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IMPROVING SOYBEAN QUALITY PARAMETERS BY SOWING ON DIFFERENT DATES IN VARIOUS CLIMATIC YEARS

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Abstract

Given the challenges posed by current climate change, which impacts food supply chain, alongside the growing global population, rising food demand, and continuous environmental degradation, it is essential to identify crop varieties that are stable in both productivity and quality. A field experiment was carried out at the Research and Development Station for Agriculture (RDSA) Turda over a period of four years (2021-2024), each representing different climatic conditions. The study included six soybean varieties of different maturity groups developed at RDSA Turda: Felix, Iris TD, Ziana TD, Raluca TD, Isa TD, Miruna TD. The soybean varieties were sown on two different soil temperatures (5°C and 7°C), based on readings taken at 8 a.m. The quality response of the soybean varieties sown at different soil temperatures was influenced by both genetic factors and the sowing date. These findings emphasize the potential of adjusting sowing dates to improve soybean quality, providing valuable guidance for farmers aiming to optimize performance in similar agroecological conditions.

Key words*: climatic conditions, sowing date, soil temperature, soybean, quality.*

INTRODUCTION

Soybean (*Glycine max* [L.] Merr.) is one of the most important food, forage, and agro-technical crops (Negrea et al., 2023), but it is highly sensitive to environmental factors and the applied technology. The development of soybeans is influenced by various environmental factors, such as temperature, precipitation, relative humidity, soil moisture, and especially photoperiod (Ávila et al., 2003).

One of the most important factors determining soybean crop yield, which can be implemented in current technology without additional costs, is the sowing date. The sowing date is a critical factor affecting the yield and quality of soybeans (Rahman et al., 2005), with early sowing being considered significant in the scientific literature for plant weight, leaf area index, and growth rate (Öztürk and Sögüt, 2018). Currently, the optimal sowing date for soybeans in Europe is within a broad range, from mid-April to mid-May (Dima, 2016), and according to some authors, soybean sowing should be done when the daily average soil temperature reaches 8ºC (Jarecki and Bobrecka-Jamro, 2021).

The soybean crop is currently considered the richest and cheapest source of proteins, minerals, vitamins, and high-quality fats (Sheshama et al., 2016). The composition of soybean seeds is an important factor in determining the economic value of soybean beans for commercialization (Brumm and Hurburgh, 2006). The global production of oil and protein is based on soybean seeds, due to their high protein and fat content, averaging 40% and approximately 20%, respectively (Stein et al., 2008).

In recent years, as consumers become increasingly aware of the health benefits of soybeans, there is growing interest in breeding programs aimed at improving taste and health benefits (Muntean et al., 2019).

In the context of climate change and the growing demand for food, this study aims to provide answers regarding the influence of changes in sowing date and soybean varieties from different maturity groups on the chemical composition of the seeds.

MATERIALS AND METHODS

In order to assess the quality of soybean seeds, an experiment was set up at the Agricultural Research and Development Station (ARDS) Turda over four different agricultural years

(2021-2024), aiming to study the influence of the sowing time on the main quality parameters. The study was carried out on a Vertic Phaeozem soil, typical of the Transylvanian Plateau. Chemically, the soil is weakly alkaline with a neutral pH, contains a moderate to high level of humus, is well supplied with nitrogen and potassium, and has a medium phosphorus content.

The biological material studied consisted of six soybean varieties developed and registered at Turda. With the exception of the early soybean variety Felix, which was registered in 2005, the remaining five varieties were registered after 2017, making them the most recent soybean varieties developed at Turda. Among them, the Isa TD variety is classified as very early, while the Iris TD, Ziana TD, and Miruna TD varieties are considered early-maturing genotypes. The Raluca TD variety, registered in 2019, is a semi-early soybean variety and is the latest genotype included in the experiment. Primary soil preparation consisted of plowing, which was performed in the autumn following the harvest of the preceding crop. The seedbed was then prepared two days prior to sowing. The crop was sown at a rate of 550,000 seeds per hectare, with a row spacing of 0.5 meters. Weed management was carried out through two mechanical hoeing operations conducted during the vegetation period. In the field, the experiment was conducted using the split-plot design with three replications, with the sowing time selected based on the soil temperature measured at 8:00 AM. Two different temperatures were chosen: 5°C (early sowing) and 7°C (optimal), with each temperature being measured over three consecutive days before sowing. In the laboratory, using near-infrared spectrophotometry, the seeds from the experimental variants were analyzed for protein content, oil content, and four fatty acids: stearic acid, oleic acid, linoleic acid and linolenic acid. Data processing was performed using the Past4 and Microsoft Excel programs.

