

Optimization of Sowing Date for Enhanced Yield and Quality of Soybean

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Abstract. Soybeans, recognized as the most widely cultivated plant globally, are notably affected by weather conditions, particularly drought and elevated temperatures during their reproductive phase. In 2024, a field study was conducted at the Agricultural Research and Development Station (ARDS) in Turda to examine how varying sowing dates impact the yield and quality of three soybean varieties (Felix, Romina TD, and Potaissa TD). The findings indicated that the yields of the three soybean types were comparatively low in relation to their yield capacity; however, sowing earlier (at 5°C) than the optimal time (at 7°C) resulted in higher yields, whereas very early sowing (at 3°C) led to significantly lower yields. Quality parameters such as protein and fat content experienced slight reductions with earlier sowing.

Keywords: soybean, sowing date, weather conditions, yield, protein, oil

INTRODUCTION

The global food system is currently facing increasing risks due to climate change, even as farmers attempt to adapt (Hultgren et al., 2025) through various natural resource management practices.

Among the main measures taken by farmers to adapt to climate change is the identification of meteorological factors that most affect crop development and the adjustment of the sowing date (Mourtzinis et al., 2019) so as to prevent adverse effects of weather extremes (Wing et al, 2021) on yield.

Global oil and protein yield is based on soybeans, due to their high protein and fat content, on average 40% and 20% of the dry weight of the seeds (Stein et al, 2008; Hudson, 2022), soybean is a very important crop for the food security of the globe (Lemaoui et al., 2018).

Soybeans are generally cultivated as a rain crop worldwide and are very often exposed to various abiotic stresses (Sarchevic et al., 2022). Soybean sowing date is an important factor affecting growth, development, yield, and quality (Umburanas et al., 2018), which can be modified according to climatic conditions (Bastidas et al., 2008). Among soybean producers, there is currently a growing anticipation of sowing, intending to record ever-increasing yields (Tagliapietra et al., 2021).

Some researchers, such as Dencescu et al. (1982), affirm that soybean requires a soil temperature above 7°C for optimal germination. Research by Inouye (1983) in the laboratory has shown that soybeans can germinate more slowly, even at 3 degrees Celsius.

Previous studies on soybean have shown the importance of water supply as the main limiting factor of yield (Sentelhas et al., 2015), both in the germination phase and especially in the reproductive period.

In this context of climate change and the need to mitigate its effects on agriculture, the purpose of this study was to examine the sensitivity of soybean crops to variable weather conditions during the growing season and various sowing dates on yield and quality of the newest soybean varieties.

MATERIAL AND METHODS

The research was conducted in 2024, at the Agricultural Research and Development Station (ARDS) Turda, in a field study located on a Phaeozem-type soil (SRTS, 2012), with clay texture and favorable hydrophysical properties: porosity of 59% on the surface and 47% in depth, high water holding capacity (32%) and wilting coefficient (WC) of 18%. The agrochemical characteristics of the soil are: pH 7.00; humus content 2.94%; total nitrogen 0.162%; phosphorus 9 ppm; potassium 140 ppm. Soybean varieties, created at SCDA Turda, were sown at a distance of 50 cm between rows and at a density of 55 germinating grains per m². The seed was not inoculated before sowing. The experiment was of a bifactorial type and included the following factors:

A – sowing date with three levels:

- S1 - sowing at 3°C soil temperature,
- S2 - sowing at 5°C soil temperature,
- S3 - sowing at 7°C soil temperature (control variant);

The timing of sowing was determined based on soil temperature at 8 am, measured for three consecutive days. Sowing was carried out on 01.04.2024 for S1, 09.04.2024 for S2, respectively 26.04.2024 for S3.

B – soybean variety with three genotypes:

- Felix,
- Romina TD,

- Potaissa TD.

The experiment was conducted using a split-plot design, randomized with three replications, each plot having an area of 48 m². Prior to harvesting, front and side borders were removed to minimize edge effects, resulting in a harvestable area of 20 m².

