Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 2, 2024
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

YIELD STABILITY AND SEED QUALITY UNDER DIFFERENT CLIMATIC CONDITIONS AT SOME EUROPEAN AND CHINESE SOYBEAN GENOTYPES

Dina Ramona GALBEN[1], Camelia URDĂ[2], Raluca REZI[2], Adrian NEGREA[2], Alina ȘIMON[2], Marcel Matei DUDA[1]

[1]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, 400372, Cluj-Napoca, Romania
[2]Research and Development Station for Agriculture, 27 Agriculturii Street, 401100, Turda, Romania

Corresponding author email: camelia.urda@scdaturda.ro

Abstract

A field experiment organised in three different years (2021, 222, 2023) at Research and Development Station for Agriculture (RDSA) Turda studied the yield stability and seed quality of some soybean genotypes of European and Asian origin, cultivated in the conventional system. The 119 soybean genotypes were sown in the experimental field of the Soybean Breeding Laboratory and consisted of seven different maturity groups (MG), from 0000 MG to III MG, characterised by different growing season. Based on the experimental results, genotypes that originated in Europe performed better in terms of grain yield compared to Asian genetics. In years with high temperatures and water deficit during the growing season, such as 2022, it seems that better results were obtained in genotypes with purple flower compared to those with white flower; with grey pubescence compared to the brown one, and in terms of growing season, the extremes of the experiment, namely extra and very early soybean genotypes along with late and very late genotypes, overcame critical phases characterized by lack of water and high temperatures, achieving superior yields.

Key words*: Asian, European, genotypes, soybean, yield stability.*

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.), with its multiple uses, is one of the most important crop plants worldwide (Hahn and Medanier, 2013), especially for developing countries facing mal-nutrition and food insecurity (Yirga et al., 2022). As demand for plant foods increased, protein (≈40%) and oils (≈20%) (De Visser et al., 2014) of soybeans have gained importance in recent years (Singh, 2010).

Soy protein has a number of advantages over other types of natural proteins: increased biological value, lower price and relatively long shelf life due to stability (Deng et al., 2012), soybean oil being used and appreciated in various fields of gastronomy due to its versatility (De Maria et al., 2020).

With changing climate and environmental conditions, throughout the growing season, soybeans can often encounter several stressors (abiotic and biotic) that affect the reproductive structure and ultimately lead to lower yields (Kesar et al., 2023).

Identifying biological material with tolerance to climate stress and a good adaptability, as high as possible to various external disturbing factors, can be a starting point for creating new soybean varieties (Melnyk et al., 2022) that are stable in time and space for both productivity and quality.

A basic requirement for successful crop breeding is to secure and continuously use genetic diversity, in order to ensure the existence of traits for tolerance that will be led to adapt crops to new environmental conditions and climate change (Andrijanić et al., 2023).

Crop yields level is dependent on environmental conditions (Suciu et al., 2021), so the adap-tability of varieties to environmental changes is important to ensure stability regardless of year or location (Habtegebriel and Abebe, 2023).

Some characteristics of soybeans, such as stem pubescence colour or flower colour, although not part of the main selection criteria for pro-duction and quality, are nevertheless correlated with tolerance to abiotic stress conditions (Xie, 2007). Authors such as Morrison and Voldeng (1994) point out that the colours of the

pubescence of the soybean stem and hilum have a direct or indirect influence on the growth, development and even yield of plants.
In the context of global climate change, Romania is also affected by an increase in air temperature and a lack of precipitation in critical phases for plants. Thus, the study of such a varied biological material allowed the identification of genotypes adapted to these changing conditions, capable of achieving high yields even in the presence of stressors.

MATERIALS AND METHODS

For evaluating the stability of the yield capacity and the quality of a biological material with origin in Europe and China, respectively, at RDSA Turda a field experiment was conducted in the climatic conditions of: 2021, 2022, 2023. The 119 soybean genotypes (Figure 1) evaluated in the study consisted of:
- 65 European genotypes;
- 54 Asian genotypes.

