Research Paper Agricultural Science

Effect of Water Stress on Selected Physiological Responses of Soybean

Eleonóra Krivosudská Dr. Eleonóra Krivosudská, PhD., Department of Plant Physiology, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 01 Nitra, Slovak Republic

Angelika Filová Dr. Angelika Filová, PhD., Department of Plant Physiology, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 01 Nitra, Slovak Republic

ABSTRACT

The objective of this research was to investigate possible genetic variation in the sensitivity of soybean cultivars for nitrogen fixation rates in response to soil drying. This stress had a negative impact on the physiological parameters. By comparing the RWC values, the decrease was more significant at the end of dehydration, which was monitored in Maverick and Drina genotypes using the Nitrazon inoculants and water stress effect. Inoculated stressed Nigra and Polanka genotypes have kept higher water content till the end of dehydration period. Also the proline accumulation was monitored during the water stress, whilst higher content of free proline reached of Maverick. More remarkable decrease of osmotic potential was again registered in a foreign Drina and Maverick genotypes in the inoculated variations. Nigra and Polanka genotypes responses not so significant in the given conditions. The highest values of SPAD number were registered on the stressed inoculated Polanka.

KEYWORDS soybean, drought, physiological responses

INTRODUCTION

A year of origin has got a significant influence on the crop of soybean seed and negatively affects the seed crop in the years with deficient rainfall and long periods of drought during the vegetative season as a consequence of global warming. Therefore, it is required from the future point of view the testing and right choice of appropriate biological material for the stress conditions and of course to test inoculants and nitrogen nutrition. Croppers in the Slovak Republic have not still fully appreciated an importance of soybean. It is only a loss for our croppers that a process of widening its sowing areas and with this connected building of manufacturing capacity for soybean are presently very slow (Krivosudská, Filová, 2013).

From the point of view of ecophysiology, it is important to solve a question of climatic changes by the means of detailed cognition of physiological processes rules in the plant. Overall, the results of this study indicate that important genetic variations for sensitivity of nitrogen fixation to soil drying exist in soybean, and that the variation may be useful in physiology and breeding studies. Process, experienced this way, can be objective and rationally used by agronomist and breeders. Drought is considered the major abiotic stress in many parts of the world and is responsible for heavy production losses in food legumes (Malhotra *et al*., 2004).

Soybean as a moisture-demanding crop plant is reflecting a significant drop of seed crop during a season with the unbalanced rainfall and a lack of moisture. This crop drop is discouraging a plenty of croppers who have tried its growing. In spite of this disadvantage, it is undoubtedly a kind of crop with an important position in a seeding process which it gained thanks to a fact that it represents a foregoing crop plant as it leaves a huge amount of mineral nitrogen in a soil (Riccardi et al., 2001).

Material and methods

In the floricultural year 2014 an experiment with four genetic resources of soybean was launched. The genotypes selection was undertaken according to their provenance. Seed corn was provided by Gene Bank of the Slovak Republic in Piešťany. Sowing of Maverick (USA), Drina (HRV), Nigra (SVK) and Polanka (CZK) genotypes was carried out in the containers of 15 l capacity. The sowing consists of several repetitions with Nitrazon (Agrokomp, spol. s r.o. in Modra) inoculants and variants without inoculation, too. Regarding the selected bacteria it is prepared separately for each crop species of the soybean family (*Fabaceae*). It has a high content of live bacteria (max. 3.08 x$10^{9)}$. It directly contributes to increase of protein content in grown crops and is beneficial to yield increase and better microbial soil activity.

At the beginning of the growth phase R1 and R2 – flowering, water stress was simulated by suspending the irrigation and preventing any moisture to occur. Water content in the leaves, osmotic potential, free proline level and content of chlorophyll a + b in the leaves (SPAD value) on the dehydrated variants as well as on the irrigated variants were monitored during water stress. The above mentioned physiological parametres were during water stress period evaluated on 2^{nd}, 6^{th} and 9^{h} day (the end of dehydration) on the inoculated variants and also on the variants without inoculation comparing to the control fully hydrated plants and variants with dehydration.