The harvest was carried out with the Wintersteiger combine on 23.09. 2024, after all varieties reached maturity and recorded a humidity close to STAS.

Productivity elements such as thousand kernel weight (TKW), hectoliter weight (HW), and yield were evaluated, but also quality indicators such as proteins and fats. The results obtained were statistically processed by the analysis of variance method and establishing the least significant difference -LSD- (5%, 1% and 0.1%) (ANOVA, 2015). The climatic data presented in this paper were recorded from the Turda Meteorological Station, located on the coordinates of longitude: 23°47'; latitude 46°35'; altitude 427 m.

The temperature and precipitation data recorded in Turda during the experimental period showed a clear increase in the mean monthly temperatures across all months relevant for soybean cultivation. These values deviated significantly from the long-term averages, indicating atypical thermal conditions that could potentially affect the phenology, growth rate, and physiological processes of the crop. In some periods, the temperature increase was accompanied by variations in precipitation, further intensifying abiotic stress and negatively influencing plant establishment and development.

During the experimental period, the average monthly precipitation was lower than the long-term average, intensifying heat stress and drought conditions in the crop. Consequently, the precipitation deficit caused significant production losses, highlighting the vulnerability of soybean to dry climatic conditions. The most severe problems were observed in June and July, corresponding to the critical reproductive phase of soybean. During this period, plants have a high demand for water and nutrients to support flowering and pod formation, and the combined effects of low precipitation and high temperatures exacerbate water stress (Figure 1).

