Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 1, 2024
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

PHYSIOLOGICAL RESPONSE OF SOME SOYBEAN GENOTYPES TO WATER STRESS AND COMPENSATION EFFECT AFTER REHYDRATATION

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Abstract

Soybean is a very important crop due to its multiple uses, but hydric stress can substantially reduce soybean production. The response of soybean plants to drought and the compensation effect of growth after rehydration has been very little studied. In this context, this paper presents results regarding the response of some soybean genotypes to water stress and soil rehydration. Our goal being to identify genotypes that have a compensation mechanism in response to drought to support breeding for drought resistance and higher yields. Eight soybean genotypes were studied under greenhouse conditions. Water stress inhibited the growth of soybean plants. After rehydration, soybean plant height and leaf surface showed a rapid growth/recovery and produced good compensation compared to the root system where the compensation phenomenon was less. Water stress reduced the chlorophyll content and upon rehydration, different levels of compensation were observed in each studied genotype, there was even one genotype that showed an overcompensation.

***Key words**: soybean, drought, compensation effect, physiological traits.*

INTRODUCTION

In recent years, the European Union has paid special attention to the cultivation of soybeans, being aware of the benefits that the increase in cultivated areas can bring. In Romania, the data published by the Ministry of Agriculture and Rural Development highlight a decrease in the areas cultivated with soybeans in 2022 (135 thousand hectares) compared to 2018 (169 thousand hectares), (https://www.madr.ro). But, in terms of production, it is worth noting the good average productions of years 2018, 2019 and 2021 when more than 2.5 tons per hectare were obtained, which confirms that profitable soybean crops can be made in Romania. To obtain high yields, soybeans need a sufficient supply of water during the growth and development process, the drought can significantly reduce plant growth, chlorophyll content, production (Petcu E., 2008).

A number of studies have shown that if a certain level of drought stress is followed by a period of hydration, soybean plants can show a positive growth compensation or even overcompensation in terms of metabolism so that production losses caused by drought can be reduced (Xue et al., 2013, Buezo et al., 2019).

Compensation is an important self-regulatory mechanism used by plants to defend against physical injury or abiotic stress (Dai, 2007). It is also a major physiological reference for efficient water control in plants and an indicator of water use efficiency in agriculture An obvious example of compensation consists in the external morphology of the plant after the removal of a stress, such as the rapid increase in the plant height and leaf area, i.e. the growth compensation effect (Bu et al., 2009).

The new Romanian soybean varieties are productive, with good production stability, with resistance to the main stress factors (Barbieru and Stanciu, 2021). They have been studied for the assessment of resistance of low temperature, scanning for size, genotype color and *Cercospora* blight detection (Petcu Victor et al., 2021) but studies on drought resistance are relatively few (Petcu et al., 1995).

Our goal to investigate soybean responses to drought stress and growth through metabolism compensation after rehydration, and to establish an optimal soybean screening method based on physiological traits which can be exploited in breeding to develop water stress tolerant cultivars.

MATERIALS AND METHODS

Eight soybean genotypes provided by the Oil Plant Breeding laboratory of INCDA Fundulea were studied. The experiments were carried out under greenhouse conditions. The experimental variants were:

- control, plants grown in chernoziom cambic soil in pots up to the V3 growth stage with optimal watering (70% of the soil's water capacity)
- water stress, plants grown in cambic chernoziom soil in pots up to the V3 growth stage with watering 45% of the water capacity of the soil, for 14 days;
- rehydration, plants grown in cambic chernoziom soil in pots up to the V3 growth stage with watering 45% of the soil's water capacity for 14 days after which they were watered at 70% of the soil's water capacity for 14 days .

The determinations made were: plant height and the length of the main root (with the help of a ruler), the leaf surface (the method of measuring the length and width of the leaves to which a correction coefficient for soybean is added), the chlorophyll content (with the help of the chlorophyll meter SPAD-502), accumulation of aerial and root biomass (weighing).

