Acta fytotechn zootechn, 29, 2026(2): 197–204
http://www.acta.fapz.uniag.sk

Original Paper

Agronomic Evaluation of Bulgarian Elite Soybean Breeding Lines

Galina Naydenova[1], Mariana Radkova[2], Katerina Stefanova[2], Anelia Iantcheva[2]

[1]*Agricultural Academy, Research Institute of Mountain Stockbreeding and Agriculture, Troyan, Bulgaria*
[2]*Agricultural Academy, Agrobioinstitute, Sofia, Bulgaria*

Article Details: Received: 2026-01-21 | Accepted: 2026-03-16 | Available online: 2026-06-30

https://doi.org/10.15414/afz.2026.29.02.197-204

During a three-year field trial (2023–2025) conducted at RIMSA–Troyan in Northern Bulgaria, medium-early-maturing (MGI) stabilized recombinant soybean lines were evaluated. The lines originated from the following varietal crosses: ♀Romantica × ♂Oria (R2), ♀Romantica × ♂Srebrina (R5), ♀Saikai 20 × ♂Romantika (S2), ♀Saikai 20 × ♂Galina (S3 and S32), ♂Atlanta × ♂Romantika (A1), and ♂Atlanta × ♂Houta (A3). Their productivity, quality, and drought resistance traits were compared with those of the Bulgarian standard variety Avigea. The results demonstrated selection progress in the most important soybean yield components in lines S3 (♀Saikai 20 × ♂Galina) and R5 (♀Romantica × ♂Srebrina). These lines should be included in competitive trials and subsequently registered as new varieties. The superiority of line S3 over the standard in the number of pods and seeds per plant, as well as in harvest index, provides a significant advantage in individual plant productivity, despite its lower absolute seed mass. Line R5 recorded the highest values for absolute seed mass and harvest index. Both lines produce a large number of first-order branches, which contributes to their higher productive potential. They exceeded the standard in crude protein content without statistically significant differences, while showing lower crude fat content. Line S3 was comparable to the standard variety in its ability to regulate transpiration under dry conditions. Line S32 (♀Saikai 20 × ♂Galina) exhibited the highest phenotypic stability for the seed yield components most strongly correlated with individual plant productivity, namely total plant dry mass at harvest, number of pods and seeds per plant, and harvest index.

Keywords: soybean, breeding lines, morphological and qualitative traits, harvest index, seed yield

1 Introduction

Soybean (*Glycine max* (L.) Merr.) is a crop of great economic and ecological importance (Popović et al., 2013a; 2013b; Đorđević et al., 2025; Shepilova et al., 2025; Tóth et al., 2025). Although it is considered important and traditionally grown in Bulgaria, its areas in 2023 amounted to 3799 ha, and in 2024 were reduced to 731 ha, which represents only 2.2% of the areas with protein crops in our country (Agrostatistics, 2024). Significant quantities of soybean meal from Brazil and Argentina are being imported into Bulgaria with an increasing trend, which meet the needs of our well-developed feed industry. The local soybean production has great potential importance and a niche in terms of food production, especially organic and functional ones.

Sowing with seeds of accidentally imported varieties, along with non-irrigated cultivation during increasingly frequent and prolonged summer droughts, are identified as the main reasons for the constantly decreasing areas and yields in our country, which are some of the lowest in Europe (https://ourworldindata.org/grapher/soybean-yields). According to Aleksieva (2015), the use of adapted genotypes and shifting of critical phenological periods through the use of variety are the most effective approaches to stabilizing soybean yields in non-irrigated cultivation in Bulgaria. According to the study by Rotundo et al. (2024), concerning the factors for expanding European soybean production, the cultivation of the crop on the Balkan Peninsula requires mainly selection for drought resistance.

***Corresponding Author:** gmvg@abv.bg

In response to these challenges, breeding for specific local adaptation has been a central objective of soybean improvement programs in Bulgaria over recent decades. This effort has resulted in the development of several medium-early-maturing (MGI) varieties, including Srebrina, Avigea, Biser, and Daniela 97, which have shown good agronomic performance under local conditions. However, as of 2025, only one Bulgarian soybean variety – Avigea – remains listed in the national variety register. This situation underlines the need for the development, evaluation, and registration of new, locally bred soybean genotypes with improved adaptation to current agro-climatic conditions.

Against this background, the present study aimed to evaluate the agronomic performance and quality traits of elite recombinant soybean lines and to assess their potential for use in production and breeding programs under the agro-climatic conditions of Northern Bulgaria.

2 Material and Methods

In a three-year field trial conducted during the period 2023–2025 at RIMSA–Troyan, Dryanovo branch, at an altitude of 308 m, on gray forest, pseudopodzolic soils, medium-early-maturing (MGI) stabilized recombinant lines originating from the following varietal crosses: ♀Romantica × ♂Oria (line R2), ♀Romantica × ♂Srebrina (line R5), ♀Saikai 20 × ♂Romantika (line S2), ♀Saikai 20 × ♂Galina (lines S3 and S32), ♂Atlanta × ♂Romantika (line A1), and ♂Atlanta × ♂Houta (line A3) were compared with the Bulgarian standard variety Avigea.

