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Physiological and agronomical traits evaluation of soybean accessions, part of the National collection at IPGR – Sadovo

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Abstract

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Glycine max [L.] Merr. is one of the most important protein crops and one of the five grains (rice, wheat, barley, soybean and millet) essential for human nutrition. The main aim of this study was to assess some physiological and agronomical traits of *Glycine max* accessions, maintained at Sadovo Genebank and to select the best performing genotypes appropriate for soybean breeding programs. Twelve soybean genotypes with different origins were field grown in randomized complete block design in three replications. The assessment of agro-morphological traits was performed according to the International Descriptor for *Glycine max*. The physiological traits as photosynthetic rate (A), transpiration rate (E), sub-stomatal cavity CO_2 concentration (Ci), stomatal conductions of water vapour (gs) and instantaneous water use efficiency (WUEi) were evaluated using a portable intelligent photosynthesis system LCpro T. All obtained results were subjected to Duncan analysis. Three accessions (BOBM 0013, BGR3091 andBGR 3100) were selected with the highest leaf net photosynthesis and stomatal conductance. The same genotypes including BGR3140 distinguished with better leaf instantaneous water use efficiency (WUEi). Under the dry field condition of the experiment, these accessions demonstrated a relative high drought tolerance. Regarding the grain yield per plant, pods per plant, grains per pod and harvest index three accessions were selected as the most promising ones (BGR43585, BGR3100 and BGR40900). These three genotypes were included in early and medium early maturity groups. The early ripening accession BGR3100 is recommended in soybean breeding program as donor parent of drought tolerance and good yield traits. The use of these early and medium early maturity accessions could contribute to increasing soybean productivity and guaranteeing a good income for farmers.

Keywords: Glycine max; drought tolerance; grain yield per plant

Introduction

Glycine max L. Merrill is the world‘s most important oil and protein crop in terms of international trade of grain legume, total production and its higher nutritional and industrial values. The soybean provides 50% of the total production of oil seed crops in the world (Islam et al., 2016). Soybean has been long conserved among plant genetic resources and there are more than 230,369 accessions maintained in germplasm collections throughout the world. In Bulgaria soybean seeds as PGR are maintained in the National genebank in the IPGR-Sadovo. Totally 758 accessions from *Glycine max* (L.) Merrill are conserved under long term storage condition at subzero temperatures (-18°C) in hermetically closed containers (Desheva et al., 2017).

Grain yield and yield components in legumes are affected by abiotic stresses as imbalances in water, temperature, or mineral availability (Dwivedi et al., 2005). Crop yield is reliant on the sum of photosynthetic active radiation (PAR) absorbed by the crop during the growing season and subsequently converted into grain yield (Rattalino Edreira et al., 2020). Efforts to increase the yield have to be directed also for improving the physiological processes that allow the crop to utilize this energy for grain production. Leaf photosynthetic capacity is one of the most promising approaches to further boost crop yield.

Drought stress is the main factor that limits yield of soybean around the world. The drought exerted detrimental effects on photosynthetic attributes, stomatal conductance, transpiration leaf production, pigment and water content, plant growth, and dry matter production of soybean. The pod and seed production, grain size, and seed yield of soybean were also adversely affected by the drought, where genotypic variations were conspicuous (Fatema et al., 2022; Ribas-Carbo et al., 2005). Adequate water is needed for the development and growth of plants. The consequences of less than optimal water are oxidative stress and a reduction in photosynthetic characteristics (Guo et al., 2018). Reduction of photosynthesis results in decreased CO_2 diffusion into the leaves because of lower internal (Ci) and stomatal conductance (gs). It also results in the inhibition of photosynthesis due to limited leaf growth because of decreased cell proliferation (Lawlor & Tezara, 2009; Wu et al., 2018).

The use of plant genetic resources (PGR) in crop improvement is one of the most sustainable ways to conserve useful genetic resources for the future and increasing food security and agricultural production. Key to successful crop improvement is to utilize the genetic diversity with new or improved target traits in breeding programs (Upadhyaya et al., 2011).