During the gradual dehydration RWC in % was monitored which showed us the water content in leaf tissue relatively to the maximum water content in the tissue after saturation. After saturation the sample was drying for 12 hours by temperature 100 ˚C for a determination of dry basis weight. A psychrometric method (Wescor, Logan, Utah, USA) was used for Ψ_s measuring. Free proline is being determined by (Bates, 1973) method in the leaf tissue. The coloration intensity is spectrophotometrically measured at 520 nm compared to the clean toluene. Chlorophyll meter SPAD – 502 (Minolta, Japan) measuring of the nitrogen in the leaves. Portable device SPAD – 502 works on a measuring method of light transmission through the leaves in two wave lengths 650 and 940 nm. The device will automatically calculate an average of these two data and indicate the so called SPAD number.

Results and Discussion

Drought stress is defined as conditions, in which a capacity of water accessible for plants is so small that they are insufficient for plant species growth. Correlation between total water content in the plant and the water capacity by full turgescence is expressed with the relative water content (RWC in %). Under the given circumstances it was therefore intended to monitor RWC decrease in selected soybean genotypes. When comparing RWC values a more significant decrease at the end of dehydration was registered in foreign genotypes Maverick (41.59%) and Drina (38.24%) using Nitrazon inoculant and the effect of water stress. Inoculated stressed genotypes Nigra (SVK) and Polanka (CZK) maintained higher water content at the end of dehydration (64.12% and 60.05%).

In controlled watered variants with inoculation RWC content in foreign genotypes was as follows: 80.78% (Maverick) and 80.38% (Drina) compared to the inland genotypes, which maintained higher levels of RWC (Nigra 90.46%, Polanka 88.01%).

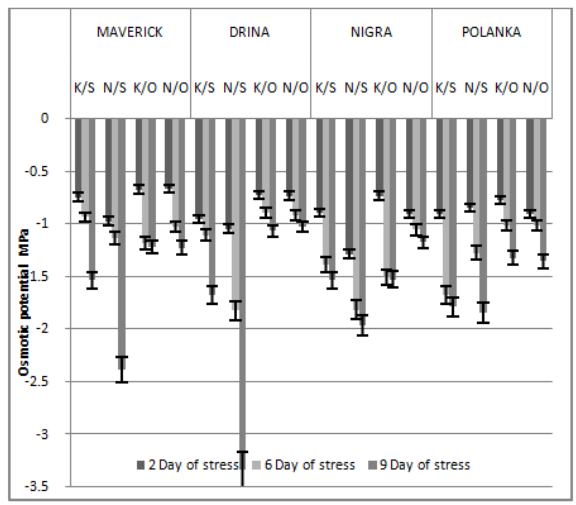
Many studies showed the positive correlation between the proline accumulation and plant osmotolerance and that the increasing proline level is a stress consequence (Tokihiko *et al.*, 1999). During water stress was therefore also monitored the proline accumulation, whilst the higher level of free proline was by the dehydrated plants with inoculant usage as follows: 18.57 μmol.g^{-1}FW (Maverick) a 17.46 μmol.g^{-1}FW according to calculations to 100% of RWC (Drina), which is associated with a more remarkable RWC content decrease in the leaves. Inland stressed genotypes, which kept higher RWC levels on the 9th day of dehydration and therefore also in the accumulation of proline achieved lower values (Nigra 4.68 μmol.g^{-1}FW and Polanka 4.48 μmol. g^{-1}FW according to calculations to 100% of RWC). Comparing the genotypes without inoculation, exposed to the water stress, level of free proline in leaves was lower (Maverick 2.14 μmol.g^{-1}FW, Drina 2.37 μmol.g^{-1}FW, Nigra 3.22 μmol.g^{-1}FW and Polanka 3.11 μmol.g^{-1}FW).

Handa (1986) found that in proline accumulation the level of proline is independent of the water potential or turgor of cells, but not of the osmotic potential. Proline final level depends on the adaptation degree. Therefore within the ongoing water stress it was necessary to monitor another important indicator – increasing of osmotic potential values (Figure 1). More significant decrease was again recorded in foreign Drina (-3.34 MPa) a Maverick (-2.39 MPa) genotype in inoculated, variants, exposed to the water stress. Genotypes less Nigra (-1.97 MPa) and Polanka (-1.85 MPa) responded less remarkable in the given conditions.