The genotypes were sown annually between April 20 and May 1, in rows 4 m long, with 70 cm row spacing and 5 cm within-row spacing, in three randomized replications. In 2023 and 2024, the following seed yield components were studied: biomass yield per plant at harvest (R8), plant height (cm), number of branches, number of pods per plant, number of seeds per plant, seed weight per plant (g), thousand-seed weight (g), and harvest index (%). Biometric measurements were taken on 10 plants per genotype. The main seed/grain quality traits were also analyzed: crude protein content determined by the Kjeldahl method and crude fat content extracted using a Soxhlet-type extractor. In 2025, the lines and the standard variety were not harvested due to a prolonged summer drought (Figure 1). In order to assess genotypic differences in drought tolerance, as observed in both 2025 and 2024, the lines were evaluated relative to the standard using the following growth and physiological traits: specific leaf area (was calculated as leaf area per unit dry mass, cm2/g), dry matter coefficient (as the ratio of dry to fresh leaf biomass, %), and transpiration intensity (as water loss per unit leaf area over time, mgH2O/g/h). Observations were carried out in July of both experimental years, after a prolonged period without precipitation (> 20 days), under very high daytime temperatures. Measurements were taken once per day at 1:00 p.m., using leaf samples from 10 plants of each genotype.

The experimental data on the observed bioproductive and growth traits were processed using two-factor analysis of variance with the factors year, genotype, and their interaction. The experimental years were considered as environments, with the differences between them being predominantly due to the levels of natural water availability during the growing season (Figure 1). Data on quality and physiological traits were analyzed, respectively, by two-factor analysis of variance without replications (year and genotype) and by one-factor analysis of variance (genotype). The magnitude of factor effects was determined using the eta-squared (η^2), representing the relative share of factorial variance in the total variance (Richardson, 2011), with the following interpretation of values: $\eta^2 < 0.02$ – very small effect; $0.02 \leq \eta^2 < 0.13$ – small effect; $0.13 \leq \eta^2 < 0.26$ – medium effect; and $\eta^2 \geq 0.26$ – large effect. The stability of each line for the studied traits was assessed using the values of G×E variance (S^2G×E). The significance of differences between means was determined using the LSD test at a significance level of 0.05. Pearson's correlation

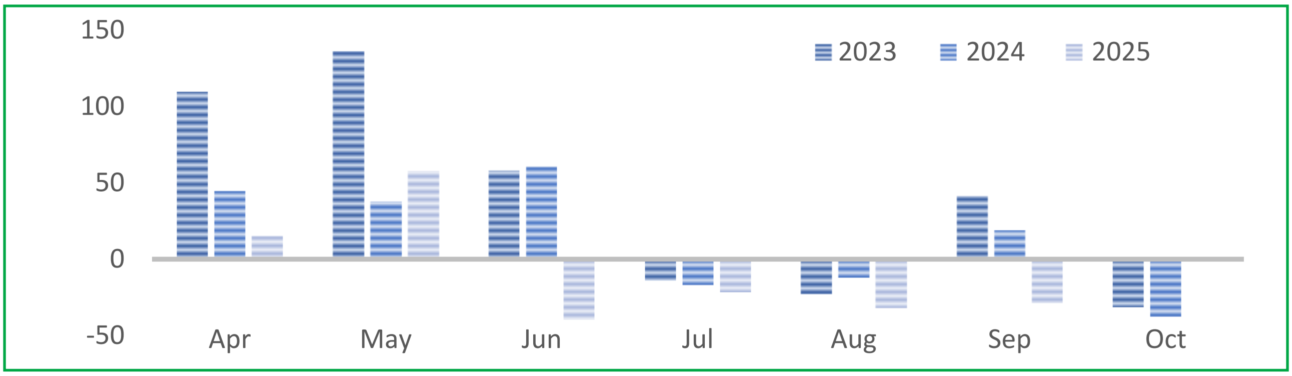


Figure 1 Monthly precipitation sums as deviations from the climatic norm for the region.

coefficients were used to assess phenotypic relationships among the studied traits.

3 Results and Discussion

According to the analysis of variance, the factors year/environment and genotype, both individually and in interaction, significantly affected all observed seed yield components (Table 1).

For the trait biomass yield per plant at harvest (BMYP), the strongest positive phenotypic correlation was found with individual plant seed yield (SYP) – Figure 2. This relationship is well known in soybean breeding work, with modern breeding programs extending the later reproductive phases without changing the period from sowing to flowering, which increases both biomass and harvest index (Yang et al., 2022). The studied breeding lines differed significantly in their mean values for this trait, with only line S3 significantly outperforming the standard. Based on the eta-squared (η^2) values, environmental conditions/the year of cultivation had a stronger influence on the variation of this trait than the genotypic factor (η^2_E = 0.34*** > η^2_G = 0.27***). A comparable effect of genotype × environment interactions was also observed ($\eta^2_{G \times E}$ = 0.26***), indicating specific genotypic responses in total plant biomass formation to the climatic conditions of the two experimental years. Total biomass accumulation across different phenophases, including R8, provides a reliable indicator of genotypic responses to growing conditions and is valuable for variety selection and breeding decisions (Pieralisi et al., 2024). In this context, newly selected genotypes with stable trait expression are of particular interest. Among the lines studied, S32 and R2 exhibited greater phenotypic stability compared with the standard variety.

