PhD THESIS

Study of the influence of the sowing period and genotype on soybean productivity and quality in the Transylvanian Plateau

(SUMMARY OF Ph.D. THESIS)

PhD student **Andrei George Ionuț Varga**

Scientific coordinator **Prof. univ. dr. Matei-Marcel Duda**

CLUJ-NAPOCA, 2024

INTRODUCTION

The nutrient content of soybeans (Glycine max L.) plays a crucial role in assessing the quality of soybeans (Glycine max. L.), as they are essential for maintaining the nutritional value of soybeans. Of all these components of soybeans, protein is of the greatest importance, as it contributes 60% of the overall plant protein. There is usually an inverse correlation between the amount of protein and the oil present in soybeans (Wijewardana et al., 2019).

Heat treatment procedures, necessary to reduce anti-nutritional compounds, are expensive and require specialized facilities. Also, reducing the antitrypsin content by germination is a complex technique that is not universally applicable. Therefore, the most effective approach, although requiring extensive efforts in plant breeding or genetic engineering, would involve the development of soybean genotypes with a low concentration of trypsin inhibitors. One of the goals pursued by researchers at the Agricultural Research and Development Station in Turda, Romania, is to achieve this.

The main purpose of the research is to evaluate the influence of the sowing epoch on the level of soybean production and quality, studying a genetic material of different maturity, being experimented 10 very early, early or semi-early soybean genotypes. The biological material under study consists of 7 commercial varieties and 3 perspective lines in advanced generations of selection, most of the cultivars being created at Turda Agricultural Research and Development Station. In addition to the varieties and lines created in Turda, the Italian variety Avatar, known for its low antitrypsin content, was also experimented.

The structure of the doctoral thesis entitled "Study of the influence of the sowing period and genotype on soybean productivity and quality in the Transylvanian Plateau" consists of two parts that include eight chapters.

The first part "CURRENT STATE OF KNOWLEDGE" includes 3 chapters, which present important current data and aspects from the specialized literature, the history and origin of soybeans, the spread of this species worldwide, European and national, as well as technological aspects, and important elements in soybean cultivation.

The second part, "PERSONAL CONTRIBUTION", combines theoretical and methodological aspects with practical ones and is structured in eight chapters.

1.History, origin, distribution and chemical composition of soybean *(Glycine max* L.*)*

Chapter 1 includes 3 subchapters and 2 sub-sub-chapters, which present data on the history, origin, spread and chemical composition of soybeans, as well as its spread worldwide, in Europe and in Romania.

2. Systematics aspects and ecological requirements

This chapter consists of two subchapters dealing with the systematics and peculiarities of soybean cultivation.

3. Technological peculiarities of soybeans

Chapter 3 consists of 4 subchapters, in which are presented, the technological requirements of this crop related to rotation, ferticization, sowing and maintenance of the crop throughout the growing season

4. Research objectives

Chapter 4 presents the main purpose of the research and the specific objectives pursued in this paper.

5. The particularities of the natural environment in the experimental field at SCDA Turda

Chapter 5 describes the relief, hydrology, thermal, pluviometric regime and soil in the experimental area.

6. Research material and method

In this chapter are presented all the characteristics of the varieties taken in the study, the experimental design, the research method, as well as the observations made.

7. Results and discussion

Chapter 7 contains the results obtained and the discussion on them. It is structured in 2 subchapters:

7.1 The influence of the sowing age on some morphoproductive characteristics

In the case of plant height, the technological factor, namely the sowing age, has shown a very significant impact on plant growth. Therefore, we can say that in the two experimental years the sowing period has no repercussions on vegetative processes or, at least in the Transylvanian Plateau area, the delay in sowing does not significantly affect plant growth. F-test values indicate a very significant influence of the interaction between genotype and epoch.

In general, a waist too large, over 120 cm, increases the sensitivity of plants to fall, sensitivity that can also be influenced by the sowing thickness. Modern soybean cultivars have a determined growth, having short internodes and a large number of pods/knot. Even if plant height is a characteristic with a pronounced genetic determinism, however, climatic variations influence plant growth quite markedly. Thus, between the averages of plant height in the 2 years there are differences of almost 35 cm. All genotypes recorded higher values in 2021 compared to 2022.

The insertion of the first basal pod is a particularly important technological feature in preventing losses in mechanized harvesting. Thus, it is known that a height of over 12 cm of the insert significantly reduces harvest losses. In both experimental years, the values of sample F corresponding to the two experimental factors by their significance suggest a very significant influence on this important technological feature. Also, the double interaction between the two factors indicates a very significant influence in 2022 and only distinctly significant in 2021.