Osmotic potential decresed less significant on the dehydrated variants (Maverick -1.54 MPa, Drina -1.68 MPa, Nigra -1.54 MPa a Polanka -1.79 MPa) in the conditions without inoculation, what partially indicates their smaller tolerance to the drought.

Large differences in midday leaf water potential were observed in rainfed legume crops, with chickpea and lentil reaching –3.3 MPa while pea and faba bean reached –2.0 MPa, but only chickpea maintained photosynthesis below –3.0 MPa (Leport *et al.,* 2003). Within SPAD value measurement – number, which method is based on a direct measurement of chlorophyll a + b content, whilst a gradual decrease of the mentioned parameter was registered in the drought conditions. The highest values of SPAD number were measured on 9th day of dehydration on the stressed inoculated Polanka (34.8) genotype. Other tested genotypes Maverick, Drina, Nigra reached average SPAD values in a range between 29.7 - 31.6. By monitoring an influence of Nitrazon inoculants, we can conclude that notable differences occurred mainly in the above mentioned Polanka genotype, because it had in average much lower SPAD value (21.9) under water stress without inoculation.

Figure 1: Osmotic potential in soybean genotypes leaves depending on dehydration period and seeds inoculation [MPa] K/S control and water stress, N/S Nitrazon and water stress, K/O control variant, N/O Nitrazon variant



CONCLUSIONS

The work confirmed that the selected physiological characteristics (RWC, SPAD and proline) are good evaluating parameters for the determination of water stress in plant. In the floricultural year 2014 an experiment with four genetic resources of soybean was launched. Sowing of Maverick (USA), Drina (HRV), Nigra (SVK) and Polanka (CZK) genotypes was carried out in the containers of 15 l capacity. The sowing consists of several repetitions with Nitrazon inoculants and variants without inoculation, too. At the beginning of the growth phase R1 and R2 – flowering, water stress was simulated by suspending the irrigation and preventing any moisture to occur. Water content in the leaves, osmotic potential, free proline level and content of chlorophyll a + b in the leaves (SPAD value) on the dehydrated variants as well as on the irrigated variants were monitored during water stress. The most sensitive parameter is probably proline concentration in leaves. The selection of genotypes with needed resistance to drought and quantification of their productive qualities in the structures of plants, monitoring and ensuring of non-limiting enviromental conditions by measuring the RWC, SPAD, Ψ_S and proline allows an important insight into the regulation of productivity growth. Understanding of heterogeneity of genotype productive capabilities offers an assumption for a better characterization of new and prospective biological material in breeding practice. Negative effects of climate change can be mitigated throught appropriate choice of plant species, improving water management and irrigation systems.

Acknowledgements

This study was financed by project: Vybudovanie výskumného centra ,,AgroBioTech", ITMS kód: 26220220180.

REFERENCES

[1] Bates, L. S. and Waldren, R. P. (1973), "Rapid determination of proline for water stress studies." Plant and Soil, 39: 113–127 | [2] Handa, S. and Hasegawa, P. (1986), "Proline accumulation and the adoptation of plants to water stress." In Plant Physiology, 80: 938-945 | [3] Krivosudská, E. and Filová, A. (2013), "Evaluation of selected soybean genotypes (Glycine max. L.) by physiological responses during water deficit." In: Journal of Central European Agriculture. Vol. 14, no. 2 p. 213-228, | [4]Leport, L., Turner, N.C., French, R.J., Thomson, B.D., (2003), "Physiological responses of cool-season grain legumes to drought in the lowrainfall Mediterranean environment of south-western Australia. In: N.P. Saxena (Ed.), Management of Agricultural Drought: Agronomic and Genetic Options, pp.163–172, UK. | [5] Malhotra, R.S., Sarker, A., Saxena, M.C., (2004), "Drought tolerance in chickpea and lentil-present status and future strategies." Challenges and Strategies for Dryland Agriculture, no. 32, Crop Science Society of America and American Society of Agronomy, USA, 257–273 | [6] Riccardi, L., Polignano, G.B., de Giovanni, C. (2001), "Genotypic response of faba bean to water stress." Euphytica, 118: 39–46 | [7] Tokihiko, N., Masatomo, K., Yoshu, J., Yukika, S., (1999), "Biological functions of proline in morphogenesis and osmotolerance revealed in antisence transgenic Arabidopsis thaliana L." The Plant Journal, 18: 185-193