31)	120± 9 *** (32)	3,26±0,37 (91)
	Dobrudjanski 7			
control	14,26±1,13	3,87±0,29	358±20	3,69±0,29
drought	3,43±0,21 *** (24)	0,70±0,05 *** (18)	68± 6 *** (19)	4,89±0,35 * (131)

* P<0.05, *** P<0.001

Таблица 2. Промени в относителното водно съдържание (**RWC** [%]), водния потенциал в листата (**Ψw**[MPa]), съдържанието на пролин (**P**[mg g^{-1}]) и транспирацията на единица маса (**T** [g g^{-1} day^{-1}]) при два сорта фасул (*Абритус* и *Добруджански 7*) след 10-дневно почвено засушаване

Table 2. Changes in the leaf relative water content (**RWC** [%]), leaf water potential (**Ψw** [MPa]), proline content (**P** [mg g^{-1}) and transpiration per unit plant weight (**T** (g g^{-1} day^{-1}] of two bean cultivars (*Abritus* and *Dobrudjanski 7*) after 10-day of soil drought

Variant	**RWC**	**Ψw**	**P**	**T**
	Abritus			
control	92,7±3,4	-0,6±0,02	37,4±2,7	16,20±0,94
drought	67,5±2,8 ** (73)	-2,3±0,07 *** (26)	112,3±4,6 *** (300)	9,74±0,71 ** (60)
	Dobrudjanski 7			
control	92,4±3,9	-0,5±0,02	28,7±1,9	15,40±0,82
drought	71,9±3.1 ** (78)	-2,2±0,08 *** (23)	80,3±3,7 *** (280)	7,40±0,68 ** (48)

** P<0.01, *** P<0.001

changes, ensuring plant adaptation to the drought treatment (Paleg et al., 1984; Zlatev, 2005). T decreased significantly in studied cultivars – more than twice in cv. *Dobrudjanski 7* and by 40% in cv. *Abritus*.

The plants of tested genotypes showed identical response in terms of the water relation parameters - relative water content (RWC) and water potential. RWC decreased to a lesser extent, while the Ψw reduction was by more than four times.

During period of water deficit water potential and relative water content decreased with an associated decrease of net photosynthetic rate, transpiration rate and stomatal conductance (Yordanov et al., 2001). These authors have found a significant correlation among the components of leaf water status and the measured photosynthetic parameters. Our results showed that under drought conditions net CO_2 fixation rate decreased in studied cultivars, although not to same extent, due to decreasing stomatal conductance and transpiration rate. The decrease of photosynthesis caused by drought has been attributed to both stomatal (restricted CO_2 availability) and non-stomatal limitations (Shangguan et al., 1999; Yordanov et al., 2000). Stomatal closure was the most prominent determinant for the increased WUE. In addition, our results support observations that transpiration efficiency differed significantly between cultivars with different drought acclimation capabilities.

Metabolic acclimation via the accumulation of compatible solutes is also regarded as a basic strategy for the protection and survival of plants in extreme conditions (Yordanov et al., 2001). Te synthesis of proline in leaves can enhance protection to drought. The major role of metabolites like proline, sugar alcohols, amino acids and their derivatives is to serve as organic osmolytes with compatible properties at high concentrations. Such osmolytes increase the ability of cells to retain water without disturbing normal cellular function (Yordanov et al., 2001). Differences between cultivars can be also due to operation of additional mechanisms functioning in some cultivars but not in others.

CONCLUSIOM

Many studies have illustrated the complexity of the photosynthetic responses and changes in water relations to drought stress. The results presented in this work suggest that the degree of tolerance to drought of bean cultivars is the result of their different plasticity and ability to short and long-term acclimation. It was established that the cultivar reaction to drought is identical, but some differences are maintained. In cv. *Dobrudjanski 7* E and gs are decreased in greater extent than A, and WUE is significantly higher. In cv. *Abritus* A is decreased in greater extent than E and gs, and WUE is slightly reduced. The leaf water potential (Ψw) is parameter of water relations, which is reduced at about four times.

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