Journal of Wildlife and Biodiversity
Online ISSN: 2588-3526

Volume 9(2): 323-330 (2025) (http://www.wildlife-biodiversity.com/)

Research Article

Selection of sources with superior agronomic traits from F3 hybrid generation soybean genotypes

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Received: 01 February 2025 / Revised: 21 May 2025 / Accepted: 22 May 2025/ Published online: 26 May 2025.
How to cite: Kurbanbaev, I., et al. (2025). Selection of sources with superior agronomic traits from F3 hybrid generation soybean genotypes, Journal of Wildlife and Biodiversity, 9(2), 323-330. DOI: https://doi.org/10.5281/zenodo.15520752

Abstract
This study investigated the selection of promising lines with valuable agronomic traits from F3 hybrid generation plants of soybean (Glycine max (L.) Merr.). Eight different hybrid combinations were evaluated based on morphological and yield-related traits. According to the results, the ♀Ehtiyoj × Nena♂ combination showed the highest performance in terms of number of pods (183.5 ± 13.01), number of seeds (370.3 ± 35.76), and seed weight (61.81 ± 4.99 g). Additionally, the "Tezpishar" line derived from the Sochilmas × Genetik-1 hybrid was notable for maturing within 70 days, which is significant for the development of early-maturing varieties. The results are consistent with data reported in international literature and confirm the potential for developing high-yielding and climate-adapted new cultivars under the conditions of Uzbekistan. The selected lines are recommended as promising genetic material for further improvement to cultivar level and enrichment through molecular breeding techniques.
Keywords: soybean (*Glycine max*), F_3 generation, hybrid combinations, vegetation period, donor lines

Introduction

Soybean (*Glycine max* (L.) Merr.) is one of the most important crops worldwide, widely used for food, industrial, and fodder purposes due to its high protein and oil content (Toshmatov *et al.*, 2024; Kurbanbaev *et al.*, 2024). Soybean seeds contain approximately 35–40% protein and 18–22% oil, distinguishing it from other leguminous crops. The development of high-yielding, stress-tolerant, and locally adapted varieties and lines is among the pressing directions of soybean breeding. In Uzbekistan, a total of 122,731 hectares of oilseed crops were cultivated in 2020 (Hakimov et al., 2023; Khamraev et al., 2025; Azimov et al., 2025). Specifically, soybean was grown on 18,500 ha in 2018, 19,800 ha in 2019, and 17,314 ha in 2020 (Khudayqulov & Mukhtarov, 2021). Several studies have also been conducted by Uzbek scientists on various physiological and biochemical characteristics of soybean, including chlorophyll content, seed protein and oil levels, and its role in enhancing soil fertility (Yunuskhanov et al., 2019; Abdurazakova *et al.,* 2020a, b; Jaynaqov *et al.,* 2022; Omonov *et al.,* 2023).

Soybean is a crop of growing importance due to increasing demand. Its seeds are rich in high-quality amino acids and are considered comparable to essential food products like meat, milk, and eggs, with 28–52% protein and 18–27% ecologically pure vegetable oil. Soybeans also contain numerous minerals and vitamins, making them exceptionally valuable. Over 400 products can be derived from soybean seeds and protein. Currently, the area under soybean cultivation is steadily increasing (Kurbanbaev *et al.,* 2023).

In breeding work with the F_3 generation, attention is focused on traits of economic significance, such as yield, plant height, seed mass, growth period, and resistance to diseases and stress. These traits are polygenic and can be effectively evaluated through genetic selection and analysis.

In recent years, global soybean breeding efforts have intensified to expand genetic diversity and develop varieties adapted to specific bioclimatic conditions (Kodirova *et al.*, 2024). Particularly in the F3 generation, high levels of genetic variation and recombinational diversity make it a crucial stage for identifying promising lines for selection. Ongoing breeding studies have shown that F2–F4 generations exhibit significant variability in morphological and agronomic traits (Singh *et al.,* 2018; Raza *et al.,* 2020), with the F3 generation being the phase where the highest selection potential is often realized.