Genotypes are classified into 7 different maturity groups, from extra-early to very late, as following:
- Maturity group of extra early (0000) and very early (000) soybean genotypes: 18 genotypes;
- Maturity group of early (00) soybean genotypes: 20 genotypes;
- Maturity group of semi-early (0) soybean genotypes: 38 genotypes;
- Maturity group of semi-late (I) soybean genotypes: 40 genotypes;
- Maturity group of late (II) and very late (III) soybean genotypes: 3 genotypes.

The varieties were sown mechanized, experiment being placed linearly, each cultivar being sown on:
- two rows with a length of 10 m;
- 50 cm distance between rows;
- sowing density was 55 germinate grains per m^2.

During the growing season, notations were made regarding: emergence date, flowering date, flower colour, maturity beginning date, maturity end date, pubescence colour. Based on the notations, the growing season of each genotype was calculated.
The harvesting was mechanized, using a Classic Wintersteiger Combine for experimental plots, the yield of each genotype being related to ha. The experimental data were statistically processed using Excel.

Figure 1. Aspects from experimental field (original)

RESULTS AND DISCUSSIONS

Of the three experimental years, the climatic conditions from 2022 were totally unfavourable for soybean crop. Based on the climatic conditions from 2021, respectively 2023, good yields were obtained, 2021 being the most favourable. Although of the three experimental years, the conditions from the first year allowed the studied genotypes to achieve the highest yields, late-maturing cultivars do not reach their genetic potential due to the limiting climatic factor. The drought in the last decade of June and in the first two decades of August affected the flowering stage of late genotypes, respectively on the phase of pod formation and grain filling for early genotypes (Figure 2).
The months of April and May, which are the timing of sowing and emergence periods, were not only dry but also cool. The summer months presented a general warming trend for almost the entire soybean growing season.

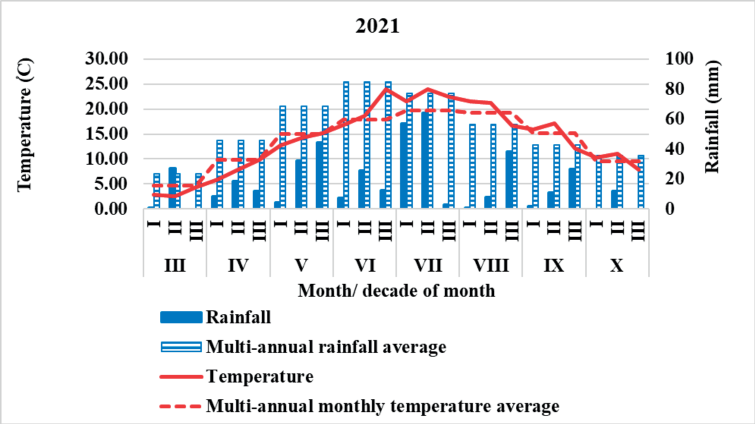

Figure 2. Mean air temperature and rainfall of each month during soybean growing season (Turda, 2021)

The analysis of the data on the thermal and pluviometry regime recorded in 2022 in Turda presented in Figure 3, highlights that 2022 can be characterized as a hot and excessively dry year, until August, September when we have an excess of precipitation.

The water reserve and the evolution of temperatures at the beginning of the year (January-April 2022), at RDSA Turda, were less favourable to sowing in optimal humidity and temperature conditions. Thus, the genotypes had a difficult start in vegetation, the emergence being noted at a time interval of two weeks after sowing.

Reproductive stage and development were greatly affected by climatic conditions in June and July, especially by the lack of rainfall, but also by the high temperatures during this period. Also, the beginning of maturity and the end of maturity were affected by the climatic conditions of this year, due to the rainfall recorded at the end of August and September, respectively, the harvesting of very early genotypes but also of those with a longer vegetation period was delayed. With the exception of very early genotypes harvested in the third decade of September, most genotypes were harvested in the first decade of October.