Over the past four years, Turda has experienced notable variations in temperature, with a clear trend toward warmer weather, especially during spring and summer months (Table 1).

In 2021, spring was notably cooler than average, especially in April, which was 2.1°C below the multiyear norm, but the summer brought a brief heat surge, with July rising 3°C above average. The year 2022 followed with a mild spring and a significantly warmer summer, marked by a July deviation of +3.3°C and an exceptionally warm October (+2.6°C). In 2023, temperatures were generally above average, with an unusually hot autumn, September and October recorded deviations of +3.8°C and +4.2°C, respectively, indicating a prolonged summer season.

The year 2024 was the warmest of all, with every month from March to October exceeding the multiyear average; March alone was 4.4°C warmer than usual, and July reached +4.2°C, with negative impact on soybean crop development, soybean yield and quality.

In terms of rainfall registered in Turda (Table 2), a significant interannual variability was identified, with periods of both drought and intense precipitation. In 2021, rainfall was close to average overall, with high values in May and July, but June and October were markedly dry, showing deficits of -39.8 mm and -24.0 mm, respectively.

The year 2022 was highly irregular: while spring and early summer were generally drier, especially July, with 52.8 mm less than average, late summer and early autumn brought heavy rainfall, particularly in August and September, which exceeded norms by +38.5 mm and +77.5 mm.

In contrast, 2023 saw an extremely wet June (+59.9 mm), along with consistently high rainfall in late summer and early autumn. However, the spring months were notably dry, with May recording 36.2 mm less than average. The year 2024 returned to predominantly dry conditions, with June experiencing a major shortfall of -48.4 mm and several months showing rainfall below average, although September stood out slightly wetter (+21.8 mm). Overall, the four-year period reflects increasing variability in rainfall distribution, highlighting irregular seasonal patterns and the growing unpredictability of precipitation, with negative impact on soybean yield and quality.

Table 1. Monthly average temperatures and deviations from multiyear average in Turda (2021-2024)

Year	Temperature (°C)	Month							
		III	IV	V	VI	VII	VIII	IX	X
2021	Average	3.3	7.8	14.1	19.8	22.7	19.7	15.0	9.7
	Deviation from multianual average	-1.4	-2.1	-0.9	1.9	3	0.4	-0.1	0.2
2022	Average	3.6	8.8	16.3	21.1	23.1	22.3	14.3	12.4
	Deviation from multianual average	-0.8	-1.2	+1.3	+3.1	+3.3	+2.8	-0.9	+2.6
2023	Average	6.3	8.8	15.4	19.0	21.8	22.1	19.0	14.0
	Deviation from multianual average	1.9	-1.2	0.4	1.0	2.0	2.6	3.8	4.2
2024	Average	8.8	13.3	15.8	21.7	24.0	23.4	17.9	11.7
	Deviation from multianual average	4.4	3.3	0.8	3.7	4.2	3.9	2.7	1.9

Table 2. Monthly rainfall and deviations from multiyear average in Turda (2021-2024)

Year	Rainfall (mm)	Month							
		III	IV	V	VI	VII	VIII	IX	X
2021	Sum	27.3	38.4	80.8	45.0	123.1	52.9	39.1	11.6
	Deviation from multianual average	3.7	-7.5	12.1	-39.8	46	-3.6	-3.4	-24.0
2022	Sum	8.3	42.5	82.9	41.8	25.2	94.6	119.9	16.3
	Deviation from multianual average	-16.0	-3.1	+13.5	-42.8	-52.8	+38.5	+77.5	-19.1
2023	Sum	10.8	30.5	33.2	144.5	85.8	98.5	116.1	19.8
	Deviation from multianual average	-13.5	-15.1	-36.2	59.9	7.8	42.4	73.7	-15.6
2024	Sum	37.7	38.8	60.7	36.2	49.3	36.7	64.2	14.4
	Deviation from multianual average	13.4	-6.8	-8.7	-48.4	-28.7	-19.4	21.8	-21.0