The heritability of morphological traits, along with their genetic variance and phenotypic/genotypic coefficients, plays a vital role in selection efficiency (Burton & Devane, 1953). International research has demonstrated the effectiveness of F3-based selection in identifying high-protein, short-duration, and salt-tolerant lines (Malik *et al.,* 2021; Zhang *et al.,* 2019). In Uzbekistan, soybean breeding efforts are primarily conducted by the Republican Scientific Research Institute of Agriculture (Bozorov, 2017). The potential for effectively utilizing the F3 generation in developing adaptive varieties suitable for local agro-climatic conditions has been confirmed. Moreover, the application of marker-assisted selection (MAS) techniques enables rapid and precise identification of promising lines (Varshney *et al.,* 2005).

This study aims to identify agronomically promising lines from F3 hybrid soybean plants and to recommend them as potential donors for future breeding programs.

Materials and methods

The experiments were conducted at the Dormon field trial station of the Institute of Genetics and Plant Experimental Biology, Academy of Sciences of the Republic of Uzbekistan. The research materials consisted of soybean cultivar samples and F_3 hybrid generation lines from the “Genetics of Leguminous and Oilseed Crops" laboratory. The following hybrid combinations were used: ♀Sochilmas × Genetik-1♂, ♀Genetik-1 × Sochilmas♂, ♀Sochilmas × Selekta-302♂, ♀Selekta-302 × Sochilmas♂, ♀Ehtiyoj × To'maris♂, ♀To'maris × Ehtiyoj♂, ♀Ehtiyoj × Nena♂, and ♀Nena × Ehtiyoj♂.

All experiments were conducted in three replications, and the collected data were analyzed using the ANOVA module of the STATGRAPHICS statistical software.

Results

The development of early-maturing, high-yielding soybean varieties with superior quality traits plays an important role in addressing food security and human health issues. In Central Asia, water scarcity is becoming an increasingly serious concern. Considering these challenges, identifying biotypes with early maturity and high seed quality indicators to create new varieties is of critical importance. According to the results of hybridological analysis of F_2 plant combinations, experimental fields with a plot size of 3 m^2 were planted to study subsequent generations and develop new varieties. Ten plants from each combination were selected and sown in separate rows for evaluation.

Table 1 presents the average values and coefficients of variation (V%) for four main morpho-agronomic traits—plant height, number of nodes, number of branches, and number of pods—of eight F_3 hybrid combinations. These traits are among the most important phenotypic indicators for selection. Plant height, which reflects vegetative biomass and photosynthetic capacity, showed the highest value in the ♀Nena × Ehtiyoj♂ combination (152.5 ± 9.32 cm), indicating strong vegetative growth and a solid foundation for yield elements. The lowest plant height was recorded in the ♀Genetik-1 × Sochilmas♂ combination (96.3 ± 4.9 cm), suggesting limited potential for selection based on height.

Table 1. Morpho-agronomic trait indicators in soybean F_3 hybrid families

Soybean F3 hybrid families	**Plant height, cm**		**Number of joints in a plant, pcs.**		**Number of harvested branches, pcs.**		**Number of pods, pcs.**	
	X±Sx	**V%**	X±Sx	**V%**	X±Sx	**V%**	X±Sx	**V%**
♀Sochilmas x Genetik-1♂	103,0±10,12	31,06	19,4±0,77	26,42	4,6±0,65	44,9	111,7±7,79	46,9
♀Genetik-1 x Sochilmas♂	96,3±4,90	16,13	19,2±0,25	17,92	2,5±0,43	54,16	82,4±3,5	28,16
♀Sochilmas x Selekta 302♂	105,5±3,98	11,92	20,0±0,25	8,16	3,5±0,40	36,27	124,7±9,61	51,12
♀Selekta 302 x Sochilmas♂	110,5±2,70	8,11	18,5±0,57	10,27	3,1±0,46	49,16	106,8±8,13	25,26
♀Ehtiyoj x Nena♂	119,9±6,48	17,09	24,4±0,54	14,61	5,6±0,89	42,26	183,5±13,01	47,03
♀Nena x Ehtiyoj♂	152,5±9,32	19,32	25,0±0,45	11,58	2,9±0,53	57,36	88,3±2,86	18,94
♀Ehtiyoj x To'maris♂	114,5±4,97	13,72	25,6±0,47	12,24	6,5±0,69	33,43	133,2±2,65	13,22
♀To'maris x Ehtiyoj♂	120,0±1,67	4,39	27,1±0,29	7,06	4,7±0,63	42,61	143,2±4,04	18,73