The main aim of this study was to assess some physiological and agronomical traits of *Glycine max* accessions, maintained at Sadovo Genebank and to select the best performing genotypes appropriate for soybean breeding programs.

Material and Methods

Field experiment

The field experiment was carrying out at the experimental field of the Institute of Plant Genetic Resources – Sadovo, on cinnamon forest soil after a precursor of wheat, during the period 2021–2022. Twelve soybean genotypes (Table 1) were grown in randomized complete block design (RCBD) in three replications. Plot size was 2 m × 2.5 m, with following distances: block to block 1 m; plot to plot 70 cm; line to line 40 cm: plant to plant 10 cm.

Sowings were made by hand, in optimum sowing time, according to the technology of cultivation. The assessment of agro-morphological traits of accessions was performed according to the International Descriptor for *Glycine max* L. 1984. The studded accessions were cultivars with Bulgarian and foreign origin. During the vegetation period all

Table 1. Passport information of the tested *Glycine max* (L.) Merr accessions

Number of the accessions in the National collection	Name of the accessions	Origin	Biological status
BGR3091	Man-Tzan-Din	China	CV
BGR3092	Shtik-Huan	China	CV
BGR3100	–	Russia	–
BGR3140	Amsoy	USA	CV
BGR3202	S 2596	unknow	L
BGR3318	BH-384	unknow	L
BGR6913	Dornburger (st 151)	unknow	CV
BGR1846	Tetbiate	Mexico	CV
BGR43585	Avigea	Bulgaria	CV
BGR40900	Srebrina	Bulgaria	CV
BGR40899	Mira	Bulgaria	CV
BOBM0013	Richy	Bulgaria	CV

L – breeding line, CV – cultivar

growing techniques (sowing, weeding, pesticide sprays, ect.) were performed in time, in the optimal period. Data were collected from 10 randomly selected plants of each plot and included plant height, pods per plant, grains per plant, 100 grain mass, yield per plant and harvest index. The length of vegetation period comprised the days from plant germination to 80% ripening of plants. The studded genotypes were divided into four maturity groups – very early (100–110 days); early (100–110 days); medium early (120–130 days) and late (more than 140 days) (Georgiev et al., 2015).

Physiological experiment

Leaf gas exchange parameters-Gas exchange measurements were performed using a portable intelligent photosynthesis system LCpro T (ADC BioScientific, UK). The photosynthetic rate (A), transpiration rate (E), sub-stomatal cavity CO_2 concentration (ci) and stomatal conductions of water vapour (gs) were obtained from the instantaneous measurements. The instantaneous water use efficiency (WUEi) at leaf level was calculated as the ratio between A/E. These parameters were estimated two times in the year in two different growth stages (full flowering and beginning of ripening) for all accessions during the two consequent growing seasons. The measurements were done of the fully expanded matured six leaves from three plants per genotype. The data were collected between 09:00 AM and 10:00 AM on the field experimental area.

The range of the ambient conditions measured by the LCpro T in the measuring days by years was as follows:

In 2021 – the chamber temperature was 28.5–29.5°C and 26.7–28.4°C, the air relative humidity (RH) was 22.7–19.2

mbar and 15.3–18.0 mbar, the photosynthetic active radiation (PAR) was 1100–1400 µmol $m^{-2}s^{-1}$ and 1300–1600 µmol $m^{-2}s^{-1}$ and the ambient CO_2 concentration was 395–404 vpm and 392-403 vpm.

In 2022- the air temperature was 29.5–32.5°C and 28.3–30.0°C, the air relative humidity (RH) was 17.8–15.2 mbar and 20.3–23.9 mbar, the photosynthetic active radiation (PAR) was 1300–1600 µmol m-2^{s-1} and 1000–1300 µmol $m^{-2}s^{-1}$ and the ambient CO_2 concentration was 400–406 vpm and 436–444 vpm.