In the case of 2021, all varieties showed a first pod insertion height of more than 12 cm, except for the Perla variety, whose insertion height of the first pod was 7.95 cm. The Onyx, Raluca TD and T-6126 varieties are noted, these having very significant positive differences from the control, the control being the average of all varieties taken in experience, the Perla variety showed very significant negative differences from the control. In 2022, the Onyx variety stands out again with distinctly significant positive differences from the control, and the Perla variety is at the opposite pole with distinctly significant negative differences. On average, it could be said that in 2021 the insertion height recorded values slightly higher than 2022, and the Onyx variety stands out in particular, which in both experimental years recorded high values.

In order to achieve grain production, one of the essential productivity characteristics is the number of pods / plant, this being a character influenced by the genotype, but also by the cultivation technology and pedo-climatic conditions. Thus, according to the variance analysis table, in 2021 the influence of genotype on the number of pods per plant was significant and in 2022 the differences between genotypes did not register significant differences. In comparison, the sowing age had a very significant influence on the number of pods per plant in both experimental years. The double interaction between the two factors influenced this attribute very significantly in 2021 and 2022, respectively.

In both experimental years compared to the average of that year, genotypes showed no statistically assured differences, except for the perspective line T4203, which achieved a significantly higher pod/plant count than the control. However, comparing the values from the two experimental years, we can say that in all genotypes in 2021 there were a higher number of pods than in 2022, except for the cultivar Avatar.

The number of grains/plant is an important agronomic feature of soybean

production and is greatly influenced by environmental conditions and technological elements that could control to some extent the influence of the abiotic environment. Thus, from the table of variance analysis it can be seen that in both experimental years the sowing epoch greatly influenced the generative stage. The differences between genotypes were only statistically secured at significant thresholds in one year, and the interaction between the two factors marked very significantly the number of berries / plant only in 2021.

Together with the number of grains/plant and the mass of grains/plant (MMB), it is an important quantitative character dependent on environmental conditions and maturity group. Analyzing the data on the analysis of variances for MMB, it can be concluded that in years when climatic conditions are superimposed on as large a range as possible compared to genotype requirements, the influence of the sowing epoch on this quantitative character is greatly diminished, practically does not significantly affect the MMB. An eloquent example of this is 2021, when the sowing era did not significantly influence the size of the grains.

In almost all genotypes, this important direct and indirect attribute of grain quality registered considerably higher values in 2021 compared to 2022, which is also reflected at the level of the averages of the two years. In the Avatar variety in 2021 compared to the average of the year, there were very significantly positive differences, while in the Onyx variety the differences were significantly negative. In 2022, genotype influenced the MMB of soybeans, the differences being significantly negative in the case of Onyx and Perla varieties and in the case of the other varieties there were no statistically assured differences.

In general, we can say that the delay in sowing has negative repercussions on soybean production, the differences compared to the first epoch being very significantly negative .

Usually, in experiments aimed at the production of several varieties, the most representative variety is chosen as a control, among those analyzed, the most cultivated variety. Consequently, in our experiment we chose the Felix variety as a control. Among the genotypes analyzed, the most efficient cultivar was the Avatar variety, a variety that is from group I of maturity, being chosen in this experiment also as a control for the antitrypsin content. Among the autochthonous genotypes that have a fairly similar vegetation period, the genotype Cristina, Raluca and the T295 line stand out in particular. In fact, the Felix witness was outperformed by all experimental variants with statistically assured differences, except for the T4203 line and the Perla and Onyx varieties. Based on these results, we could recommend using the Avatar variety as a genitor to improve both production and antitrypsin content, which, if it could improve simultaneously, would be the idea. Also, the use of the Avatar variety as a genitor must

be done with certain reservations, given the maturity group to which it belongs and the growing area.

In 2021, all genotypes in the experiment exceeded the control in production, the differences being statistically assured, except for the Onyx variety, to which they were not statistically assimilated. In 2022, a less favorable year for soybeans, no statistically assured positive differences were recorded compared to witness Felix, while three of the 10 genotypes had negative differences statistically assured as very significant or distinctly significant. Therefore, the Felix genotype remains a cultivar with a good ability to adapt to less favorable environmental conditions (fig. 1).