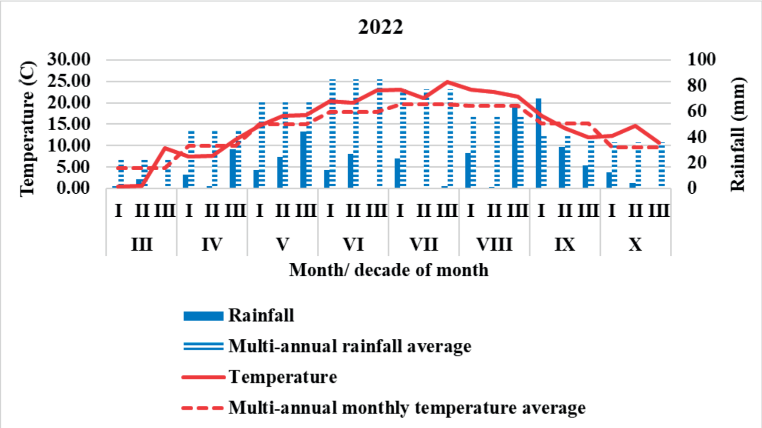

Figure 3. Mean air temperature and rainfall of each month during soybean growing season (Turda, 2022)

The analysis of the data on the thermal and pluviometric regime recorded in 2023 in Turda, presented in Figure 4, highlights the fact that 2023 can be characterized as a warm and excessively dry year in spring. However, in the summer months except July, and in the first month of autumn, due to significant rainfall, they were characterized as excessively rainy.

The water reserve and the evolution of temperatures pre-sowing (January-April 2023) at RDSA Turda were less favorable regarding optimal humidity and temperature conditions. Thus, genotypes had an uneven emergence, in staggered stages, at a time interval of three weeks after sowing. However, the main vegetative and generative stages were not affected to a significant extent by next climatic conditions. The harvesting of soybeans was slightly delayed due to rainfall in early September, but without having a negative influence on yield and quality.
With the exception of very early genotypes harvested in the third decade of September, most genotypes were harvested in the first decade of October.

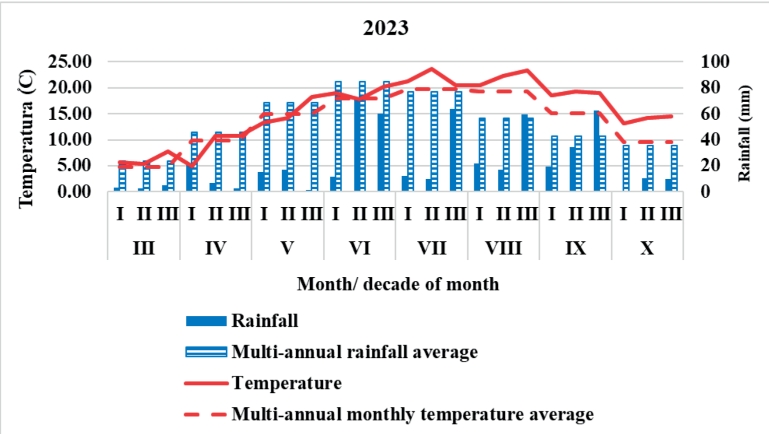

Figure 4. Mean air temperature and rainfall of each month during soybean growing season (Turda, 2023)

It is well known that a crop that has been developed to adapt to the climate of a particular country cannot be fully successfully grown in other countries (Jung et al., 2023), but through breeding processes a certain degree of adaptability can be achieved.
The ecological plasticity of a genotype, evidenced by the stability of yield capacity from one year to another and from one location to another, allows the choice of valuable cultivars that could capitalize, in the context of current climate change, the difficult climate and soil conditions by maximising grain production.
The analysis of stability of the studied genotypes (Figure 5) according to their origin indicates that the biological material coming from Europe seems to have a superior behaviour to the Asian one under the conditions of the three experimental years. Djanta et al., (2020) highlights that the lack of locally adapted soybean varieties is one of the major factors restricting crop production.
However, in 2022, a totally unfavourable year for soybean cultivation in the reference area, it would appear that both germplasm types were strongly affected by atypical climate conditions, with the average yield of China genotypes being at the same level as European ones.