RESULTS AND DISCUSSIONS

The chemical composition of soybeans is influenced by a range of factors. These factors can include environmental conditions, soil quality, cultivation practices, and the specific variety of soybeans, all of which impact the overall nutrient profile and quality of the seeds. One of the most crucial aspects determining the crop's end use is the content of proteins and fats in the seeds.

These components are particularly important when it comes to utilizing soybeans in various food and animal feed industries. Furthermore, fatty acids, offer significant nutritional benefits for human health. Soybeans are especially valued for their ideal balance of unsaturated, monounsaturated, and polyunsaturated fatty acids, making them a beneficial source of fats for the human body.

Figure 1 shows the variation in oil content, averaged over the four experimental years. This analysis covered five soybean varieties from three distinct maturity groups (very early-000, early-00, semiearly-0).

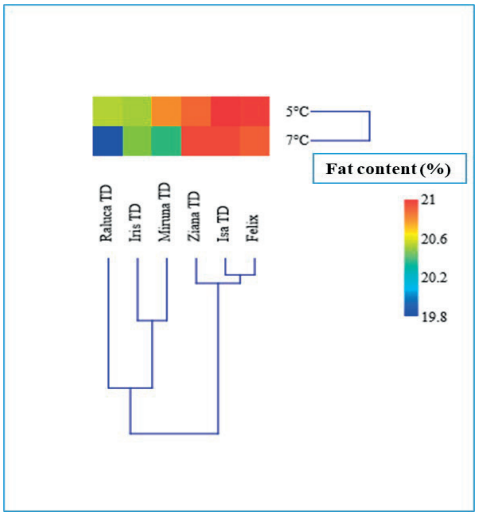

Figure 1. Fat content obtained in five soybean varieties depending on soil sowing temperature (Turda, 2021-2024)

The variation in oil content was observed in relation to the soil temperature at sowing time, as represented by the heat map. Warm colours correspond to higher values, while cool colours indicate a lower fat concentration in the seeds. The oil content varied between 19.8% and 21%, with the minimum of the experiment observed in the latest maturing soybean genotype (Raluca TD), when sowing was done at the optimal temperature (7°C).

Generally, higher fat content values were identified when soybeans were planted at 5°C, with the highest value of 21% reached by the very early-maturing Isa TD variety. Based on cluster analysis, it can be seen that the varieties Ziana TD, Isa TD, and Felix exhibited similar behaviour, showing high fat content values for both sowing dates. For the Miruna TD variety, an increase higher than 0.5% in fat content was observed when sowing was done early, compared to the optimal temperature, similar results were also obtained by Assefa et al. (2019), who found that delayed planting led to a decrease in oil content.

A greater variation in protein content was noted across the different soybean genotypes, with the genetic factor playing a more significant role than the sowing time (Figure 2).

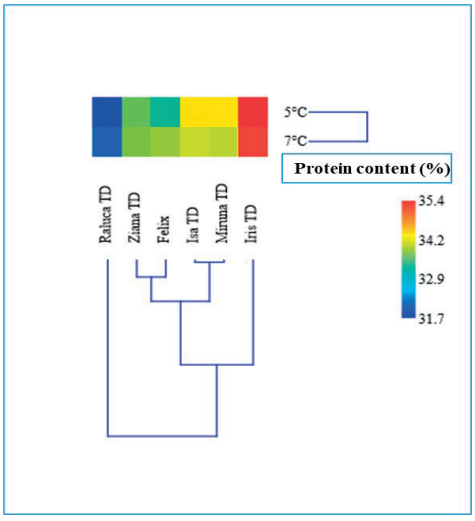

Figure 2. Protein content obtained in five soybean varieties depending on soil sowing temperature (Turda, 2021-2024)