Plant height (PH) in the studied group of breeding lines was negatively associated with important bioproductive traits such as plant branching (BP) and harvest index (HI). Harvest index was used by us as a main selection criterion in previous generations, which explains the obtained results, according to which the majority of the breeding lines were significantly shorter than the standard variety. Lines A1 and A3 did not differ significantly in plant height from the standard Avigea. According to the estimates of factor effects, this trait was significantly but very weakly influenced by environmental conditions (η^2_E = 0.01*). The observed variance depended almost entirely on the genotypic factor (73%). Genotype × environment interactions had a small effect on plant height ($\eta^2_{G \times E}$ = 0.12). Lines S3, A3, and S2 exhibited relatively high stability for this trait.

The number of branches formed per plant (BP) is one of the most important components of seed yield in soybean. According to the correlation analysis, this trait is positively associated with harvest index (HI) and the number of pods per plant (PP) in the studied group of genotypes. The number of branches determines the increase in assimilatory organs, leading to greater plant biomass, while branching plasticity is important for the response to environmental changes (Chu et al., 2023). The high productive and adaptive potential of the standard variety Avigea is primarily associated with the large number of first-order branches (Aleksieva, 2013; Petrova & Chipilski, 2024). According to the present trial, line S32 significantly outperformed Avigea. Higher values, though without statistically significant differences compared to the standard, were also recorded for lines S3, S2, and R5. Based on estimates of factor influence, variation in the number of branches per plant depended most strongly on the genotypic factor (η^2_G = 0.40***), while differences in summer water availability during the experimental years also had a strong effect on this trait (η^2_E = 0.32***). Genotype × environment interactions had a medium-strength effect ($\eta^2_{G \times E}$ = 0.19***). Among the tested lines, the most stable phenotypic expression for the number of branches per plant was observed in line R2.

The number of pods per plant (PP) and the number of seeds per plant (SP) are yield components that are difficult to improve through selection due to the strong influence of environmental factors, particularly water availability, as highlighted in numerous studies (Varnica et al., 2018; Srebrić et al., 2020) conducted under conditions similar to ours. The results of the present trial also indicate a greater influence of the environment, specifically differences in summer water availability during the experimental years, than of the genotype on the variance of these traits. According to the obtained data, these traits showed lower estimates for the strength of the genotypic effect (η^2_G = 0.24 and 0.14, respectively), with only line S3 exhibiting significantly higher mean values compared with the standard variety. The most stable expression among the studied genotypes for the number of pods and seeds per plant was observed in breeding line S32. Line R2 exhibited phenotypic stability for the number of pods, which may be associated with its stable expression for the number of branches per plant.

.The number of seeds per pod (SPod) was evaluated as an indicator of genotypic differences in drought tolerance, since some seeds may fail to develop under water stress. Correlation analysis showed that SPod was significantly associated with growth traits specific leaf area (SLA) and dry mass coefficient (DMC), which were also measured to assess genotype-specific responses to drought. Across the study period, line A3 produced the highest number of seeds per pod. The standard variety and most other genotypes had lower values, although the differences were not statistically significant. The large-seeded breeding line R5 exhibited the lowest number of seeds per pod and, correspondingly, the highest proportion of undeveloped or aborted seeds. This trait showed the strongest effect of climatic conditions ($\eta^2_E = 0.53^{***}$), while the genotypic factor and genotype × environment interactions had weak effects ($\eta^2_G = 0.12^{***}$; $\eta^2_{G \times E} = 0.12^{***}$). The most stable phenotypic expression for this trait was recorded for the standard variety Avigea and line S3.

Absolute seed mass is a trait with strong genetic determination, and some of the studied lines were also selected for large seed size. As a result, very high genotypic variability was observed for the 100-seed mass (m100). Lines R5 and A3 showed a significant increase compared to the standard variety, while lines S2 and S3 were significantly smaller-seeded. Among the studied lines, only line R2 exhibited stable phenotypic expression for this trait, comparable to that of the standard.

Related to the results presented so far is individual plant productivity, assessed by seed weight per plant (SYP). Lines S3 and R5 (fig 3) showed significantly higher individual productivity compared to the standard variety Avigea. According to the phenotypic correlation coefficients, plant seed productivity is strongly positively associated with biomass yield per plant at harvest (BMYP), as well as with the number of pods (PP) and seeds (SP) produced per plant. Thus, the superiority of line S3 over the standard variety in these yield components provides a significant advantage in individual plant productivity. Line R5 recorded the highest values for absolute seed mass and harvest index, highlighting the importance of these components in achieving high yield. This trait showed the lowest genotypic effect among all observed traits ($\eta^2_G = 0.10^{***}$). Only line S32 exhibited higher stability in individual plant productivity compared to the standard.