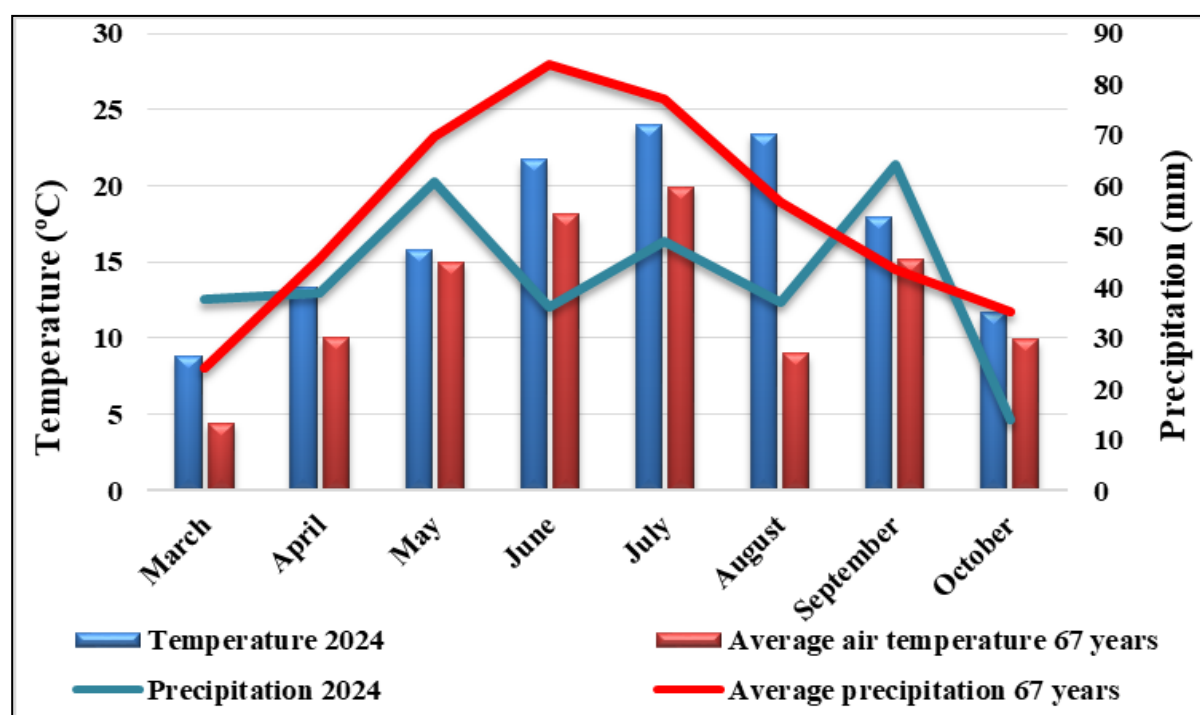


Figure 1. Climatic conditions during the soybean vegetation period

RESULTS AND DISCUSSIONS

The climatic conditions during the growing season are the most important factor in an agricultural culture, totally dependent on the abiotic factors involved in yield (Simon et al., 2023). Although it is a low-temperature-sensitive crop, in the climatic conditions of 2024, soybeans recorded the highest yields when sowing was done earlier than normal, with a 2°C difference, resulting in a yield difference of 155 kg/ha compared to soybeans sown at 7°C in the same soil, which was statistically proven to be significantly distinct.

Although earlier soybean sowing brought yield increases, the advancement of sowing more, to 3°C in the soil, is not beneficial because although the seeds sprouted in a relatively short time, the low temperatures that occurred after emergence significantly affected soybean plants. Low temperatures during the emergence-first leaf

formation period had a significant impact on plant growth and development, causing stagnation of physiological and metabolic processes. At temperatures below the optimum threshold, photosynthesis was slowed down. These physiological constraints led to slow growth, delayed vegetative development and, ultimately, to the appearance of stress symptoms, such as reduced height, number of flowers and biomass. Hence, they developed more slowly than plants sown later, and yield was adversely affected, resulting in a very significant negative difference of 268 kg/ha compared with sowing at the optimal time (Table 1).

Similar studies were executed by Varga et al. (2024), which concluded that the delay in sowing soybean may cause yield losses of more than 100 kg/ha, and also by Licht and Huffman (2017), which confirmed that soybean yield decreases with the delay of sowing date. The other two elements (TKW and HW) determined were negatively influenced by the earlier sowing, the differences from the sowing at 7°C being significant.

Previous studies conducted on different sowing data and soybean varieties from different maturity groups have shown that soybeans react very well to the sowing date, but also that by delaying the sowing date of soybeans, there are significant yield losses, correlated with the number of days in which the sowing is delayed.

Table 1. The influence of the sowing date on the yield components

Experimental variant	Yield components		
	Yield (kg/ha)	TKW (g)	HW (kg/hl)
Sowing at 7°C (control)	1750 ^(c.v.)	148 ^(c.v.)	72.0 ^(c.v.)
Sowing at 3°C	1482 ⁰⁰⁰	142 ⁰	69.5 ⁰⁰
Sowing at 5°C	1905 ^{**}	148	70.7 ⁰
LSD (p 5%)	61	3	1.1
LSD (p 1%)	101	6	1.8
LSD (p 0.1%)	190	11	3.3

(c.v.- control variant; * significantly positive; ** distinctly significantly positive; *** very significantly positive; ⁰ significantly negative; ⁰⁰ distinctly significantly negative; ⁰⁰⁰ very significantly negative)

The Potaissa TD variety, approved in 2025, demonstrated a yield increase of 101 kg/ha compared to the Felix variety, which was approved in 2005. This difference is statistically significant. The data indicate that the Potaissa TD variety is more tolerant of adverse environmental conditions and has a higher thousand-kernel weight (TKW) than the other two varieties studied. Additionally, a very significant decrease in hectoliter weight (HW) was observed for this variety, as shown in Table 2.

Table 2. The influence of the variety on the yield component

Experimental variant	Yield components		
	Yield (kg/ha)	TKW (g)	HW (kg/hl)
Felix (control)	1671 ^(c.v.)	145 ^(c.v.)	71.9 ^(c.v.)
Romina TD	1694	143	71.5
Potaissa TD	1772 ^{**}	150 ^{***}	68.8 ⁰⁰⁰
LSD (p 5%)	60	3	0.6
LSD (p 1%)	84	4	0.9
LSD (p 0.1%)	119	6	1.2

(c.v.- control variant; * significantly positive; ** distinctly significantly positive; *** very significantly positive; ⁰ significantly negative; ⁰⁰ distinctly significantly negative; ⁰⁰⁰ very significantly negative)

Although soybeans have been cultivated for many years on extensive areas in most areas of the globe, little is known about the influence of certain climatic factors and their interaction with management practices (for example, the date of sowing) in determining the yield potential of soybeans (Zanon et al., 2016).