The ♀To‘maris × Ehtiyoj♂ combination led with 27.1 ± 0.29 nodes, which increases the potential for pod development. A high variation coefficient for node number indicates rich genetic resources for selection. The number of branches determines the potential for pod formation. The ♀Ehtiyoj × To‘maris♂ combination showed the highest number of branches (6.5 ± 0.69), making it promising for high-yield selection. The high variation (V% = 33.43) suggests sensitivity to environmental conditions.

The number of pods is a key yield component. The ♀Ehtiyoj × Nena♂ combination significantly outperformed others with 183.5 ± 13.01 pods, making it a top candidate for high-yield selection. Conversely, the ♀Genetik-1 × Sochilmas♂ combination had the lowest pod number (82.4 ± 3.5), indicating lower yield potential. Table 2 shows the results of three key quantitative traits in F_3 hybrid combinations: 1000 seed weight per plant, number of seeds per plant, and total seed weight per plant. In the Ehtiyoj × Nena combination, 1000 seed weight was 165.48 ± 3.49 g, seed number was 370.3 ± 35.76, and total seed weight was 61.81 ± 4.99 g, indicating the heaviest and most numerous seeds. The Nena × Ehtiyoj combination had a slightly lower 1000 seed weight (162.82 ± 1.66 g), fewer seeds (223.8 ± 15.42), and lower total seed weight (36.35 ± 2.60 g). The Ehtiyoj × To‘maris combination had a lighter 1000 seed weight (152.65 ± 5.19 g) but a high seed number (307.4 ± 14.75), resulting in a relatively high total seed weight (48.78 ± 3.36 g).

Table 2. Quantitative trait indicators in soybean F_3 hybrid families

Soybean F3 hybrid families	Weight of 1000 grains per plant, g.		Number of grains per plant, grains		Grain weight per plant, g.	
	X±Sx	V%	X±Sx	V%	X±Sx	V%
♀Sochilmas x Genetik-1♂	140,87±5,81	13,03	218,2±34,12	49,45	30,81±4,72	48,5
♀Genetik-1 x Sochilmas♂	153,16±2,01	2,01	157,9±13,43	26,89	23,79±2,29	30,5
♀Sochilmas x Selekta 302♂	144,25±3,86	8,46	241,3±30,43	39,88	35,10±4,71	42,4
♀Selekta 302 x Sochilmas	163,52±0,85	1,72	204,1±14,86	24,31	34,14±2,73	25,26
♀Ehtiyoj x Nena♂	165,48±3,49	6,68	370,3±35,76	30,54	61,81±4,99	25,55
♀Nena x Ehtiyoj♂	162,82±1,66	3,23	223,8±15,42	21,79	36,35±2,60	22,6
♀Ehtiyoj x To‘maris♂	152,65±5,19	10,76	307,4±14,75	15,18	48,78±3,36	21,77
♀To‘maris x Ehtiyoj♂	163,30±1,56	3,02	271,9±14,32	16,66	43,62±2,82	20,46

To‘maris × Ehtiyoj showed average values in all three traits. Selekta 302 × Sochilmas had high 1000 seed weight (163.52 ± 0.85 g) but low seed count, resulting in lower total seed weight. Sochilmas × Selekta 302 had low 1000 seed weight but average seed number, keeping total weight moderate. Sochilmas × Genetik-1 had very low 1000 seed weight and seed number, resulting in low total seed weight. Genetik-1 × Sochilmas had moderate 1000 seed weight but very low seed number and total weight. These results selected plants with superior quantitative trait indicators from F_3 hybrid combinations. These selected families were multiplied in control nurseries.