Through the harvest index (HI), productivity can be considered as the genotypically determined efficiency of resource use. According to Mazur et al. (2023), the harvest index should be used as a primary selection criterion in breeding for productivity under stress conditions, and thus for adaptability, as it is most strongly associated with cenotic yield. In the present study, the influence of the genotypic factor ($\eta^2_G = 0.41^{***}$) exceeded that of the environmental factor ($\eta^2_E = 0.35^{***}$), while genotype × environment interactions had a very low effect ($\eta^2_{G \times E} = 0.07^{***}$) on the variation in harvest index. Consequently, significant genotypic diversity was observed in the studied group of breeding lines. A positive, statistically significant difference of 5.9 percentage points compared with the standard variety Avigea was observed only for line S3. Lines R5 and S32 also outperformed the standard, but without significant differences. It is important to note that the highest stability for harvest index was observed in the standard variety, while among the breeding lines, relatively high phenotypic stability was observed in S3, A3, and S32.

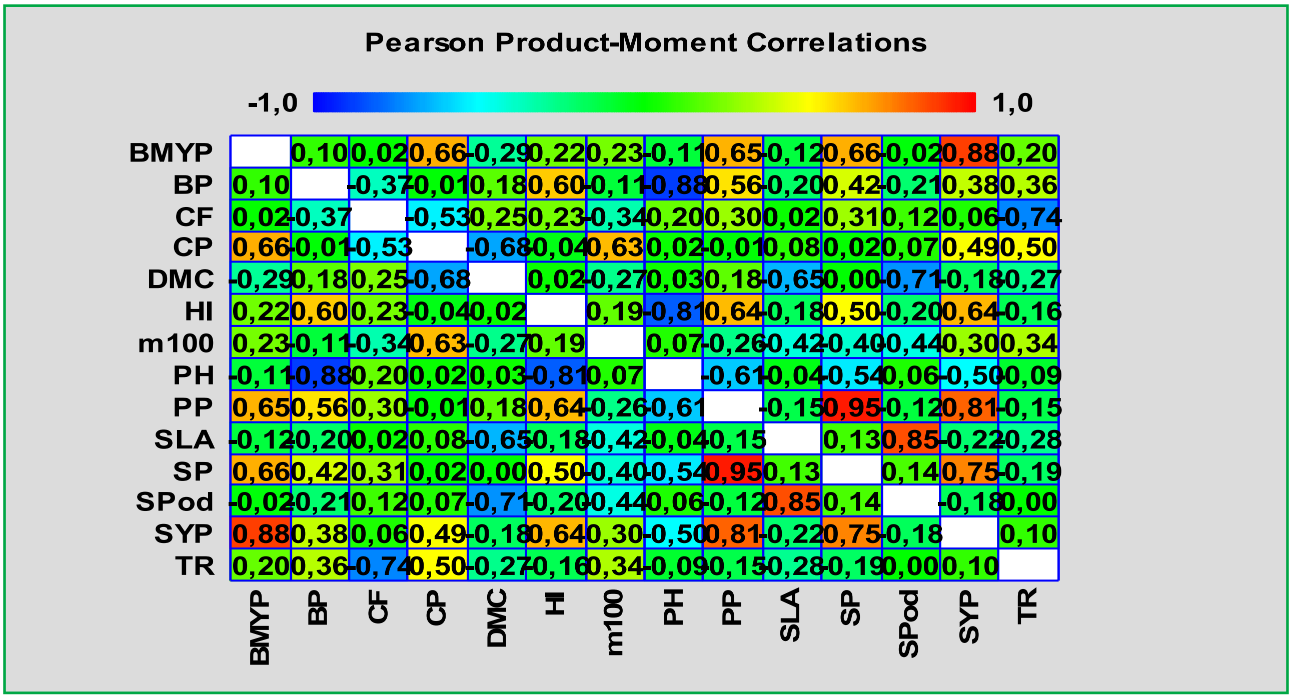
All breeding lines exceeded the standard in crude protein content (CP), with non-significant differences of up to 2.9 percentage points observed for line A3. Corresponding to the negative correlation between crude protein and crude fat (CF) content, all lines had lower fat content than the standard by up to 2.6 percentage points. The environmental factor had a twice stronger effect than the genotypic factor on grain protein content. Under conditions of lower water availability during pod and seed formation in 2024 (Fig. 1), the mean crude protein concentration (37.3%) exceeded that of the previous year (34.7%) with a significant difference of 2.6 percentage points. This is a well-known effect of drought during the reproductive stages R5–R6 on grain quality under Bulgarian conditions (Matev et al., 2022; Ilin et al., 2025). Interactions among the factors had no significant effect on grain protein content. A prolonged period of grain development in 2010 resulted in larger-sized grains, an increased protein content, and a decreased oil content (Popović et al., 2013a; 2013b).