The semi-early variety Raluca TD exhibited protein values below 32% in both experimental variants, while the highest protein content of 35.4% was found in the early-maturing variety Iris TD. Regardless of the sowing temperature, cluster analysis revealed similar patterns for the varieties Ziana TD and Felix TD, as well as for Isa TD and Miruna TD. The Raluca TD and Iris TD varieties did not form clusters and remained independent, as they represented the extremes of the experiment in terms of protein content. The research results conducted by Sadeghi and Niyaki (2013) showed that earlier sowing of soybeans improved seed quality compared to delayed sowing. As planting was delayed, the protein content tended to decrease in early-maturing varieties, but remained stable between sowing dates in varieties from other maturity groups (Morris et al., 2021).

The analysis of the four fatty acids indicates a considerable variability, both depending on the variety analysed and the sowing date (Figure 3). Varga et al (2024), following their studies, concluded that the fatty acid profile varied depending on the sowing date, with higher results for oleic acid and linolenic acid obtained from delayed sowing of the crop.

An improvement in stearic acid content (+0.21%) was observed in the very early soybean variety Isa TD when sown early compared to the optimal sowing date. For the Felix variety, sowing at the optimal time led to a significant increase in oleic acid content, which reached 26% in this experimental variant. As for linoleic acid, with the exception of the Raluca TD variety, where maximum values of the experiment were reached (>55%) at both sowing dates, the other varieties studied showed a similar profile, with much lower values compared to the latest variety in the experiment. The content of linolenic acid varied the most within the experiment. It ranged from 3.58% to 7.2%, with higher values generally identified when soybeans were sown at 7°C. The maximum value of the experiment was observed in the early soybean variety Miruna TD, sown at the optimal time, while Raluca TD exhibited the lowest values of the experiment at both sowing dates.