Previous studies on soybean sowing earlier to avoid a lack of rainfall as well as high temperatures during the reproductive stage have shown that soybean yield can increase significantly when plant development is carried out at temperatures suitable for each phenological stage. Other studies, such as those conducted by Liu and Dai (2020), have shown that an increase in temperature during the vegetation period can change the phenology of soy and shorten its growth stages.

The interaction between the experimental factors of sowing season and soybean varieties shows that sowing at 5°C is beneficial for all three varieties. The yields increased by 90 kg/ha and 53 kg/ha for the Felix and Romina

TD varieties, respectively, although these increases were not statistically significant. In contrast, the Potaissa TD variety experienced a yield increase of 321 kg/ha, which was statistically significant (Table 3).

Table 3. The interaction between the sowing season and the biological variety on the yield component

Experimental variant	Yield components		
	Yield (kg/ha)	TKW (g)	HW (kg/hl)
Sowing at 7°C x Felix (control)	1754 ^(c.v.)	149 ^(c.v.)	73.3 ^(c.v.)
Sowing at 3°C x Felix	1414 ⁰⁰⁰	138 ⁰⁰	71.4 ⁰
Sowing at 5°C x Felix	1844	147	71.0 ⁰⁰
Sowing at 7°C x Romina TD (control)	1726 ^(c.v.)	145 ^(c.v.)	72.8 ^(c.v.)
Sowing at 3°C x Romina TD	1577 ⁰	139 ⁰	70.3 ⁰⁰
Sowing at 5°C x Romina TD	1779	145	71.5
Sowing at 7°C x Potaissa TD (control)	1770 ^(c.v.)	150 ^(c.v.)	70.0 ^(c.v.)
Sowing at 3°C x Potaissa TD	1456 ⁰⁰⁰	151	66.8 ⁰⁰
Sowing at 5°C x Potaissa TD	2091 ^{***}	151	69.6
LSD (p 5%)	104	5	1.4
LSD (p 1%)	154	8	2.1
LSD (p 0.1%)	240	13	3.5

(c.v.- control variant; * significantly positive; ** distinctly significantly positive; *** very significantly positive; ⁰ significantly negative; ⁰⁰ distinctly significantly negative; ⁰⁰⁰ very significantly negative)

The chemical composition of soybeans is influenced by a number of factors, these may include environmental conditions, soil quality, cultivation practices, and specific soybean variety, all of which impact the overall nutritional profile and quality of seeds (Simon et al., 2025).

Regarding the quality indices of soybeans resulting from the second sowing season (5°C), there is a distinctly significant decrease of about 0.7% in protein content compared to sowing in the optimal sowing season (7°C), but also a decrease in fat content for both earlier sowing variants. A slight increase in the percentage of protein was observed when sowing at 3°C, but without statistical assurance (Table 4).

Different environmental conditions during the grain filling period can have a considerable effect on the soybean protein content, so in regions where soybean is grown without irrigation, the lack of rainfall is a problem not only in the production achievement and its quality.

A study conducted by Yaklich and Vinyard (2004) to estimate the effects of temperature and precipitation on soybean protein and oil shows that the increase in maximum temperature during reproduction reduced proteins, and the increase in minimum temperature during reproduction was associated with an increase in oil content.