Specific leaf area (SLA) and dry mass coefficient (DMC) are functional growth traits that reflect the adaptive strategies of plants and are important for assessing the response of a given genotype to environmental conditions, particularly soil and atmospheric moisture (Chowdhury et al., 2016). They were used to comparatively evaluate the response of the studied lines to the severe summer drought observed during the second and third experimental years, which affected the crop during critical reproductive phenophases; flowering to pod formation, seed setting (July), and grain filling (August). These traits are negatively correlated phenotypically, as also evident from our data (Figure 2). According to the results of the conducted analysis of variance, the observed genotypic variance for specific leaf area and dry mass coefficient was significant, with the effect of the genotypic factor assessed as medium in strength ($\eta^2_G = 0.19$ and 0.21, respectively). Based on the data, only line R2 significantly exceeded the standard in specific leaf area, which indicates a higher relative growth rate or mass-based maximum photosynthetic activity under drought conditions. Lines A3 and S2 also showed higher specific leaf area relative to the mean value of the studied genotype group. The increase in dry

Table 1 Mean values, significance of differences, and strength of factorial effects for the observed bioproductive, growth, and physiological traits

	BMYP (g)	PH (cm)	BP (Nb)	PP (Nb)	SP (Nb)	SPod (Nb)	m100 (g)	SYP (g)	HI (%)	CP (%)	CF (%)	SLA (cm^2/g)	DMC (%)	TR 2024yr, mgH$_2$O/g/h	TR 2025yr, mgH$_2$O/g/h
Авигея St	39.5^{c}	96.7^{a}	3.4^{bc}	63.7^{b}	111.1^{b}	1.7^{ab}	13.3^{c}	14.9^{c}	37.5^{bc}	34.3	20.7	202.9^{bcd}	33.1^{a}	62.0	12.4^{c}
R2	53.1^{abc}	87.4^{b}	3.9^{abc}	73.7^{b}	146.2^{b}	1.8^{ab}	13.7^{c}	19.9^{bc}	35.0^{c}	36.7	18.3	238.1^{a}	29.4^{bc}	75.9	8.0^{c}
R5	58.0^{abc}	79.3^{c}	4.5^{ab}	82.8^{b}	128.9^{b}	1.4^{c}	19.7^{a}	26.9^{ab}	41.9^{ab}	36.9	17.9	174.6^{d}	31.7^{ab}	108.3	46.0^{ab}
S2	42.8^{bc}	75.6^{c}	4.6^{ab}	75.2^{b}	149.2^{b}	1.8^{ab}	11.9^{d}	17.6^{bc}	36.8^{bc}	35.0	17.9	217.8^{ab}	31.5^{ab}	105.7	21.0^{bc}
S3	68.1^{a}	73.5^{c}	4.7^{ab}	138.8^{a}	248.7^{a}	1.7^{abc}	11.7^{d}	31.1^{a}	43.1^{a}	35.6	20.2	202.8^{bcd}	32.4^{ab}	71.8	65.8^{a}
S32	52.2^{abc}	76.1^{c}	5.2^{a}	86.5^{b}	146.0^{b}	1.8^{ab}	13.5^{c}	21.0^{abc}	39.2^{abc}	36.2	18.1	204.9^{bc}	30.4^{ab}	127.0	15.4^{bc}
A1	56.5^{abc}	106.6^{a}	3.6^{bc}	71.0^{b}	128.1^{b}	1.6^{bc}	13.4^{c}	18.2^{bc}	28.8^{d}	36.0	18.4	186.7^{cd}	31.4^{ab}	112.2	22.1^{bc}
A3	62.7^{c}	95.5^{a}	3.3^{bc}	71.5^{b}	149.5^{b}	2.0^{a}	15.9^{b}	24.1^{abc}	35.6^{c}	37.2	19.0	225.0^{ab}	26.5^{c}	111.0	22.5^{bc}
η^2_E	0.34	0.01	0.32	0.32	0.42	0.53	0.04	0.41	0.35	0.46	0.47	0.23	0.01ns	–	–
η^2_G	0.27	0.73	0.40	0.24	0.14	0.12	0.67	0.10	0.41	0.23ns	0.30ns	0.19	0.21	0.13ns	0.39
$\eta^2_{G\times E}$	0.26	0.12	0.19	0.18	0.10	0.12	0.15	0.10	0.07	–	–	0.08	0.09ns	–	–

BMYP, g – biomass yield per plant at harvest; PH, cm – plant height; BP – number of branches per plant; PP – number of pods per plant; SPod – number of seeds per pod and per plant (SP); m100, g – absolute mass of seeds/mass of seeds; SYP, g – seed yield per plant; HI, % – harvest index; SLA, cm^2/g – specific leaf area; DMC, % – dry mass coefficient; CP, % – crude protein content; CF, % – crude fat content; TR, mgH$_2$O/g/h – transpiration rate; * mean values sharing the same letter are not significantly different ($p > 0.05$); ns – non-significant effect of the factor