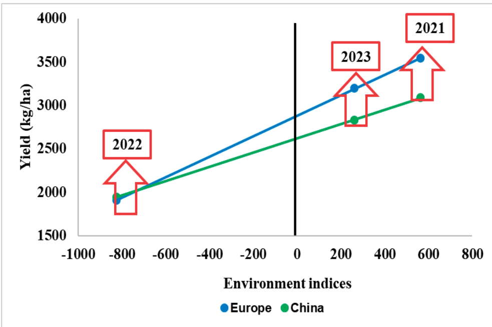

Figure 5. Stability of yield capacity depending on the origin of biological material

In 2019, Voss-Fels et al. point out that intensive research was needed to develop improved and highly stable soybean varieties that fit food standards worldwide.
The stability of the genotypes yield capacity in the three experimental years, at RDSA Turda, was also evaluated according to the maturity group analysed in the experiment (Figure 6).

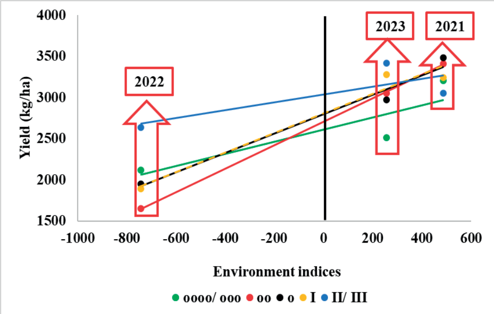

Figure 6. Stability of yield capacity depending on the maturity of biological material

In this case it is noted that out of the three experimental years, 2022 was very unfavourable for soybean cultivation. If in the favourable conditions of 2022, early and semi-early soybean genotypes had the highest yields, which were otherwise recommended to be grown in our growing area, in 2022, good yields were obtained in very early soybean genotypes and in late and very late ones.

Some authors consider that often the long period of the growing season is directly correlated with high yield potential (Mushoriwa et al., 2022), but even if it would seem that genotypes with a longer vegetation period are more productive, their cultivation in our growing area presents a high-risk factor in years with heavy rainfall. This could extend their growing season, delaying harvesting.

Chaudhary and Wu stated in 2012 that it is important to investigate the stability over time of soybean varieties in terms of quality parameters under current and future climate change.

Regarding the analysis of the stability of yield capacity according to the colour of the steam pubescence, it would seem that (Figure 7), genotypes with grey pubescence show better adaptability to adverse environmental conditions, while under normal conditions, brown genotypes achieve higher yields. The 2022 year was characterized by soybean yields below 2000 kg/ha. The best year for soybean cultivation was 2021, in which yields of 3500 kg/ha were obtained, on average, at cultivars with brown pubescence.

Research by Zhou et al. (2024) has shown that unlike soybean plants with grey pubescence, plants with brown pubescence possess higher yield capacity and improved stability in cold regions, and that this characteristic of soybeans also indicates cold-resistant ability, so it is recommended to specifically select soybean varieties with brown pubescence.

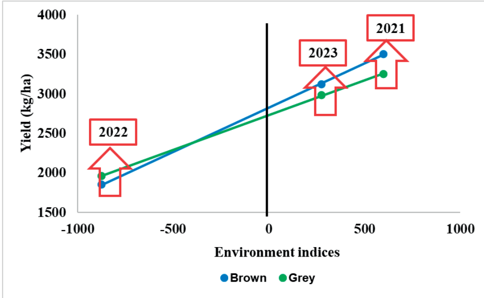

Figure 7. Stability of yield capacity depending on pubescence

Most cultivated soybean varieties are characterized by the purple colour of the flower, which is dominant. From the analysis of the stability of soybean yield capacity depending on the colour of the flower, on average, regardless of the environmental conditions encountered, purple flower genotypes have a consistently good behaviour and superior production to those with white flower (Figure 8).

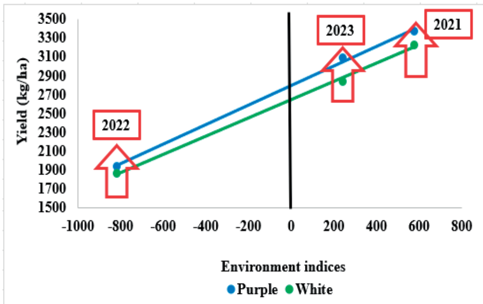

Figure 8. Stability of yield capacity depending on the colour of flowers

The experiment located at RDSA Turda during the three years allowed the study of Asian and European origin biological material and with different maturity.