Data analysis

All data obtained from each trait were statistically analyzed using SPSS 19.0. for Windows and Microsoft Office Excel 2007. Means for significant effects were separated using Duncan's multiple range tests at the 5% probability level ($p < 0.05$) All obtained results were subjected to Duncan analysis (Duncan, 1955).

Result and Discussion

Physiological responses of soybean

The environmental conditions during the first year of the experiment, 30 days before the first and second measurement, were more unfavorable regarding the water availability, compared to measurement dates in 2022 (Figure 1). The sum of precipitations and relative humidity were lower, and the average temperatures were higher. This fact was confirmed partially by Lc proT during the measurement days. The photosynthetic rate (A) and stomatal conductions of water vapour (gs) values were the highest for the accessions BOBM 0013, BGR 40900, BGR40899, BGR 3091 and BGR 3100 (Table 2). Higher level of stomatal conductance was observed also by De la Rosa et al. (2020) in drought tolerant genotypes of vetch (*Vicia sativa*). The more optimal ratio between parameters ci, gs and A was observed for cultivars BOBM 0013 and BGR 40900. Better instantaneous water use efficiency (WUEi) was estimated in BOBM 0013, BGR 40900, BGR 3092 and BGR 3100.

During the second year of experiment (2022) the photosynthetic activity expressed by parameters A and gs increased due to more favorable combination of ambient conditions. Similar results were observed by Mahajan & Tuteja (2005) and Mutuva et al. (2015). Decreasing in transpiration rate and stomatal conductance in leaves under drought was reported by Zhang et al. (2016) and Iqbal et al. (2019). Better performance was observed in accessions BGR 3100, BGR 3202, BGR 3140, BGR 3091 and BOBM 0013. Additionally, the accessions BGR 3100 and BGR 3091 showed low values of CO_2 concentration (Ci), combined with high net photosynthesis rate. Similarly, Deng et al. (2010) connected the intercellular CO_2 concentrations as indicator for lack of non-stomatal limitation, i.e. down-regulation of photochemical activity and damage of photosynthetic apparatus.

Zhang et al. (2019) considered that at mild and moderate drought, WUEi generally decreased with increasing of soil water content. During favorable 2022, due to higher transpiration, parameter WUEi decreased for most of the accessions. However, this fact was not observed for accessions BGR 3091, BGR 1846 and BOBM 0013, which distinguished with the highest WUEi.

The performed Duncan analysis for a period 2021–2022 separated the accessions BOBM 0013, BGR 3091 and BGR 3100 in the groups with the highest net photosynthesis and stomatal conductance (Table 2). The accessions in this groups have with 42% higher net photosynthesis compare to the accessions in group d. The same accessions including and BGR 3140 distinguished with better instantaneous wa-