	BMYP	BP	CF	CP	DMC	HI	m100	PH	PP	SLA	SP	SPod	SYP	TR
BMYP		0,10	0,02	0,66	-0,29	0,22	0,23	-0,11	0,65	-0,12	0,66	-0,02	0,88	0,20
BP	0,10		-0,37	-0,01	0,18	0,60	-0,11	-0,88	0,56	-0,20	0,42	-0,21	0,38	0,36
CF	0,02	-0,37		-0,53	0,25	0,23	-0,34	0,20	0,30	0,02	0,31	0,12	0,06	-0,74
CP	0,66	-0,01	-0,53		-0,68	-0,04	0,63	0,02	-0,01	0,08	0,02	0,07	0,49	0,50
DMC	-0,29	0,18	0,25	-0,68		0,02	-0,27	0,03	0,18	-0,65	0,00	-0,71	-0,18	-0,27
HI	0,22	0,60	0,23	-0,04	0,02		0,19	-0,81	0,64	-0,18	0,50	-0,20	0,64	-0,16
m100	0,23	-0,11	-0,34	0,63	-0,27	0,19		0,07	-0,26	-0,42	-0,40	-0,44	0,30	0,34
PH	-0,11	-0,88	0,20	0,02	0,03	-0,81	0,07		-0,61	-0,04	-0,54	0,06	-0,50	-0,09
PP	0,65	0,56	0,30	-0,01	0,18	0,64	-0,26	-0,61		-0,15	0,95	-0,12	0,81	-0,15
SLA	-0,12	-0,20	0,02	0,08	-0,65	-0,18	-0,42	-0,04	-0,15		0,13	0,85	-0,22	-0,28
SP	0,66	0,42	0,31	0,02	0,00	0,50	-0,40	-0,54	0,95	0,13		0,14	0,75	-0,19
SPod	-0,02	-0,21	0,12	0,07	-0,71	-0,20	-0,44	0,06	-0,12	0,85	0,14		-0,18	0,00
SYP	0,88	0,38	0,06	0,49	-0,18	0,64	0,30	-0,50	0,81	-0,22	0,75	-0,18		0,10
TR	0,20	0,36	-0,74	0,50	-0,27	-0,16	0,34	-0,09	-0,15	-0,28	-0,19	0,00	0,10	

Figure 2 Phenotypic correlations among the observed traits

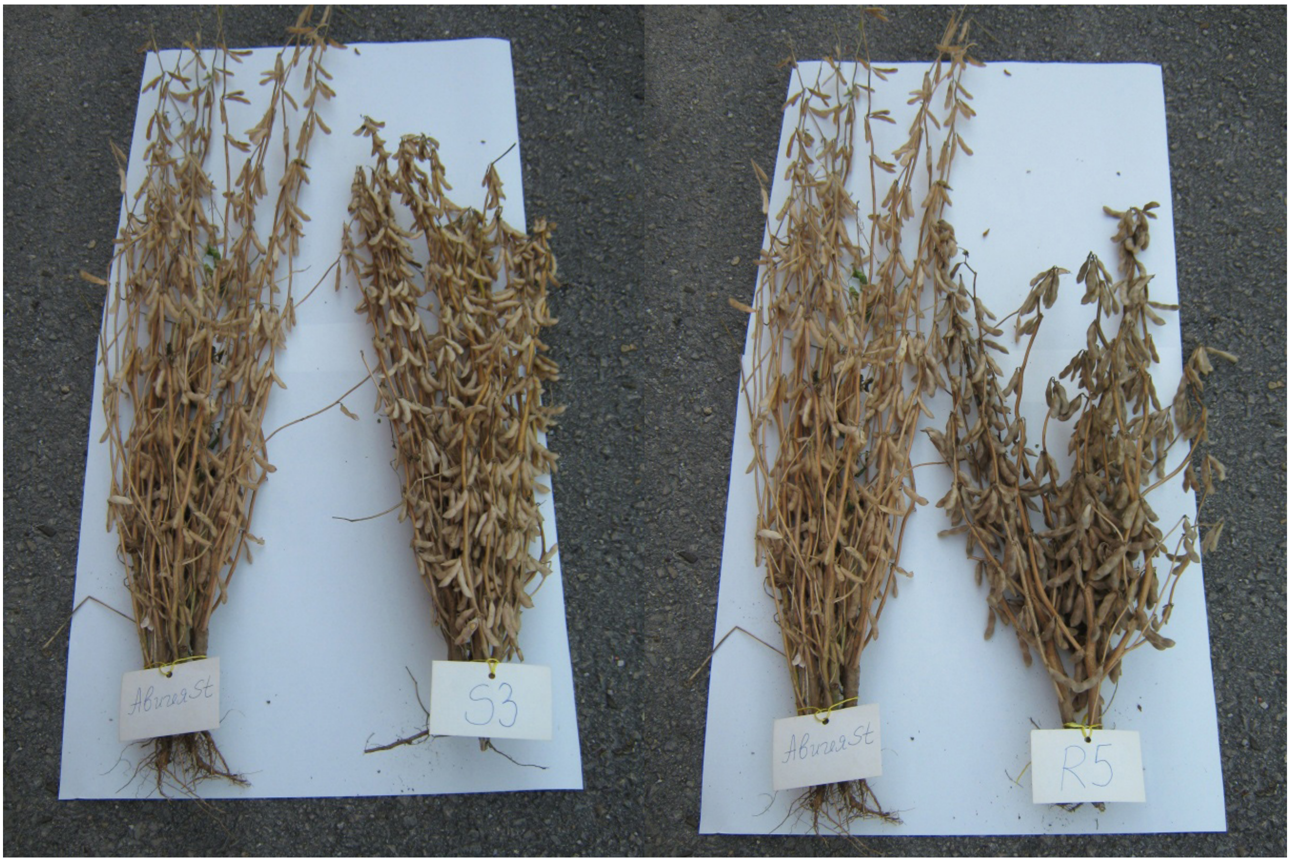
matter content under drought is a response aimed at maintaining structural integrity and reducing water potential. The standard variety exhibited the highest values for the relative proportion of dry matter per unit of fresh mass, indicative of effective adaptation to drought in Bulgarian breeding. The majority of the lines fell within a homogeneous group with the standard for this trait, suggesting comparable drought tolerance.