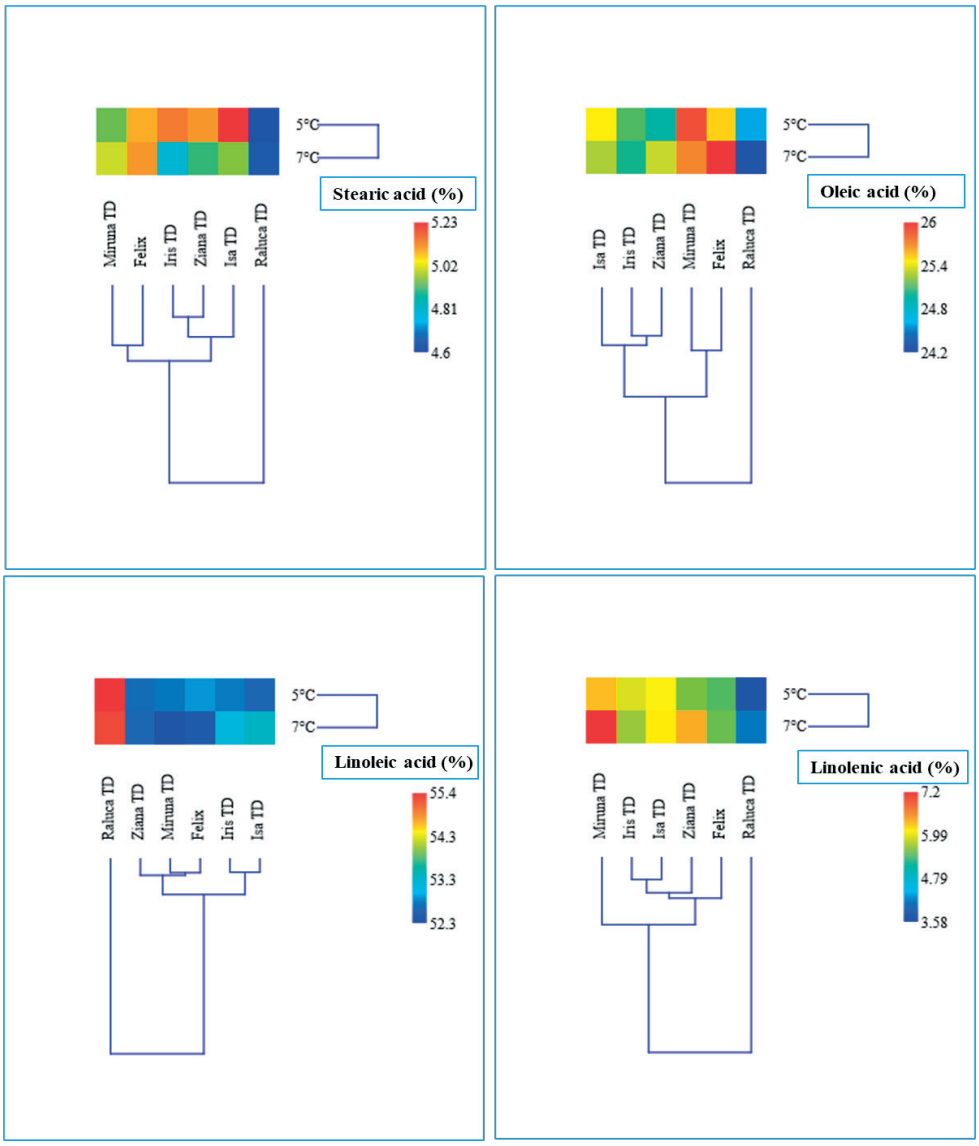

Figure 3. Fatty acid profile obtained in five soybean varieties depending on soil sowing temperature (Turda, 2021-2024)

Although seed quality is genetically determined, it exhibits considerable variability depending on environmental conditions and agronomic practices. The development of a new soybean cultivar is a time-intensive process, the identification of technological factors that could enhance seed quality being essential for sustainable agriculture. Using the method proposed by Eberhart and Russell (1966) the stability of soybean seed quality can be assessed in relation to the climatic conditions over the four experimental years and varying sowing dates.

Figure 4 illustrates the stability of oil content in the six soybean cultivars studied. When soybean was sown at a soil temperature of 5°C, it was evident that in 2022, the seeds had lower oil content compared to the other three experimental years. Notably, the very early-maturing cultivar Isa TD demonstrated superior performance relative to the other four cultivars under unborable environmental conditions.

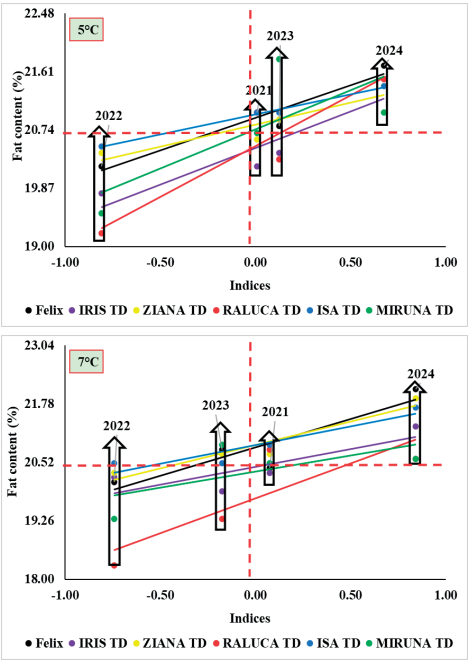

Figure 4. Fat content stability based on environment indices (Turda, 2021-2024)

When soybeans were sown at a soil temperature of 7°C, the varieties experienced optimal conditions for oil accumulation in the seeds only in the years 2021 and 2024, with lower oil content observed in the other two years.

The strongly positive trend of the regression lines indicates that oil content in soybean seeds showed significant variability across the four experimental years. When soybean was sown at the optimal temperature, a shallower trend of the regression lines was observed, with the exception of the Raluca TD cultivar. The remaining four cultivars exhibited more consistent oil content. Despite the improved stability of this quality parameter when soybeans is sown at the optimal time, seeds sown early generally contained higher oil levels. It is important to highlight that, irrespective of the sowing date, the year 2024 proved to be the most favourable for oil yield in the soybean crop.