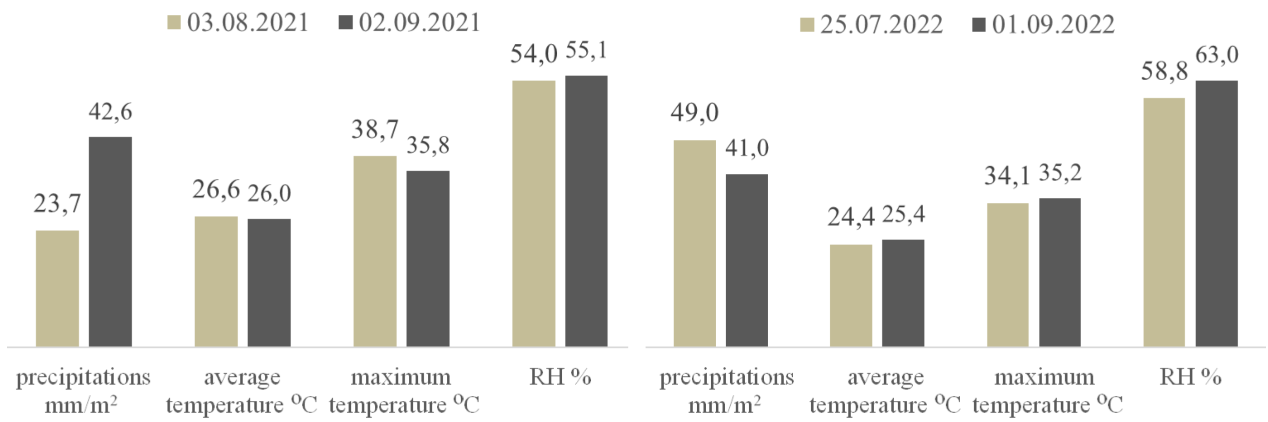

Fig. 1. Meteorological conditions for 30 days before the measurement data

Table 2. Leaf gas exchange parameters of the soybean accessions

Accessions number	Mean value 2021					Mean value 2022					Mean value 2021–2022				
	ci vpm	E mmol $m^{-2} s^{-1}$	gs mmol $m^{-2} s^{-1}$	A µmol $m^{-2} s^{-1}$	A/E ratio	ci vpm	E mmol $m^{-2} s^{-1}$	gs mmol $m^{-2} s^{-1}$	A µmol $m^{-2} s^{-1}$	A/E ratio	ci vpm	E mmol $m^{-2} s^{-1}$	gs mol $m^{-2} s^{-1}$	A µmol $m^{-2} s^{-1}$	A/E ratio
BGR3091	264.2 ±11.0	2.06 ±0.26	0.15 ±0.021	8.94 ±1.25	4.34 ±0.65	217.0 ±8.13	3.16 ±0.30	0.18 ±0.022	15.12 ±1.10	4.78 ±0.68	240.6 cd	2.61 ab	0.17 bc	12.03 ab	4.56 ab
BGR3092	234.2 ±10.3	1.46 ±0.11	0.08± 0.006	7.05 ±0.85	4.83 ±0.49	259.7 ±15.48	3.19 ±0.31	0.18 ±0.019	11.08 ±1.19	3.47 ±0.58	247.0 abc	2.33 b	0.13 bc	9.07 cd	4.15 bcd
BGR3100	253.0 ±7.2	1.83 ±0.25	0.13 ±0.023	8.31 ±1.49	4.54 ±0.72	278.6 ±2.59	4.31 ±0.26	0.38 ±0.018	17.81 ±0.46	4.13 ±0.35	265.8 a	3.07 a	0.26 a	13.06 ab	4.34 bcd
BGR3140	234.3 ±14.6	1.41 ±0.03	0.08 ±0.004	6.31 ±0.42	4.48 ±0.38	212.6 ±3.43	3.39 ±0.42	0.17 ±0021	14.03 ±1.03	4.14 ±0.75	223.5 d	2.40 ab	0.13 bc	10.17 bcd	4.31 abc
BGR3202	241.7 ±13.1	1.67 ±0.08	0.10 ±0.005	7.36 ±0.70	4.41 ±0.41	246.6 ±5.35	4.17 ±0.36	0.24 ±0.016	16.40 ±0.68	3.93 ±0.41	244.2 abc	2.92 ab	0.17 bc	11.88 abc	4.17 bcd
BGR3318	283.3 ±4.4	2.04 ±0.20	0.12 ±0.015	6.22 ±0.81	3.05 ±0.50	245.8 ±4.07	3.75 ±0.61	0.19 ±0.030	12.71 ±1.61	3.39 ±0.77	264.6 ab	2.90 ab	0.16 bc	9.47 cd	3.22 f
BGR6913	262.5 ±13.1	1.89 ±0.27	0.11 ±0.023	7.43 ±1.62	3.93 ±0.78	241.2 ±8.06	3.76 ±0.54	0.15 ±0.021	11.65 ±1.47	3.10 ±0.85	251.9 abc	2.83 ab	0.13 bc	9.54 d	3.52 ef
BGR1846	254.3 ±11.2	1.92 ±0.19	0.12 ±0.018	7.05 ±0.44	3.67 ±0.38	230.4 ±8.74	2.44 ±0.19	0.14 ±0.011	10.97 ±0.29	4.50 ±0.34	242.4 bcd	2.18 b	0.13 bc	9.01 d	4.09 bcd
BGR43585	247.1 ±6.8	1.88 ±0.09	0.11 ±0.008	7.77 ±0.40	4.13 ±0.30	266.3 ±6.21	2.75 ±0.70	0.15 ±0.050	9.80 ±1.74	3.56 ±0.56	256.7 abc	2.32 b	0.13 c	8.79 d	3.85 de
BGR40900	234.6 ±3.8	2.41 ±0.16	0.16 ±0.017	11.11 ±0.93	4.61 ±0.54	259.3 ±7.67	2.79 ±0.12	0.14 ±0.011	10.44 ±0.63	3.74 ±0.38	247.0 abc	2.60 ab	0.15 bc	10.78 bcd	4.18 bcd
BGR40899	259.8 ±8.8	2.57 ±0.16	0.16 ±0.016	9.54 ±0.86	3.71 ±0.48	258.0 ±4.84	3.13 ±0.16	0.17 ±0.008	12.86 ±0.85	4.11 ±0.50	258.9 abc	2.85 ab	0.17 bc	11.20 bcd	3.91 cde
BOBM0013	236.2 ±10.3	2.72 ±0.13	0.19 ±0.015	12.36 ±0.73	4.54 ±0.42	256.6 ±13.90	3.17 ±0.13	0.27 ±0.016	16.21 ±0.76	5.11 ±0.45	246.4 bcd	2.95 ab	0.23 a	14.29 a	4.83 a