In order for soybeans to be not only an important source of vegetable protein, but also a very good precursor for autumn grain crops, especially winter wheat, it must be harvested as early as possible.

That stated soybean genotypes characterized by growing season of less than 135 days and yield of more than 3 t/ha were highlighted. Grouping genotypes by maturity and production revealed a group of 13 cultivars, 10 of European origin and 3 of Asian origin, which could be extended into Transylvanian Plateau area of cultivation. Some of these are: Heinong 64, Heihe 39, Ns Kaca, Augusta, Alexa, Ancona, Regina, Heihe 5, Pannonia Kincse, TriaDa, Ns Hogar, and NS L-401156 (Figure 9).

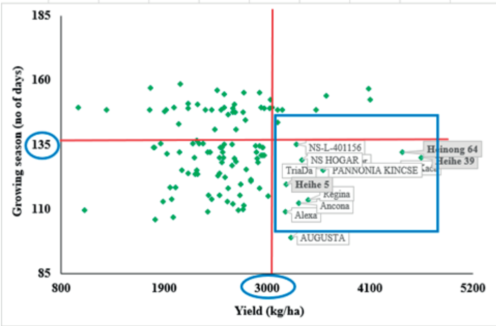

Figure 9. Genotypes with high yield and suitable growing season

For future research, there is an interest in obtaining high yielding genotypes with high values for thousand kernel weight to allow the use of soybeans in the food industry. In this sense, out of the 119 genotypes studied, 7 had yields greater than 2500 kg/ha and TKW over 160 g. Among them we mention the Obelix and Paco varieties, but also the Mengdou 30 variety, which had a thousand kernel weight of almost 180 g (Figure 10).

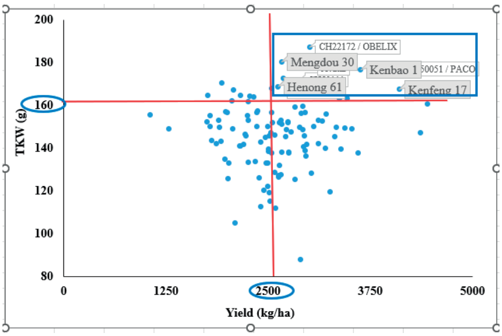

Figure 10. High-yielding, high-grain genotypes

There is known the negative relationship between protein and oil, and because of this is difficult to improve them simultaneously. Grouping the 119 genotypes according to the two quality indices (Figure 11), revealed a group of 15 genotypes that had a fat content of over 22 percent and a protein content of over 40 percent. Also noted was the Paco variety for the highest protein content and the Dongnong 50 variety which proved to be the oiliest.

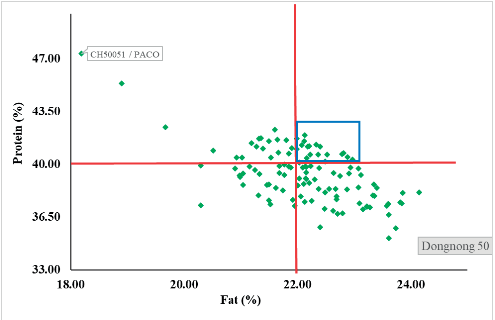

Figure 11. High protein and fat genotypes

Ray et al., (2008) stated that in the case of soybeans, characteristics such as protein and oil are influenced by environmental and genetic variables as well as their interactions, and the protein and oil content of soybeans correlate negatively (Hurburgh et al., 1987).
Yield response of the best soybean genotypes is highlighted in the following table (Table 1). More than 4 t/ha yield was observed at three European soybean varieties (Es Gladiator, Ns Kaća and Paco) and two Asian varieties (Beidou 30, Kenfeng 17).
The average of top ten best performing European genotypes in terms of yield (3,657 kg/ha) was 200 kg/ha higher than of Chinese genotypes.
Paco soybean variety is not only high yielding but also appreciated for its high values of TKW and protein content respectively.