Based on the stability analysis of protein content in the six soybean cultivars grown across four distinct growing seasons and at two different sowing dates (Figure 5), a more pronounced stability was observed in the Raluca TD cultivar when was sown at a soil temperature of 7°C, as well as in the early-sown Iris TD cultivar when was sown at a soil temperature of 5°C. In this case, the regression lines were nearly parallel to the x-axis. A gentler trend was observed for the other cultivars at both sowing dates, indicating a good level of stability in protein content, though with relatively lower values. However, protein content exhibited considerable variation primarily due to the genetic factor. Across all experimental years and sowing dates, the early-maturing Iris TD cultivar consistently demonstrated superior performance. This cultivar appears to be the most advantageous in terms of seed protein content. Nevertheless, over the four experimental years, protein content remained relatively low, with values consistently below 40%.

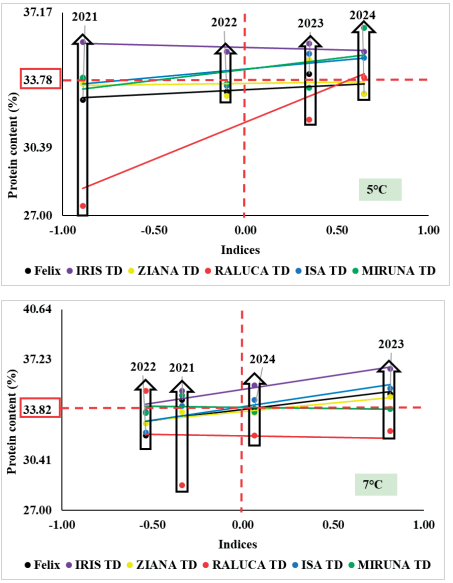

Figure 5. Protein content stability based on environment indices (Turda, 2021-2024)

Oil accumulation in soybean seeds occurs during the grain filling stage, with the highest levels typically reached around 30 days post-flowering (Wilson, 2004). Regardless of the cultivar studied or the experimental year, the beginning of flowering date was noted between June 15 and July 10. Therefore, the drought occurring in July and August, along with the high temperatures, could have affected the oil content in soybean seeds. Although for 2024 the total precipitation in July and August was lower compared to the other three years, its

distribution throughout the reproductive stage, along with lower temperatures, led to the highest fat content observed in the soybean seeds. The year 2022 was unfavourable for lipid accumulation in the seeds. Although the total precipitation reached 120 mm over the two months, it was mainly concentrated in the first decade of July and the first and last decades of August. Additionally, the average temperature during these months exceeded the long-term mean by more than 3°C, leading to small values for fat content (Figure 6).

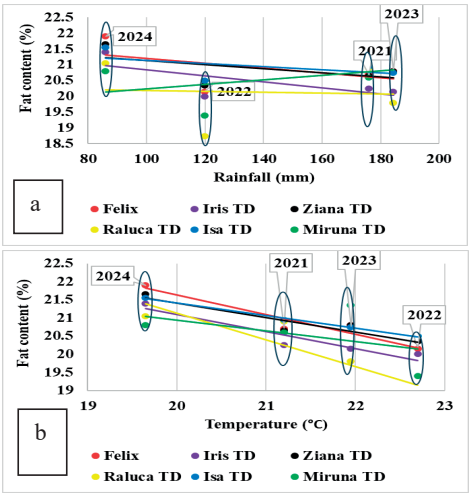

Figure 6. The relationship between oil content and the total precipitation in July and August (a), as well as between oil content and the average temperature in July and August (b) (Turda, 2021-2024)

In terms of protein content analysis in relation to total precipitation during the last two summer months and the average temperature during that period, it is evident that this quality parameter was more significantly influenced by the genetic factor. The Raluca TD variety was the only genotype that exhibit greater fluctuations in protein content, likely due to its notably longer growing season compared to the other four cultivars studied (Figure 7). The data obtained by Księżak and Bojarszczuk (2022) showed that delaying sowing until the first week of May, along with limited precipitation during the growing season, leads to the accumulation of proteins in the seeds. Other authors, such as Sheshama et al. (2016), obtained different results, namely a decrease in protein content with delayed sowing, which could be attributed to the reduced duration of the reproductive phase due to fewer days until maturity, and this may have also affected the synthesis of seed fats.