The data are presented as means±standard error (n = 6); 5% probability level of the Duncan test

ter use efficiency. These accessions differentiated in the field experiment also by better performance of some important agronomic traits. The genotypes BOBM0013 and BGR3091 had mean to high harvest index and no so tall plants while the accession BGR3140 has tall plants and also good harvest index. The accession BGR 3100 possessed the highest yield per plant and the biggest grains. This genotype also had big number of pods and grains per plant. All four accessions were gathered in a group possessing drought tolerance.

Assessment of the *Glycine max* [L.] Merr accessions for vegetation period, grain yield and its components

The results concerning the vegetation period**,** grain yield and its components obtained from evaluated soybean accessions are presented in Table 3. The genotypes differed significantly for all of the traits indicating existence of great variability.

Significant variation was observed for vegetation period among all genotypes (Table 3). The time of maturity varied from 106 days for an accession from China (BGR3091) to 173 days for an accession from Mexico (BGR1846). The studied soybean accessions were divided into four maturity groups – very early (BGR3091, BGR3092, BGR3318); early (BGR43585 and BOBM0013); medium early (BGR3100, BGR3140, BGR3202, BGR6913, BGR40900, BGR40899) and late (BGR1846).

Variation also was observed for plant height among all genotypes (Table 3). The genotype BGR 1846 was the tallest (122.90 cm) followed by BGR 3140 (99.85 cm) and BGR 3202 (86.30 cm). BOBM0013 was the shortest genotype (59.40 cm) in height followed by BGR 3092 (64.40 cm).

The highest number of pods per plant was recorded in BGR 43585 (250.30), BGR 3100 (231.60) and BGR40900 (211.30) while the lowest number of pods per plant (97.90) was observed in BGR 1846.

In contrast to our result, Islam et al., 2016 reported small variation in plant height (from 69.57 cm to 39.47 cm) as well as in the pods per plant (from 60.93 to 21.53 cm).