Table 1. Rank of soybean genotypes depending on origin using yield performance

Rank	Europe		Asia	
	Genotype	Yield (kg/ha)	Genotype	Yield (kg/ha)
1.	Es Gladiator	4,647	Beidou 30	4,445
2.	Ns Kaća	4,367	Kenfeng 17	4,105
3.	Paco	4,085	Kenbao 1	3,633
4.	Castetis	3,523	Suinong 24	3,600
5.	Regina	3,439	Heihe 36	3,468
6.	Triada	3,396	Heihe 48	3,373
7.	Ancona	3,336	Dongnong 54	3,162
8.	Ananda	3,317	Kennong 36	3,112
9.	Augusta	3,258	Dongnong 51	2,974
10.	Es Tenor	3,206	Henong 60	2,971
	Average	**3,657**	**Average**	**3,486**

CONCLUSIONS

The study of the 119 soybean genotypes grown in conventional system at RDSA Turda, in three different years in terms of climatic conditions, allowed highlighting some valuable genotypes both in terms of yield, yield stability and harvest quality.

The results obtained in this research are of equal interest to researchers who can identify valuable sources of genitors that can be used in cross-breeding, as well as soybean growers who can identify genotypes adapted to various climatic conditions.

It would appear that, in the three experimental years, genotypes that originated in Europe performed better in terms of seed yield as compared to Asian genetics.

An average yield of 3543 kg/ha in 2021, 1907 kg/ha in 2022 and 3197 kg/ha was obtained by European cultivars.

Following yield were obtained by Asian cultivars: 3088 kg/ha, 1945 kg/ha, 2829 kg/ha.

Also, in normal crop conditions, following genotypes achieve higher yields:

- brown pubescence (3503 kg/ha, 3121 kg/ha), compared to the grey one (3255 kg/ha, 2986 kg/ha);
- purple flower (3370 kg/ha, 3089 kg/ha) compared to the white one (3232 kg/ha, 2845 kg/ha);
- early (3407 kg/ha, 3053 kg/ha) or semi-early maturity (3481 kg/ha, 2970 kg/ha), compared to other maturity groups.

In years with high temperatures and water deficiency during the growing season, such as in our case 2022, it would seem that better results were obtained at genotypes with:

- purple flower (1942 kg/ha) compared to those with white flower (1870 kg/ha);
- grey pubescence (1960 kg/ha), compared to brown one (1850 kg/ha).

In terms of the limits of growing season, namely extra and very early soybean genotypes (2120 kg/ha) along with late and very late genotypes (2633 kg/ha), overcame critical phases characterized by lack of water and high temperatures, achieving superior yields in unfavourable conditions.

Grouping genotypes by maturity and yield revealed 13 cultivars, 10 of European origin and 3 of Asian origin, which could be grown in the Transylvanian Plateau. Among them are: Heinong 64, Heihe 39, Ns Kaca, Augusta, Alexa, Ancona, Regina, Heihe 5, Pannonia Kincse, TriaDa, Ns Hogar, and NS L-401156.

In terms of quality, the Paco variety stood out for the highest protein content and the Dongnong 50 variety, which proved to be the oiliest.

REFERENCES

Andrijanić, Z., Nazzicari, N., Šarčević, H., Sudarić, A., Annicchiarico, P., Pejić, I. (2023). Genetic Diversity and Population Structure of European Soybean Germplasm Revealed by Single Nucleotide Polymorphism. *Plants*, 12, 1837.

Chaudhary, K.R., Wu, J. (2012). Stability analysis for yield and seed quality of soybean [*Glycine max* (L.) Merril] across different environments in Eastern South Dakota. *Conf. Appl. Stat. Agric*.

De Maria, M., Robinson, E.J.Z., Kangile, J.R., Kadigi, R., Dreoni, I., Couto, M., Howai, N., Peci, J., Fiennes, S. (2020). Global Soybean Trade. The Geopolitics of a Bean, UK Research and Innovation Global Challenges Research Fund (UKRI GCRF) Trade, *Development and the Environment Hub: London, UK*.

De Visser, C.L.M., Schreuder, R., Stoddard, F. (2014). The EU's dependency on soya bean import for the animal feed industry and potential for EU produced alternatives. *OCL 2014*, 21, D407.