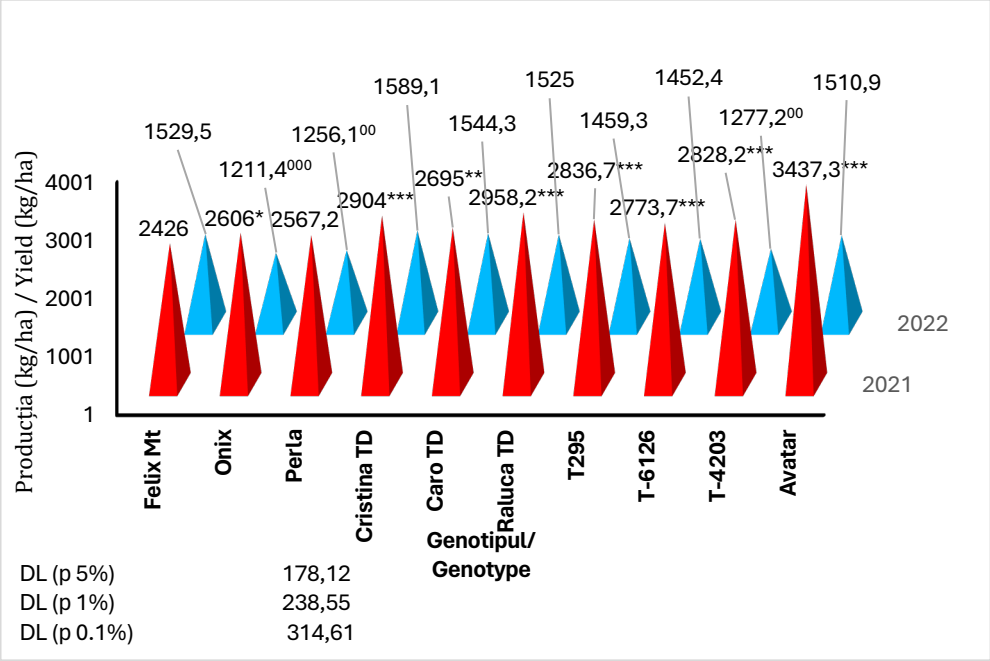

Fig. 1. Interaction of genotype and crop years on soybean production (SCDA Turda 2021, 2022)

7.2 Analysis of qualitative components in analyzed soybean genotypes

Analysis of variances for oil content indicates in 2021 a strong fluctuation of this attribute, both experimental factors showed a very significant influence. In 2022, the influence of the epoch factor was only significant between genotypes and this year there were very significant differences.

The differences between genotypes are also reflected in our study, thus, in 2021 all genotypes except the T295 line had a higher oil content compared to the Felix variety,

the differences being very significant. In 2022 the fat content varied depending on the variety, in the varieties Perla Caro TD and perspective line T 4203 the difference was very significantly positive compared to the control, and in the case of the Cristina TD variety the difference was only significantly positive. In the case of Raluca TD variety and T-6126 line, the smallest quantities of oil were recorded, the differences from the control being very significantly negative.

Linolenic acid belongs to the group of unsaturated fatty acids and is known for its positive effects on human health. Overall, unsaturated fatty acids reduce the degree of stability of the oil. As can be seen, the variance of linolenic acid content is very significantly controlled by genotype, and only significantly by the sowing age. However, it appears that the involvement of the sowing date in controlling the fluctuation of linolenic acid is variable depending on the year of cultivation. Thus, in 2022, the sowing period intervenes very significantly in the qualitative variation of linolenic acid.

In the two experimental years, genotypes behaved differently in terms of linolenic acid content, so in 2022, most of them recorded values lower than 2021. If in 2021 six of the 10 varieties registered statistically insured increases compared to the control, in 2022 in most varieties, except for the Onyx and Avatar variants, values lower than the control were recorded, the differences being statistically ensured at very significantly negative thresholds in the Perla and Raluca varieties, the Raluca genotype also registering the lowest values of this qualitative component in both experimental years.

As with linolenic acid, the analysis of variance calculated for both experimental years indicates a significant (epoch factor) and very significant (genotype factor) influence of experimental factors on linolenic acid content.

In 2021, for all genotypes, linoleic acid content registered positive deviations compared to the values recorded in 2022. Also, in 2021, in six of the ten analyzed varieties, linolenic acid registered statistically assured positive variations compared to the Felix control. In 2022, only one variety recorded statistically assured positive deviations at distinctly significant positive thresholds, namely line T6126.

It seems that the fluctuation of oleic acid content is controlled in a very significant way by the biological factor and to a much lesser extent by the sowing age, and only in 2022. Therefore, we could say that only under certain conditions is the sowing season significantly involved in the control of oleic acid.