To quantify recovery/resilience, we used equation used by Elsalahy et al. (2020) according to Orwin and Wardle (2004).

$$r \text{ (recovery index)} = 2|D0|(|D0|+ (|Dx|) -1$$

where D0 is the difference between the selected response variable of the control and the stressed plants at the end of the water stress at (t0). And Dx is the difference between the control and the stressed plants after rehidratation (time point tx chosen to measure recovery). This recovery/resilience index r could ranged by -1 and +1, with maximal resilience at +1.

Analysis of variance (ANOVA) was performed with Excel software. Differences between treatments were considered significant at $P<0.05$ according to least significant difference (LSD) tests.

RESULTS AND DISCUSSIONS

The effect of water stress on the morphology of the soybean genotypes studied

Morphological characteristics of plants directly reflect the growth and development of crops. Among them, plant height and root length are the most important indicators of plant growth and development. The leaf surface is also an important parameter that depends on the amount of light energy captured by the plant, respectively photosynthesis, transpiration, and therefore directly affects the final yield. Studying plant morphological characteristics can help determine the effects of water stress and rehydration on soybean genotypes.

The obtained results showed that water stress inhibited plant growth reflected by reducing the height of the stem, the main root and the leaf surface.

The most significant sources of variability for plant height were treatment and interaction between treatment and genotype (Table 1). The most significant sources of variability for aerial biomass, lenght of root, root biomass, leaf area and chlorophyll content were both treatment and genotypes. The effect of treatment, genotype and its interaction was significant for 0.01 level of probability (Table 1).

Table 1. The analysis of variance for morpho-physiological traits studied

Morpho-physiological traits	Source of variance (FD)		
	Factor A, treatments (3)	Factor B, genotype (7)	Interraction AxB (21)
Height of plants	2.52	58.01***	2.33**
Aerial biomass	296.8***	34.54***	24.06***
Lenght of root	2814.54***	300.34***	92.76***
Root biomass	5.18*	3.48***	14.84***
Leaf area	30.06***	48.99***	27.26***
Chlorophyll content	22.28***	47.75***	34.76***

Regarding the reduction in plant height, it was between 0.38% (Ovidiu F) and 10.29% (14004 S1-4). Compensation effect after re-watering in two soybean genotypes (Steara and Ovidiu F) was observed (Table 2).

Table 2. Height of soybean plants (cm) under optimal conditions of water supply, water stress and after rehydration

Genotype	Con trol	Water stress	Reduc tion (%)	Control	Rehydra tion	Reco very index
14004 S1-4	29.15	26.1	10.29	34.5	28.85	-0.47
14007 S1-3	28.1	25.8	8.01	34.2	28.15	-0.63
14024 S1-7	27.85	27.6	0.72	29.75	29.15	-0.20
04046 S1-101	29.8	27.6	7.21	31.9	25.65	-0.66
09022 S1-2	30.6	30.4	0.49	32.8	32.1	-0.79
Safta F	26.95	25.1	6.60	30.4	25.8	-0.61
Steara	40.5	37.3	7.90	40.6	38.2	0.33
Ovidiu	39.85	39.7	0.38	44.25	42.82	0.15
LSD 5%	*3.34*	*2.14*		*5.09*	*4.32*	

The biomass accumulations at water stress were reduced by 66.84% (14004 S1-4) and 11.82% (Steara), compared with no drought stress. The best compensation effect for aerial biomass was presented by three genotype (14007 S1-3, 14024 S1-7, 04046 S1-101 and and the most deficient from this point of view was genotype 1: 14004 S1-4 (Table 3).