Table 4. The influence of the sowing date on the quality components

Experimental variant	Yield components	
	Protein (%)	Fat (%)
Sowing at 7°C (control)	34.73 ^(c.v.)	21.87 ^(c.v.)
Sowing at 3°C	34.99	21.79
Sowing at 5°C	33.99 ⁰⁰	21.83
LSD (p 5%)	0.41	0.25
LSD (p 1%)	0.68	0.42
LSD (p 0.1%)	1.28	0.79

(c.v.- control variant; * significantly positive; ** distinctly significantly positive; *** very significantly positive; ⁰ significantly negative; ⁰⁰ distinctly significantly negative; ⁰⁰⁰ very significantly negative)

The protein content of soybeans is often negatively correlated with yield. Approaches in the breeding programme have so far had limited impact in creating new soybean varieties with high protein content (Patil et al., 2017), but as a result of the data obtained in this study and presented in Table 5, the Potaissa TD variety can also achieve high yields and high protein content.

Although the literature has an inverse correlation between yield and protein, the results presented in Table 5 show that the Potaissa TD variety obtained a high protein percentage of 35.81, with a very significant positive difference of 1.78% compared to the protein content of the Felix variety (control variant), but also a distinctly significant decrease of 0.4% for fats. Romina TD variety has recorded values very appropriate to those of the Felix

variety for both protein and fat content. Following the studies carried out, Negrea et al. (2023) hypothesized that the genotype has a great influence on yield and quality, but environmental conditions and fertilization can greatly influence the expression of these characters.

Table 5. The influence of the variety on quality components

Experimental variant	Quality components	
	Protein (%)	Fat (%)
Felix (control)	34.03 ^(c.v.)	21.98 ^(c.v.)
Romina TD	33.87	21.93
Potaissa TD	35.81***	21.58 ⁰⁰
LSD (p 5%)	0.24	0.23
LSD (p 1%)	0.33	0.33
LSD (p 0.1%)	0.47	0.46

(c.v.- control variant; * significantly positive; ** distinctly significantly positive; *** very significantly positive; ⁰ significantly negative; ⁰⁰ distinctly significantly negative; ⁰⁰⁰ very significantly negative)

In the case of the interaction of experimental factors on quality components, we note from Table 6 that only in the case of the first sowing date (3°C), there were positive differences for the Felix variety, of 1.1% compared to the sowing in the optimal sowing season. In all other experimental variants, the content of soybeans in protein was lower, with significant and distinctly significant differences for the Felix and Romina TD varieties sown in the second sowing season.

The fat content did not vary greatly, the only variant in which a significant decrease in % was observed was the Potaissa TD variety sown in the first sowing season.

Table 6. The interaction between the sowing moment and the biological material on the quality components

Experimental variant	Quality components	
	Protein (%)	Fat (%)
Sowing at 7°C x Felix (control)	33.93 ^(c.v.)	22.07 ^(c.v.)
Sowing at 3°C x Felix	35.03**	22.17
Sowing at 5°C x Felix	33.13 ⁰	21.70
Sowing at 7°C x Romina TD (control)	34.37 ^(c.v.)	21.83 ^(c.v.)
Sowing at 3°C x Romina TD	34.07	22.00
Sowing at 5°C x Romina TD	33.17 ⁰⁰	21.97
Sowing at 7°C x Potaissa TD (control)	35.90 ^(c.v.)	21.70 ^(c.v.)
Sowing at 3°C x Potaissa TD	35.87	21.20 ⁰
Sowing at 5°C x Potaissa TD	35.67	21.83
LSD (p 5%)	0.53	0.41
LSD (p 1%)	0.81	0.61
LSD (p 0.1%)	1.37	0.97

(c.v.- control variant; * significantly positive; ** distinctly significantly positive; *** very significantly positive; ⁰ significantly negative; ⁰⁰ distinctly significantly negative; ⁰⁰⁰ very significantly negative)

CONCLUSIONS

Sowing soybeans at a soil temperature of 5°C in 2024 resulted in an average yield increase of about 150 kg/ha compared to the other two planting dates.

Among the varieties, Potaissa TD stood out in 2024, achieving higher quality yields and better performance indices than the other two soybean varieties.

While sowing earlier does not significantly impact the fat content, it may, in some cases, reduce the protein percentage in soybeans.

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