The genotypes reacted quite differently to oleic acid content depending on the year of culture. In general, it can be observed that apart from the Pearl cultivar, in all other genotypes in 2022 the oleic acid content is reduced. In 2021, the top of oleic acid content is dominated by the T-4203 line and the Felix control variety, in the rest of the cultivars there are negative differences assured as very significant. In 2022, the highest

oleic acid content is recorded in the Perla variety.

Analysis of variance suggests that fluctuations in stearic acid content are influenced very significantly by factor G (genotype) and factor E (epoch) in 2021, and in 2022, the genotype factor had a distinctly significant influence, with epoch showing a very significant impact on this parameter.

Climatic conditions showed a particular impact on the average content of stearic acid. With the exception of the control variety Felix, and the very early cultivar Perla, higher values of this component were recorded in 2022 in all genotypes compared to 2021. In both experimental years, Felix and Perla cultivars are distinguished by high values of stearic acid, and in 2022 next to the two, the Onyx and Caro varieties are added.

Analysis of the variance of protein content under the influence of genotype and sowing season, is of great practical importance. Even if it is considered that the percentage of protein is closely related to the genotype, however, experiments over time have shown that, along with the genotype, technological and climatic factors can contribute to the variation in protein content. In this regard, it can be noted that in 2021 experimental factors marked protein very significantly, and in 2022, the sowing age factor did not contribute significantly to the variation of this parameter.

Thus, we can see that in 2022, higher amounts of protein have accumulated in all cultivars, the most stable genotype with the smallest annual oscillations is the Pearl variety. Even if the Felix control variety does not excel in terms of protein content, it is a variety with a special food value, being preferred by those in the food industry due to the quality of protein. In 2021, they accumulated protein at very significantly positive differences from witness Felix, Perla varieties and lines T295 and T4203 respectively. In 2022, the ranking of protein content changes, in the sense that the first place was the Avatar variety, followed by the lines T295, T4203, T6126 and the Cristina variety, all registering very significant differences from the witness Felix. We particularly note the new soybean lines T295 and T4203, which in both experimental years exceeded the control with very significant increases.

Worldwide, there is an increased interest in obtaining varieties with a low trypsin content, but also in identifying technological solutions that could lead to a decrease in the inhibitory activity of this enzyme. The literature states that this parameter can be significantly controlled by fertilization. One of the objectives of our study was to see if the sowing season can also influence the antitrypsin content. In this sense, from the table of variance analysis it follows that between varieties there are very significant differences in antitrypsin content, but also the sowing age can contribute very significantly to the variation of antitrypsin .

Among the varieties of European germplasm with a low content of antitrypsin is the Avatar variety. Therefore, in our experiments we chose this variety as a control for the antitrypsin content. Also, this study represents a starting point in the assessment

of the biological material created at SCDA Turda regarding trypsin content, being the first experiment of this kind started in Romania. Compared to the Avatar control variety, all genotypes had very high thresholds of antitrypsin content, the differences being very significantly positive in both experimental years .

However, we must emphasize that in 2022 all genotypes recorded considerably lower values compared to 2021. So, climatic conditions had a major impact on the variation in antitrypsin content. It is also necessary to emphasize that in experimental years, in the Avatar variety, antitrypsin values oscillated very slightly. An effect contrary to that of 2021 was observed in 2022, namely that by delaying sowing, the antitrypsin content increased very significantly, except for lines T6126, T4203 and the Avatar variety, where very significant negative differences, respectively distinctly significant, were recorded.

8. CONCLUSIONS AND RECOMMENDATIONS

One of the most important morphological characteristics of soybean plants is plant height, which has a direct influence on the fall resistance of plants. Although this feature shows a high genetic determinism, climatic conditions in the crop year significantly affected plant growth.

A very important characteristic of the new cultivars introduced into the crop is represented by the insertion height of the first pod and the number of pods/plant and the number of grains/plant. The insertion height of the first pod showed high values in the second sowing age in 2021 compared to the first age. Due to favorable conditions for plant growth and development in 2021, the number of pods / plant and the number of berries / plant, was higher than in 2022 according to experimental data.

Due to the different climatic conditions in the experimental years, analyzing the data as a whole, we can state that the influence of the sowing epoch on the MMB was not significant. In 2021, the influence of the sowing period was not significant, but in 2022 the influence of this technological element was very significant.