Table 3. Assessment the agronomical and biological traits of soybean accessions

Accessions number	Vegetation period (days)/group of maturity	Mean value of plant height, cm	Mean value of number of pods per plant	Mean value of number of grains per plant	Mean value of yield per plant, g	Mean value of 100 -grains mass, g	Mean value of harvet index, %
BGR3091	106/very early	78.40 def	143.50 cd	189.90 bc	21.62 b	14.60 cd	20.82 cd
BGR3092	107/very early	64.40 gh	137.30 cd	175.20 c	16.20 b	10.80 f	19.91 bcd
BGR3100	124/medium early	80.75 de	231.60 ab	272.30 ab	54.99 a	19.77 a	20.82 de
BGR3140	127/medium early	99.85 b	158.25 c	149.50 c	21.68 b	16.75 b	21.74 de
BGR3202	129/medium early	86.30 cd	200.80 b	145.80 c	23.72 b	16.28 bc	17.11 cd
BGR3318	110/very early	78.70 def	134.90 cd	158.60 c	20.40 b	14.68 cd	17.22 abc
BGR6913	125/medium early	92.70 bc	140.30 cd	103.90 c	14.55 b	13.60 de	12.86 e
BGR1846	173/late	122.90 a	97.90 d	150.13 c	26.41 b	19.03 b	19.89 bcd
BGR43585	113/early	69.33 fgh	250.30 a	312.70 a	46.62 a	17.03 b	29.26 a
BGR40900	121/medium early	74.30 efg	211.30 ab	312.80 a	36.74 ab	17.33 b	22.62 ab
BGR40899	120/medium early	68.90 fgh	121.60 cd	124.30 c	15.16 b	12.30 ef	22.10 bc
BOBM0013	116/early	59.40 h	138.50 cd	146.05 c	20.51 b	12.68 e	20.55 cd

5% probability level of the Duncan test

The greatest number of grains per plant was produced by the accession BGR43585 (312.70) followed by BGR40900 (312.80) (Table 3). The genotypes BGR 3100 (272.30) and BGR 3091 (189.90) were in the second position. The lowest number of grains per plants was produced by the genotype BGR 6913(103.90).

Yield is the final product of crop, which relies on other contributing characters. Finally, to evaluate a crop, it is essential to rank its yield potentialities (Table 3). Considering grain yield per plant, it ranged from 15.16 g to 54.99 g. Among all the studied genotypes, BGR 3100 produced the highest yield per plant (54.99 g). Next two genotypes were BGR43585 (46.62 g) and BGR40900 (36.74 g). They were statistically identical, but BGR40899 showed the lowest grain yield per plant (15.16 g), which was statistically similar to all other genotypes. In contrast with our result**s** Islam et al. (2016) established that grain yield per plant, ranged from 2.30 g to 8.83 g.

Grain mass is one of the most important yield contributing trait. The highest value of 100 grain mass (19.77 g) was recorded for BGR 3100 accession. Genotypes BGR 3140, BGR 1846, BGR43585 and BGR40900 also showed higher grain mass. The lowest grain mass was recorded for the accession BGR40899 (12.30 g).

The highest harvest index was established in genotypes BGR43585 and BGR40900 and the lowest in the accession BGR 3202 (17.11%).

Based on the obtained results, the genotypes BGR43585, BGR3100 and BGR40900 appeared as the most promising ones. Pods per plant, grains per pod, grain yield per plant and finally harvest index were higher for those genotypes. These traits are one of the most important as a selection criterion for yield improvement of soybean (Islam et al., 2016).

Conclusion

During the carried out in the course of two years field experiments with soybean accessions, several genotypes were selected possessing valuable traits. The early ripening genotype BGR43585 and medium early ripening – BGR3100, BGR40900 appeared as the most promising regarding the grain yield per plant, pods per plant, grains per plant and harvest index. Four accessions (BOBM0013, BGR3091, BGR3140 and BGR3100) from early, very early and medium early maturity group demonstrated a relative high drought tolerance. The early ripening accession BGR3100 has the highest values of all studded physiological indicators and in the same time is with the best yield per plant and the biggest grains. In conclusion, the genotype BGR3100, is recommended as donor parent in soybean breeding, combining good yield traits and drought tolerance. The use of these early and medium early maturity accessions could contribute to increasing soybean productivity and guaranteeing a good income for farmers. Also these genotypes may to be use in breeding programs with soybean because they provide bigger adaptability to the agroecological conditions of the country, which combine good resistance to diseases.

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