Deng, K., Huang, Y., Hua, Y. (2012). Isolation of glycinin (11S) from lipid-reduced soybean flour: Effect of processing conditions on yields and purity. *Molecules*, 17, 2968–2979.

Djanta, M.K.A., Agoyi, E.E., Agbahoungba, S., Quenum, F.J.B., Chadare, F.J., Assogbadjo, A.E., Agbangla, C., Sinsin, B. (2020). Vegetable soybean, edamame: Research, production, utilization and analysis of its adoption in Sub-Saharan Africa. *J. Hortic. For.,* 12, 1–12.

Habtegebriel, M. H, A. T, Abebe, (2023). Grain yield stability of soybean (*Glycine Max* (L.) Merrill) for different stability models across diverse environments of Ethiopia, *Agrosystems, Geosciences & Environment*, Volume 6, Issue 3.

Hahn, V., Miedaner, T. (2013). Soybean Cultivation in the EU. Rewarding Cultivation Without GMOs, 100% Practice, in German, DLG-Verlag: Frankfurt am Main, Germany.

Hurburgh, C.R., Paynter, L.N., Schmitt, S.G. (1987). Quality shharacteristics of Midwestern soybeans. *Appl. Eng. Agric.* 3, 159–165.

Jung, K.-C., Kim, B.-Y., Kim, M.-J., Kim, N.-K., Kang, J., Kim, Y.-H., Park, H.-M., Jang, H.-S., Shin, H.-C., Kim, T.-J. (2023). Development of a Gene-Based Soybean-Origin Discrimination Method Using Allele-Specific Polymerase Chain Reaction. *Foods*, 12, 4497.

Kezar, S., Ballagh, A., Kankarla, V., Sharma, S., Sharry, R., Lofton, J. (2023). Response of Soybean Yield and Certain Growth Parameters to Simulated Reproductive Structure Removal. *Agronomy*, 13, 927.

Melnyk, A., Romanko, Y., Dudka, A., Chervona, V., Brunyov, M., Sorokolit, E. (2022). Ecological elasticity of soybean varieties' performanceaccording to climatic factors in Ukraine, *AgroLife Scientific Journal* - Volume 11, Number 2, 91-99.

Morrison, M.J., Voldeng, H.D. (1994). Soybean Pubescence Color Influences Seed Yield in Cool-Season Climates. *Agron J*., 86, 796–799.

Mushoriwa, H., Mathew, I., Gwata, E.T., Tongoona, P., Derera, J. (2022). Grain Yield Potential and Stability of Soybean Genotypes of Different Ages across Diverse Environments in Southern Africa. *Agronomy*, 12, 1147.

Ray, C.L., Shipe, E.R., Bridges, W.C. (2008). Planting date influence on soybean agronomic traits and seed composition in modified fatty acid breeding lines. *Crop Sci.*, 48, 181–188.

Singh, G., (2010). The soybean: botany, production and uses. CABI.

Suciu, L., Tărau, A., Urdă, C., Chețan, F., Mureșanu, F., Șopterean, L., Boiu-Sicuia, O.A., Barbu, L.D.N. (2021). The influence of bacterial inoculats on pathogens, yield and quality in soybean crop. *AgroLife Scientific Journal*, *Volume 10*, Number 1, 221-226.

Voss-Fels, K.P., Stahl, A., Hickey, L.T. (2019). Q&A: Modern crop breeding for future food security. *BMC Biol.,* 17, 1–7.

Xie, Y.H. (2007). Difference analysis on DUS traits of soybean standard varieties. *Soybean Sci.,* 2, 284–286,

Yirga, M., Sileshi, Y., Tesfaye, A., & Hailemariam, M. (2022). Genetic variability and association of traits in soybean (*Glycine max* L.) genotypes in Ethiopia. *Ethiopian Journal of Crop Science*, 9(2), 49–74.

Zhou, M., Wang, J., Chen, H., Jia, Q., Hu, S., Xiong, Y., Zhang, H., Zhang, W., Wang, Q., Su, C. (2024). Genome-Wide Association Study on Candidate Genes Associated with Soybean Stem Pubescence and Hilum Colors. *Agronomy*, 14, 512.