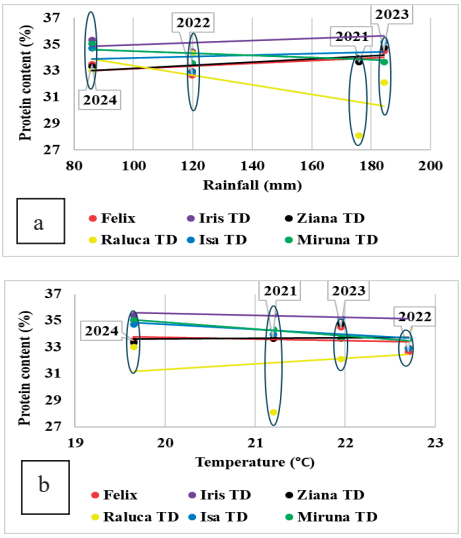

Figure 7. The relationship between protein content and the total precipitation in July and August (a), as well as between protein content and the average temperature in July and August (b) (Turda, 2021-2024)

Robinson et al. (2009) emphasized that earlier sowing of soybeans resulted in an increase in protein content, while a decrease in fat content was observed in the harvested seeds.

CONCLUSIONS

The study highlights that oil content in soybeans is significantly influenced by sowing temperature, with lower soil temperatures (5°C) leading to higher fat concentrations, particularly in early-maturing varieties like Isa TD. Additionally, the Raluca TD variety, which has a longer growing season, exhibited the lowest oil content when sown at the optimal temperature (7°C). Cluster analysis further confirmed that certain varieties, such as Ziana TD, Isa TD, and Felix TD, consistently exhibited high oil content across both sowing dates. These findings highlight the significance of selecting optimal sowing temperatures and varieties to enhance oil content, a key factor in optimizing soybean oil yield.

Protein content in soybean seeds is primarily influenced by genetic factors, with significant

variation observed across different genotypes. The semi-early Raluca TD variety consistently showed lower protein content, while the early-maturing Iris TD variety exhibited the highest values. Cluster analysis revealed that certain varieties shared similar protein content patterns, while Raluca TD and Iris TD stood out as extremes, demonstrating the critical role of genetic traits in determining protein accumulation in soybeans.

Fatty acid content in these six soybean cultivars varied significantly based on both variety and sowing date. Early sowing improved stearic acid in Isa TD and oleic acid in Felix. Raluca TD consistently had the highest linoleic acid, while linolenic acid showed the most variation, with higher levels at 7°C sowing. These findings highlight the influence of both genetic and environmental factors on soybean fatty acid composition.

In term of stability, soybean seed quality, influenced by both genetic and environmental factors, showed significant variability across the four experimental years and different sowing dates. The Isa TD cultivar performed well under challenging conditions, while the Raluca TD and Iris TD varieties exhibited stable oil and protein content, respectively. Optimal conditions for oil accumulation were observed when sowing occurred at 7°C in 2021 and 2024, with the year 2024 being the most favourable. Despite higher stability in protein and oil content at the optimal sowing time, earlier sowing generally resulted in higher oil content, highlighting the importance of environmental and agronomic practices in enhancing seed quality.

The experimental data revealed that oil accumulation in soybean seeds is primarily influenced by environmental conditions during the grain filling stage. While precipitation and temperature variations in July and August impacted oil content, the distribution of precipitation and cooler temperatures in 2024 resulted in the highest fat content. Conversely, 2022, with higher temperatures and uneven rainfall, was unfavourable for lipid accumulation. Regarding protein content, genetic factors played a more significant role, with the Raluca TD variety exhibiting greater fluctuations due to its longer growing season.

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REFERENCES

Assefa, Y., Purcell, L.C., Salmeron, M., Naeve, S., Casteel, S.N., Kovács, P., Archontoulis, S., Licht, M., Below, F., Kandel, H., Lindsey, L.E., Gaska, J., Conley, S., Shapiro, C., Orlowski, J.M., Golden, B.R., Kaur, G., Singh, M., Thelen, K., Ciampitti, I.A. (2019). Assessing variation in US soybean seed composition (protein and oil). *Frontiers in Plant Science, 10*. 298–298.