The genotypic variance for transpiration rate (TR) in 2024 was not significant, and the tested lines formed a homogeneous group with the standard variety. In 2025, under conditions of significantly lower water availability throughout the summer months, the genotypic factor had a strong effect on transpiration intensity. Line R2 and the standard variety showed better capacity to regulate transpiration under extremely dry conditions.

Table 2 Values of G×E variance (S^2G×E) for each genotype across the monitored seed yield components

Genotype Seed yield components	Avigeya St	R2	R5	S2	S3	S32	A1	A3
BMYP, g	564	392	849	650	1801	276	1524	1473
PH, cm	119	110	151	70	32	117	136	28
BP, Nb	2.6	2.2	11.4	5.7	4.7	3.1	6.0	5.8
PP, Nb	1,181.8	1,037.5	3,153.9	2,277.4	4,946.1	845.8	1,872.1	1,802.7
SP, Nb	4,621.8	7,906.1	13,568.5	12,371.6	22,744.7	4,257.1	10,072.9	11,138.4
SPod, Nb	0.04	0.17	0.26	0.17	0.04	0.07	0.20	0.17
m100, g	0.79	0.58	4.84	2.06	2.30	1.56	2.84	1.89
SYP, g	88.3	142.0	667.2	172.4	500.8	71.6	245.4	242.6
HI, %	4.7	89.5	123.8	91.9	27.4	35.1	46.5	33.0

BMYP, g – biomass yield per plant at harvest; PH, cm – plant height; BP – number of branches per plant; PP – number of pods per plant; SPod – number of seeds per pod and SP – per plant; m100, g – absolute mass of seeds/mass of seeds; SYP, g – seed yield per plant; HI, % – harvest index



Avigeya St and line S3　　**Avigeya St and line R5**

Figure 3 Plants of the most productive breeding lines compared with the standard cultivar

4 Conclusions

Selection progress in the most important soybean yield components was achieved in lines S3 (♀Saikai 20 × ♂Galina) and R5 (♀Romantica × ♂Srebrina). These lines should be included in competitive trials and subsequently registered as new varieties. The superiority of line S3 over the standard in the number of pods and seeds per plant, as well as in harvest index, provides a significant advantage in individual plant productivity, despite its lower absolute seed mass. Line R5 recorded the highest values for absolute seed mass and harvest index. Both lines produce a large number of first-order branches, which also contributes to their higher productive potential. They exceed the standard in crude protein content without significant differences, while lagging behind in crude fat content. Line S3 is comparable to the standard variety in its ability to regulate transpiration under dry conditions.

Line S32 (♀Saikai 20 × ♂Galina) exhibited the highest phenotypic stability for the seed yield components most strongly correlated with individual plant productivity, namely: total plant dry mass at harvest, number of pods and seeds per plant, and harvest index. These lines should be included in competitive trials and subsequently registered as new varieties.

Acknowledgments

This study was supported by the Agricultural Academy, under the project "Physiological, molecular and phytopathological study of Bulgarian soybean varieties", number 29

Conflict of Interest

The authors declare no conflicts of interest

Author Contributions

G. Naydenova: Conceptualization, Investigation, Formal analysis, Writing – original draft; M. Radkova: Data curation, Validation, Writing – original draft; K. Stefanova: Investigation, Validation; A. Iantcheva: Conceptualization, Project administration, Writing – review & editing.

ll authors have read and agreed to the published version of the manuscript.

AI and AI-Assisted Technologies use Declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

References

Aleksieva, A. (2013). Avigea–The First Bulgarian Early Ripening Soybean Variety. *Bulgarian Journal of Crop Science*, 50(6), 44–46.