Additionally, early-maturing plants taller than the Genetik-1 variety and with more nodes were selected from both direct and reciprocal crosses of Sochilmas and Genetik-1 varieties. These were grouped into a line named conditionally as "Tezpishar" (Early Maturing). This line demonstrated superior early maturity, maturing within 70 days under field conditions (Fig. 1).

Figure 1. General appearance of the soybean “Tezpishar” line and its roots in field conditions

Furthermore, through detailed analysis of advanced generation hybrid combinations, several promising lines were identified. These lines exhibited high yield, improved seed quality, shatter-resistance at pod maturity, and a higher position of the first fruiting branch. Future research is planned to advance these lines to varietal status.

Discussion

The findings of this study enabled the identification of promising forms for selection based on the genetic diversity and phenotypic expression of soybean (Glycine max (L.) Merr.) hybrid generations. The results demonstrated the superiority of the ♀Ehtiyoj × Nena♂ combination in terms of morpho-agronomic traits, standing out with the highest number of pods (183.5 ± 13.01), seed number (370.3 ± 35.76), and total seed weight (61.81 ± 4.99 g). These results are consistent with other studies; for instance, Malik et al. (2021) reported high-yielding and protein-rich crosses in the F_3 generation. The F_3 stage is characterized by a high degree of genetic recombination and variation, which creates a favorable environment for the selection of promising genotypes (Singh *et al.*, 2018). Phenotypic traits such as plant height, number of nodes, number of branches, and number of pods serve as key indicators during the selection process. In this study, the ♀Nena × Ehtiyoj♂ combination exhibited the tallest plant height (152.5 ± 9.32 cm), indicating a high vegetative growth potential. These results align with the findings of Raza et al. (2020), who emphasized the influence of agro-climatic conditions on morphological traits.

Furthermore, the line designated as "Tezpishar," with a 70-day vegetation period, represents a significant step toward the development of early-maturing varieties. This observation is consistent with Zhang et al. (2019), who reported the advantages of short-vegetation F_3 lines under various agro-climatic conditions.

Significant differences were also observed in quantitative traits. For instance, the ♀Ehtiyoj × To‘maris♂ combination showed high seed number and strong yield potential, indicating that transgressive recombinations could enhance selection efficiency. The concepts of heritability coefficient and phenotypic-genotypic variance analysis proposed by Burton and Devane (1953) are particularly relevant at this stage.

The results of the study indicate that the F_3 generation serves as a valuable source of material for breeding purposes. These materials are recommended as donors for the development of high-yielding and early-maturing varieties adapted to the agro-climatic conditions of Uzbekistan. This approach aligns with the breeding strategies proposed by Bozorov (2017) under local conditions.

Another important aspect is that evaluating promising lines using molecular markers will further enhance the accuracy of selection (Varshney *et al.*, 2005). Future studies aimed at molecular analysis of these forms to identify their genetic basis will improve the effectiveness of breeding programs.

Conclusion

This study examined the selection of superior lines from the F_3 generation of soybean hybrids with high yield potential, quality, and favorable morphological traits. Among the evaluated combinations, the ♀Ehtiyoj × Nena♂ hybrid demonstrated the highest performance in terms of seed number, seed weight, and pod number. This makes it a strong candidate to be recommended as a donor in breeding programs. Additionally, the “Tezpishar” line derived from the ♀Sochilmas × Genetik-1♂ hybrid stood out due to its short 70-day maturity period, making it a key source for developing early-maturing varieties. The identification of morphologically and agronomically superior forms confirms the importance of the F_3 stage for breeding purposes. It is advisable to further develop these promising lines into full-fledged varieties and analyze them in more detail using molecular markers. The results of this study are expected to contribute to the development of stable, high-yielding soybean varieties adapted to the agro-climatic conditions of Uzbekistan. This, in turn, will directly support food security, healthy nutrition, and efficient use of resources.

Acknowledgments

This article was prepared based on scientific research conducted within the framework of state scientific programs funded by the state budget of the Republic of Uzbekistan and supported by the Uzbekistan Academy of Sciences.

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