Table 3. Aerial biomass accumulation (g d.m/plant) under optimal conditions of water supply, water stress and after rehydration

Genotype	Con trol	Water stress	Reduc- tion (%)	Control	Rehydra tion	Reco very index
14004 S1-4	0.37	0.12	66.84	0.873	0.325	-0.54
14007 S1-3	0.36	0.14	59.56	0.556	0.395	0.34
14024 S1-7	0.33	0.20	40.53	0.459	0.345	0.20
04046 S1-101	0.37	0.16	57.07	0.404	0.277	0.69
09022 S1-2	0.36	0.19	46.34	0.678	0.287	-0.56
Safta F	0.28	0.16	40.21	0.581	0.398	-0.38
Steara	0.49	0.44	11.82	0.586	0.526	-0.02
Ovidiu F	0.33	0.26	21.01	0.561	0.483	-0.09
LSD 5%	*0.04*	*0.024*		*0.084*	*0.049*	

In the case of the root system, the negative effect of water stress was much more obvious. The exception is the Ovidiu F genotype, which had a reduction of only 7.42%. The most affected were genotypes 1 (14004 S1-4) and 2 (14007 S1-3), with a reduction in the length of the root system of over 65% (Table 4).

At rehydration in the case of the lenght of main root, a very good compensation was observed in genotype 4 and 5 (with 0.79 and 0.74 values for index of recovery) and an overcompression in the Steara genotype (2.14 index of recovery). Genotype 1 (14004 S1-4) did not have a good ability to compensate for the growth of the root system, the recovery degree being with negative values. The other genotypes had a partial compensation of the increase in the length of the root system (Table 4).

Table 4. Main root length of soybean plants (cm) under optimal conditions of water supply, water stress and after rehydration

Genotype	Con trol	Water stress	Reduc tion (%)	Control	Rehydra tion	Reco very index
14004 S1-4	28.75	8.85	69.22	40.2	16.25	-0.17
14007 S1-3	25.8	8.86	65.66	27.55	10.26	-0.02
14024 S1-7	26.95	21.5	20.22	33.6	24.95	-0.37
04046 S1-101	27.3	14.15	48.17	29.3	21.95	0.79
09022 S1-2	29.45	15.6	47.03	31.35	23.4	0.74
Safta F	23.4	12.75	45.51	33.65	22.6	-0.04
Steara	26	13.75	47.12	28.5	24.6	2.14
Ovidiu	28.3	26.2	7.42	35.85	34.2	0.27
LSD 5%	*1.21*	*1.30*		*1.17*	*1.53*	

It is observed that the greatest reduction was in the genotype that had the most developed root system (Genotype 4: 04046 S1-101) and the smallest in the genotype with the reduced root system (Safta F). The best compensation effect for root biomass was presented by the Steara genotype, and the most deficient from this point of view was the genotype 1: 14004 S1-4 (Table 5).

Table 5. Root biomass accumulation (g d.m/pl) under optimal conditions of water supply, water stress and after rehydration

Genotype	Con trol	Water stress	Reduc tion (%)	Control	Rehydra tion	Reco very index
14004 S1-4	0.334	0.039	88.32	1.61	0.24	-0.78
14007 S1-3	0.436	0.043	90.14	0.85	0.62	0.71
14024 S1-7	0.605	0.127	79.01	1.03	0.48	-0.13
04046 S1-101	0.812	0.072	91.13	0.67	0.30	1.00
09022 S1-2	0.497	0.098	80.28	1.07	0.29	-0.49
Safta F	0.213	0.157	26.29	0.82	0.47	-0.84
Steara	0.538	0.074	86.25	0.63	0.40	0.97
Ovidiu	0.71	0.156	78.03	0.73	0.45	0.98
LSD 5%	*0.13*	*0.040*		*0.29*	*0.13*	

The leaf area was negatively affected by water stress, the reductions being between 82.56% (Genotype 1:14004 S1-4) and 25.55% (Genotype Safta F) (Table 6).

Partial compensation for leaf area was observed in all genotypes after rehydration (14024 S1-7 genotype showed the best compensation), indicating that water stress inhibited plant growth and development, but the studied genotypes had capacity for partial compensation of leaf area after rehydration, except the Safta genotype which had an almost total compensation (Table 6).These results suggest that drought stress at V3 stages accelerates senescence of soybean plants, which could not be compensated after rehydration in some genotypes.