Ávila, M.R., Braccini, A.L., Sá, Motta, I., Scapim ,C.A., Braccini, M.C.L. (2003). Épocas de semeadura e qualidade desementes de soja. *Scientia Agricola, 60*(2). 245–252.

Brumm, T.J., Hurburgh, Jr C.R. (2006). Changes in long-term soybean compositional patterns. *Journal of the American Oil Chemists' Society, 83*(11). 981–983.

Dima, D.C. (2016). Soybean demonstration platforms: The bond between breeding, technology and farming in Central and Eastern Europe. *Agric. Agric. Sci. Procedia, 10*, 10–17.

Eberhart, S.A., Russell, W.A. (1966). Stability parameters for comparing varieties. *Crop Sci., 6*. 3640.

Jarecki, W., Bobrecka-Jamro, D. (2021). Effect of sowing date on the yield and seed quality of Soybean [*Glycine max* (L.) Merr.]. *J. Elem., 26*. 7–18.

Księżak, J., Bojarszczuk, J. (2022). The Seed Yield of Soybean Cultivars and Their Quantity Depending on Sowing Term. *Agronomy, 12*. 1066.

Morris, T.C., Vann, R.A., Collins, G.D., Heitman, J., Kulesza, S.B. (2021). Planting date and maturity group impact on soybean seed quality in the southeastern United States, *Agronomy Journal, 113*(6). 5287–5301.

Muntean, E., Urda, C., Simon, A., Rezi, R. (2019). Quality parameters and grain yields of soybean varieties produced at ARDS Turda: a chemometric approach. *Scientific Papers. Series A. Agronomy, Vol. LXII, Issue 1*. 374–379.

Negrea, A., Rezi, R., Urdă, C., Rusu, T. (2023). Soybean response to foliar and soil fertilization. *AgroLife Scientific Journal, 12*(1). 126–131.

Ozturk, F., Sogut, T. (2018). The effects of tillage methods and plant density on growth, development and yield of soybean [*Glycine max* (L.) Merrill] grown under main and second cropping system: ii. growth-development component. *Scientific Papers. Series A. Agronomy, Vol. LXI,* Issue 1. 353–359

Rahman, M.M., Hapton, J.G. and Hill, M.J. (2005). The effect of time of sowing of soybean seed quality. *Seed Sci. Technol., 33*. 687–697.

Robinson, A.P., Conley, S.P., Volenec, J.J., Santini, J.B. (2009). Analysis of high yielding, early-planted soybean in Indiana. *Agron. J., 101*(1). 131–139

Sadeghi, S.M., Niyaki, S.A.N. (2013). Effects of planting date and cultivar on the yield and yield components of soybean in north of Iran. *J. Agric. Biol. Sci., 8*(1). 81–85.

Sheshama, M.K., Rekha, M.S., Kumar, S., Meena, R.N., Kumar, V. (2016). Influence of Different Sowing Dates and Varieties on Seed Quality of Soybean in Coastal Andhra Pradesh. *J Pure Appl Microbiol., 10*(4). 3087–3091.

Stein, H.H., Berger, L.L., Drackley, J.K., Fahey, G.C., Jr., Hernot, D.C., Parsons, C.M. (2008). Nutritional properties and feeding values of soybeans and their co-products. In Soybeans, Chemistry, Production, Processing, and Utilization; Johnson, L.A., White, P.J., Galloway, R., Eds.; AOCS Press: Urbana, IL, USA; pp. 613–660.

Varga, A., Urda, C., Rezi, R., Negrea, A., Simon, A., Galben, D.R., Gheorghies, V., Duda, M.M. (2024). Soybean crop development, yield and harvest quality under two sowing date. *Scientific Papers. Series A. Agronomy, Vol. LXVII, Issue 1*. 453–460.

Wilson, R.F. (2004). Seed composition. In: Boerma, H. and Specht, J.E., Ed., *Soybeans: Improvement, Production, and Uses*, *3rd Edition*, ASA, CSSA, and SSSA, Madison, 621–668.