Aleksieva, A. (2015). Comparative evaluation of new soybean lines by economic properties. In: *Scientific Session of Jubilee 90 years Soybean Experimental Station, Pavlikeni* (pp. 50–58). In Bulgarian

Đorđević, V., Miladinović, J., Ćeran, M., Ranđelović, P., Bukonja, S., Đukić, V., & Vasiljević, M. (2025). SoyPredict: Data-Driven strategies of soybean breeding. In *Book of abstracts, International Scientific Conference" Crop Science and Technology: Shaping the Future of Agriculture",* 29 September–2 October 2025, Belgrade, Serbia (pp. 48–48). Maize Research Institute Zemun Polje.

Chowdhury, J. A., Karim, M. A., Khaliq, Q. A., Ahmed, A. U., & Khan, M. S. A. (2016). Effect of drought stress on gas exchange characteristics of four soybean genotypes. *Bangladesh Journal of Agricultural Research*, 41(2), 195–205. DOI:10.3329/bjar.v41i2.28215

Chu, G., Zhang, J., Xu, B., & Wang, C. (2023). Topping at the Seedling Stage Changes the Plant Morphology and Yield of Unbranched Type Soybean. *Proceedings of the Bulgarian Academy of Sciences,* 76 (4), 629–636. https://doi.org/10.7546/CRABS.2023.04.16

Ilin, S. Z, Popović, V., M, Djukic, V., Zivancev, D., Karic, L., Papler, D., Pogacnik, M., & Znidarcic, D. (2025). Soybean [*Glycine max* (L.) Merr.] Seed Yield and Seed Oil Content as Influenced by Different Environmental Conditions and Genotypes. *Romanian Agricultural Research*, (42), 313–332.

Matev, A., Sabeva, M., Minev, N., & Petrova, R. (2022). Influence of irrigation regime on the chemical composition of soybean grains. *Journal of Central European Agriculture*, 23(2), 365–383. https://doi.org/10.5513/JCEA01/23.2.3466

Mazur, O., Kupchuk, I., Voloshyna, O., Matviets, V., Matviets, N., & Mazur, O. (2023). Genetic determination of elements of the soybean yield structure and combining ability of hybridization components. *Acta fytotechnica et zootechnica*, 26(2). https://doi.org/10.15414/afz.2023.26.02.163-178

Petrova, S., & Chipilski, R. (2024). Physiological and agronomical traits evaluation of soybean accessions, part of the National collection at IPGR-Sadovo. *Bulgarian Journal of Agricultural Science*, 30(2), 317–322. https://www.agrojournal.org/30/02-16.pdf

Pieralisi, B., Sharma, R. K., Golden, B., Bond, J., Cook, D., Irby, J. ..., & Dhillon, J. (2024). Planting time and variety effects on biomass, harvest index, and yield of irrigated soybean in mid-Southern United States. *Crop, Forage & Turfgrass Management,* 10(2), e70012.

Popović, V., Malešević, M., Miladinović, J., Marić, V., & Živanović, Lj. (2013a): Effect of Agroecological Factors on Variations in Yield, Protein and Oil Contents in Soybean Grain. *Romanian Agricultural Research*, 30, 241–247. DII 2067-5720 RAR-207

Popović, V., Glamočlija Đ., Sikora V., Đekić V., Červenski J., Simić D., & Ilin S. (2013b): Genotypic specificity of soybean [*Glycine max* (L.) Merr.] under conditions of foliar fertilization. *Romanian Agricultural Research*, 30, 259–270. DII2067-5720RAR 255

Rotundo, J.L., Marshall, R., McCormick, R. et al. European soybean to benefit people and the environment. *Sci Rep,* 14, 7612 (2024). https://doi.org/10.1038/s41598-024-57522-z

Shepilova, T., Petrenko, D., Leshchenko, S., Vasylkovska, K., & Andreychenko, O. (2025). Influence of growth stimulants on soybean productivity in the Northern Steppe of Ukraine. *Scientific Progress & Innovations*, 28(1), 11–14. https://doi.org/10.31210/spi2025.28.01.02

Srebrić, M., Dumanović, Z., Perić, V., & Anđelković, V. (2020). Decrease of yield components and morphological traits of soybean full-sibs under drought conditions. *Genetika*, 52(3), 1249–1262. https://doi.org/10.2298/GENSR2003249S

Tóth, Š., Mižík, P., Šoltysová, B., Klemová, K., Dupľák, Š., & Porvaz, P. (2025). Case Study on 5th Year Impact of Soil Tillage on Carbon/Nitrogen Agronomy Key Nexus in Winter Wheat – Soybean Rotation. *Nitrogen*, 6(4), 87. https://doi.org/10.3390/nitrogen6040087

Varnica, I., Petrović, S., Rebekić, A., Guberac, S., Jukić, K., & Jukić, G. (2018). Characterization and interrelationships of soybean [*Glycine max* (L.) Merrill] yield components during dry and humid seasons. *Journal of central European agriculture*, 19(2), 466–481. https://doi.org/10.5513/JCEA01/19.2.2148

Yang, J. X., Richards, R. A., Jin, Y., & He, J. (2022). Both biomass accumulation and harvest index drive the yield improvements in soybean at high and low phosphorus in south-west China. *Field Crops Research*, 277, 108426. https://doi.org/10.1016/j.fcr.2021.108426