Table 6. The leaf surface of soybean plants (mm^2 under optimal conditions of water supply, water stress and after rehydration

Genotype	Con trol	Water stress	Reduc tion (%)	Control	Rehydra tion	Reco very index
14004 S1-4	5557	969	82.56	6928	3632	0.39
14007 S1-3	5117	971	81.02	4086	3046	0.99
14024 S1-7	4819	3249	32.58	4429	3636	0.98
04046 S1-101	4817	2152	55.32	4405	2748	0.61
09022 S1-2	4511	2847	36.89	5693	2587	-0.46
Safta F	3613	2690	25.55	5292	3639	-0.44
Steara	6155	2626	57.34	6287	4400	0.87
Ovidiu	5811	3291	43.37	5326	3715	0.56
LSD 5%	*253.77*	*415.99*		*338.06*	*666.15*	

The effect of water stress on the physiological parameters of the soybean genotypes studied

Chlorophyll or chlorophyll pigment represents the most important organic substance in nature and is an important component of the pigment protein of the thylakoid membrane, being crucial for photosynthesis. Chlorophyll content reflects to some extent the level of photosynthesis and greatly affects plant growth. Our results showed that fourteen days of water stress significantly affected the chlorophyll content, the reduction being from 2.72% (Genotype Steara) to 21.69% (Genotype 2: 14007 S1-3). Results showed that after rehydration, the effect of drought stress on chlorophyll could be rapidly reversed. The most affected was genotype 1 (14004 S1-4) with the lowest degree of compensation (Table 7).

Table 7. Chlorophyll content of soybean plants (SPAD units) under optimal conditions of water supply, water stress and after rehydration

Genotype	Con trol	Water stress	Reduc tion (%)	Control	Rehydra tion	Reco very index
14004 S1-4	42.6	36.5	14.32	46.75	40.2	-0.07
14007 S1-3	43.1	33.75	21.69	44.8	40.05	0.97
14024 S1-7	40.9	38.65	5.50	44.5	42.1	-0.06
04046 S1-101	41.2	39.5	4.13	42.9	41.09	-0.06
09022 S1-2	43.3	36.85	14.90	47.5	44.2	0.95
Safta F	40.85	37.1	9.18	43.35	41.45	0.97
Steara	38.6	37.55	2.72	43.3	42.75	0.91
Ovidiu F	37.12	36.25	2.34	42.9	42.15	0.16
LDS	*0.43*	*1.31*		*0.67*	*0.84*	

Other studies highlighted that the compensatory effect due to rehydration after drought stress in more advanced stages of development (R5) was not significant, indicating that water stress at this stage caused a relatively high level of chlorophyll damage. Thus, Dong et al., (2019) showed that in soybean, although rehydration after water stress led to compensation, the compensation effect varied with the growth stage when the stress occurred, the stress level and the time after rehydration. The same authors highlighted that, physiologically, after water stress at each growth and rehydration stage, membrane permeability rapidly recovered and showed equal compensation, with the fastest recovery rate found for drought at stage V3. In addition, leaf chlorophyll content recovered quickly, with overcompensation even occurring at the V3 stage. In our case, we showed that rehydration after water stress led to the compensation phenomenon that varied depending on the genotype. Elsalahy HH and Reckling M (2022) showed that a drought-tolerant soybean cultivar may partially be drought-resilient due to the recovery of photosynthetic traits, but not the leaf thermal traits. Overall, these findings will accelerate future efforts by plant breeders, aimed at improving soybean drought resilience.

CONCLUSIONS

Water stress inhibited soybean plant growth (plant height, main root length, biomass accumulation and leaf area). There was a genetic variation for all the studied physiological characters. The Ovidiu F and Steara genotypes were highlighted with the smallest reductions compared to the 14004 S1-4 genotype which was significantly negatively affected by the water stress.

After rehydration, soybean plant height and leaf area showed a rapid growth/recovery and produced fairly good compensation compared to the root system where the compensation effect was less.

Water stress reduced the chlorophyll content and upon rehydration different levels of compensation were observed in each studied genotype, there was even one genotype that showed an over compensation.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Romanian Ministery of Research, Inovation and Digitalization and was financed from Project "Adaptation of the main agricultural crops to the forecasted climate changes for Romania, throught modern genetic and technological methods", grant 44N/2023.

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