The delay in soybean sowing in climatic conditions unfavorable to this crop does not have a significant influence, but in years with favorable temperatures and precipitation, delaying sowing has had negative repercussions, yields being very significantly reduced by up to 30%.

In 2021, all genotypes in the experiment exceeded the control in production, the differences being statistically assured, except for the Onyx variety, to which they were not statistically assimilated.

In 2022, a less favorable year for soybeans, no statistically assured positive differences were recorded compared to witness Felix, while three of the 10 genotypes had negative differences statistically assured as very significant or distinctly significant.

In our case, the oil content was negatively affected by the delay in sowing, but this was closely related to the influence of climatic conditions and genetic material. In 2021, by delaying sowing, lower values of fat content were obtained, while in 2022, there were increases, some of which were statistically assured.

The content of linoleic acid by involving the date of sowing, the variation of this element, fluctuated depending on the climatic conditions of the crop year. Thus, in 2021, by delaying sowing, an increase in the amount of linoleic acid in soybean beans was obtained, but in 2022, a decrease in this element was obtained.

Regarding the behavior of the qualitative elements analyzed in this doctoral thesis, we find a decrease in stearic acid levels in 2021, and in 2022, through delayed seeding, the stearic acid content was positively influenced.

Delayed sowing, in the case of oleic acid, depending on the ripeness guppy, cultivar and climatic conditions, can have a positive or negative effect, but in most varieties taken in the experiment, higher values of this element were obtained.

The protein content was positively influenced by delayed seeding, so in both experimental years higher values were obtained than the control.

We can recommend the use of the Avatar variety as a genitor both to improve production and antitrypsin content, which, if it could improve simultaneously, would be ideal. Also, the use of the Avatar variety as a genitor must be done with certain reservations considering the maturity group to which it belongs and the cultivation area for which the new SCDA Turda creations are addressed.

In dry years it is recommended to adopt a treatment scheme based mainly on organic products to increase production and improve the quality of soybean harvest.

Climatic conditions had a major impact on the variation in antitrypsin content. It is also necessary to emphasize that in experimental years, in the Avatar variety, antitrypsin values oscillated very slightly.

Finally, we can affirm that the antitrypsin content can vary greatly depending on the sowing season and climatic conditions of the crop year, in varieties in which no improvements have been carried out to reduce this element.

9.Originality and innovative contributions of the thesis

In our research, we approached, for the first time in our country, the study of the influence of the sowing date and climatic conditions on the antitrypsin content of the beans of several soybean genotypes, both known on the market and perspective lines, in advanced generations of selection at SCDA Turda, compared to a foreign variety known for its low antitrypsin content. The 8 genotypes tested were selected to represent 3 maturity groups: very early, early and semi-early.

From this approach follows the recommendation to continue the improvement process in some soy genotypes, which have proven suitable for lowering the antitrypsin content.

Selectiv bibliography

1. GARIMA D., SHAH S., SINGH G. AND KUMAR A., 2020, Soybean and Its Products: Nutritional and Health Benefits. J Nut Sci Heal Diet 1(2): 22-29.
2. MCNIVEN M.A., GRIMMELT B., MACLEOD J.A. AND VOLDENG H., 1992, Biochemical Characterization of a Low Trypsin Inhibitor Soybean, Journal of Food Science, 57, 6, 1375-1377.
3. PARK A., KANG S.H., KANG B.H., CHOWDHURY S., SHIN S.Y., LEE W.H., LEE J.D., LEE S., CHOI Y.M. AND HA B.K., 2023, Identification of a Novel KTi-1 Allele Associated with Reduced Trypsin Inhibitor Activity in Soybean Accessions Agriculture 2023, 13(11), 1-14.
4. PERIC V., SREBRIC M., JANKULOSKI L., JANKULOVSKA M., ŽILIC S., KANDIC V. AND MLADENOVIC DRINIC S., 2009, The effects of nitrogen on protein, oil and trypsin inhibitor content of soybean, Genetika, 41, No. 2, 137-144.
5. VOLLMANN J., GRAUSGRUBER H., WAGENTRISTL H., WOHLESER K. AND MICHELE P., 2003, Trypsin inhibitor activity of soybean as affected by genotype and fertilisation, Science of Food and Agriculture, 83, 15, 1581-1586, https://doi.org/10.1002/jsfa.1582.
6. WIJEWARDANA C., REDDY K.R. AND BELLALOUI N., 2019, Soybean seed physiology, quality, and chemical composition under soil moisture stress, Food Chemistry, 278, 92-100.